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ORGANISATION AND QUALITY OF FALSEWORK CONSTRUCTION

A socio-economic study of the organisational structure of the Construction Industry with respect to the falsework production process and the quality of workmanship attained

Volume I of II

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Submitted for the degree Ph.D.

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Dedication

To the memory of Norman Birch, friend and guru.

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Acknowledgements

I wish to express my thanks to the many practitioners for their assistance and cooperation over the years and moreover for their patience. Their forthright, candid and perceptive views form the basis of the development of the models used here to explain the operations of the construction industry and which attempt to articulate, in an academic context, their commonsense rationales and shared tacit understandings.

Thanks are also due to my colleagues and friends at the Universities of Warwick and Birmingham, for their assistance and understanding during the last twelve months. These sentiments also apply to close friends and family.

Finally any thanks are insufficient acknowledgement to the work and understanding of Norman Birch, Steve Gamble and my wife and typist, Sue. Without their help and continued support, quite simply there would be no thesis or manuscript.

Declaration

This thesis draws upon data collected and analysed since 1982 up to the present. During the period the validity of this research into the topic areas of construction management and falsework were recognised by the Science and Engineering Research Council in the form of a grant for the two years, 1985 and 1986. The investigative team comprised a senior investigator, David Seymour, and an investigator, Norman Birch, from the University of Birmingham, myself as a named investigator and a research assistant, C.D. Patel, employed under the grant administered by the University of Birmingham. Seymour had the duty of observer and collator in preparation of the final report, Birch performed an advisory role. I acknowledge the assistance of my colleagues and support of the S.E.R.C. in enabling data to be generated.

I supervised the collection of data on quality and organisation, I was responsible for derivation of the method of measuring and scoring of quality, and for the choice and definition of organisational variables.

The quality scores for each site were performed, for the sake of accuracy, engineering and rigour jointly with Patel. The collection of variables and scoring was performed by the research team abstracting information from the site reports and interviews and discussion by the team of the measure of each variable on each site.

The analysis of quality and analysis of organisation has been totally re-appraised for this thesis and bear very little relationship to the report prepared for the S.E.R.C. contract. The development and use of the model of organisation and conclusions are peculiar to this thesis.

Summary

The research attempted to relate quality of falsework erection to the organisation and competence of personnel involved. The study involved field investigation using a sample of fifty four sites throughout England And Wales where different types of falsework arrangements were being erected by a range of organisations and personnel. By the establishment of a rigorous method of evaluating quality of workmanship of falsework construction this was the first study which enabled quality standards to be compared across different types of falsework arrangements. In addition this study, combined with a sociological analysis, enabled an assessment to be made between organisation, competence and quality, which to the author's knowledge, has not been undertaken prior to this study.

Subsequent analyses of the data, used the two models of organisation: the economic and occupational orders. These indicated that all sites essentially adopted the same methods and assumptions.

Any attempts to formalise the management of the process of control of falsework, along the lines of the procedures outlined in the Code of Practice for Falsework, were limited in extent and their degree of success.

The investigation found that the quality of falsework on building sites was generally of a lower standard than on civil engineering sites. This was found to be attributed to the competence of the manual workforce.

This study addresses the organisation structure of the industry at large. Although peculiar, in that it leads to a temporary product, the falsework process may be regarded as a microcosm of the overall construction process. The conclusions presented in this thesis have relevance to the current issues of concern to the industry: competence, skill shortages, training and quality (including safety) and the implementation and efficacy of Quality Assurance schemes.

CHAPTER 1

Introduction

This thesis concerns the Organisation of Falsework Construction. In terms of this thesis 'falsework' describes the structure which supports the moulds or forms to reinforced concrete floors and roof slabs in buildings and culverts or decks to bridges. The structure is temporary and is removed once the concrete has attained enough strength to support its own weight and any other construction loading. Falsework is a common, self-contained product on many building and civil engineering sites and this socio-economic study can be seen as a microcosm of the operations of the construction industry in general. The prevalence of sub-contracting and trends for supply and fix arrangements and the high fragmentation in terms of organisations and tasks also reflect the increasing trends in the organisation of other production processes in the industry. It seems conventional wisdom that there is some relationship between management or organisational control and the level of quality attained. However, no known previous study has attempted to relate organisational variables to a particular level of quality.

That there were (and are) problems with respect to the quality of falsework was recognised by the establishment in 1973 of the Bragg Committee and a British Standards Code of Practice Committee. As a result of the deliberations of these committees a series of technical and organisational recommendations were made. The formal organisational procedures recommended in the Code (B.S.5975:1982) can be seen as a typical response of classical formal organisation experiencing problems of control. In 1985 quality was still seen as a problem by many practitioners who also wished to determine the extent to which the Code of Practice requirements were being implemented. There was support from industry therefore, for a two year study of the relationship between organisation and quality of falsework which was funded by the Science and Engineering Research Council. The purpose of the grant was to enable development of a theoretical framework as well as to provide industry with immediately relevant and useful research findings.

This thesis draws upon the data collected during the period of the S.E.R.C. grant plus substantial data generated since 1982 and used to substantiate the S.E.R.C. submission. Parallel research also continued from 1985 to 1987 upon areas such as competence, quality assurance and the developments in other industries responding to changes in the political, economic and social climate since 1979.

The research methodology and analytical framework had to establish:

> The level of quality being achieved on various sites; the organisational framework within which falsework acquisition and erection take place; the practices and procedures adopted and their impact.

In particular the extent and implementation of those formal procedures recommended by the Code of Practice were of relevance to the operation of Quality Assurance schemes in industry as a whole.

The approach, therefore, had to combine engineering and sociology. Briefly to articulate it now, the emphasis was to describe practice and the rationales which inform it. The structural and contextual variables of organisation are critically examined and their relationship to quality is explored. It was borne in mind that the social arrangement broadly termed 'organisation' not only includes the formal authority structures, policies and formalised procedures initiated by management in particular economic enterprises but also all those unwritten conventions and understandings shared by practitioners in the industry at large and which are crucial to its operation.

The models used of the 'Economic Order' and 'Occupational Order' are heuristic devices in describing particular sets of rules and understandings. For example the economic order describes the rights of personnel in the hierarchical economic control structure to decide the what, where, who and when of an operation, whilst that of the occupational order describes how rights are apportioned as to how an operation is defined and performed. Such models and relationships are not independent 'formal' or 'informal' organisations but co-exist being continually addressed and referred to by practitioners. The occupational order is absolutely crucial to operations of the construction industry, the economic order providing the means for, and reason for, assembling the various parties on site. The models are used to explain the operations of the construction industry where a wide range of geographically dispersed projects are undertaken, each of which is defined by its promoter as unique in total concept.

The main hypothesis that was tested and explored was that the quality (of falsework erection) is related to the effective functioning of the occupational order.

Formal procedures such as those advocated in the falsework Code of Practice or more generally in quality assurance schemes may be effective in resisting the trend but are more likely to be applied by engineers in civil engineering than on building sites where the main problems lie.

This thesis is written for a joint audience of engineers (practitioners) and social scientists. It is necessary, therefore, to describe in detail certain engineering or organisational concepts. The reader must therefore excuse some repetition and the inclusion of what might seem fundamental or trivial material. A glossary of terms are included in the appendix, supported by figures and photographs in the text, for non-practitioners who number engineers as well as other disciplines. The thesis is arranged in four parts. Part One looks at the technical description of falsework, literature and workmanship standards. Part Two addresses the measurement and findings on quality. Part Three describes the 'formal' or economic control of falsework and the effects of structure and formalisation on quality, and goes on to demonstrate the importance of the occupational order in describing the form of control and the attainment of quality and points to consequences and possible solutions.

PART ONE

Falsework and Problems with Quality

CHAPTER 2

FALSEWORK

Introduction

This chapter provides a basic description of falsework together with a review of the historical development of the various types of support systems which are used today in the construction of falsework and formwork.

Descriptions and definitions

There are problems in defining and describing 'falsework'.

The usual definition of falsework takes the form of that in the *Code of Practice for Falsework* BS 5975 (1982):-

> "Any temporary structure used to support a permanent structure while it is not self-supporting."

Thus from this apparently wide description some kind of falsework has been in use ever since mankind started to build. Support could be in the form of earth mounds or timber centering as in the case of arch and dome construction. With the advent of concrete construction the scope of falsework has broadened considerably both for in situ and precast work and many modern structures in steel, timber or brickwork require some form of temporary support during erection.

The definition above however is limited since it refers to the support of permanent structures, it does not, for example, apply to the support of earthworks and trenches by cofferdams or sheet pile retaining walls. The Code of Practice CP 5975 essentially applies to concrete structures where supports range from those to simple beams through to massive concrete bridge decks. The Code of Practice does not apply to formwork; it only defines it:-

> "the section of temporary works used to give the required shape and support to poured concrete. It consists primarily of sheathing material (eg.wood, plywood, metal sheet or plastic sheet) in direct contact with the concrete, and joists or stringers that directly support the sheathing."

The limited scope of the definition may be justified since earthworks and formwork have, or will have, their own Codes of Practice. Earthworks has its own Code of Practice BS 6031 (1981), but guidance on support works are restricted to construction details only, with no guidance on the design of the falsework necessary in trenches and cofferdams. The construction of formwork currently has some guidance in the form of a Joint report by the Concrete Society and the Institution of Structural Engineers (1985) and a glossary of terms in BS 6100 (1987) Section 6.5; a Code of Practice is also in preparation. The support work to these and other temporary works requires a wide interpretation of the Falsework Code of Practice and the philosophy behind the earlier Bragg report (1975) so there is a need for positive guidance on falsework in other temporary structures.

It is very difficult to apply a strict demarcation between formwork and falsework although for commercial reasons formwork and falsework suppliers have to do so. Indeed the common sense rationales of practitioners frequently do not distinguish between formwork and falsework. Neither does either the Civil Engineering (1985) or Building Standard Methods of Measurement (1978) distinguish between them (unless a special structure is required by the Engineer, for example a travelling gantry) and rates in the Bill of Quantities for formwork are deemed to include for any support work. If referred to at all by practitioners, falsework is often termed 'scaffolding' or 'shoring'.

This study addresses the quality of workmanship of erected falsework structures used to support the soffits to traditional reinforced concrete beam and slab structures. The recommendations and details contained in BS 5975 are used extensively although there are difficulties when dealing with proprietary systems and proprietary decking formwork (see below).

Traditionally the predominant falsework support material to concrete slabs has been timber, but various systems and materials have come to be used and it is necessary to describe their development into the range of support types used today in the United Kingdom and encountered in the study.

For reasons of the common sense blurring of descriptions of falsework, formwork and scaffolding and their interrelation it is necessary to look at the development of all three products.

Falsework systems

As with other innovations (see Bowley,(1960,1966) and Burrows(1979) a material shortage provided the stimulus for change. Timber shortages, the cost of importing timber, problems of wastage, and little or no re-use led to the development of steel support systems. Although there are still the same problems of wastage and labour costs involved in using timber, it is still used extensively today in Europe, Canada and the United States even for bridge support structures (White 1983).

The first major development in the United Kingdom took place in 1916 when Scaffolding Great Britain (S.G.B.) patented the first universal coupler (the "band and plate") for use on steel tube, which was standard 48.3mm (1 29/32ins) outer diameter, 4mm (8 S.W.G.) thick, 6.3m (21ft) long Grade 13 (mild steel) water pipe. (Material Properties are defined in BS 1139 (1982)). In comparison with timber, steel was stronger, presented fewer wastage problems and could be reused many more times. This was in a period of high workload, labour shortage and timber shortage, and the associated costs soon made the use of time- and labour-consuming timber poles and lashing access scaffolding obsolete in the United Kingdom. Timber and bamboo scaffolding are still used in other parts of the world, for example Hong Kong, Spain and Greece, for access and support work.

Support works to concrete in the 1920s still used timber erected by joiners and the newer occupation of 'formwork carpenter'; or tube and fittings scaffolding erected by, re-skilled, scaffolders. Tube and fittings scaffolding was more appropriate for the larger, more heavily loaded structures such as bridges.

Continuing timber shortages and the pursuit of labour and time savings led further to the introduction in 1935 of the Adjustable Steel Prop (Specification appears in BS 4074,1982) in the United Kingdom by W.A. de Vigier, the founder of Acrow Ltd.

This telescopic tubular steel prop transformed the construction site. Timber props were virtually eliminated overnight and the name 'Acrow' became the generic term for adjustable steel props used to support decking, wall formwork or trench sheeting. For support heights of up to 4 metres, the Acrow prop virtually replaced timber and tube scaffolding, and the propping of slab formwork was seen more and more as part of the task of the formwork carpenter.

During the same period in the United Kingdom and abroad, systems scaffolding were being developed. These consisted of welded frames which could be slotted or clipped together to form access or support towers. These resulted in reduced labour costs and required less skill in assembly.

They also offered, in certain instances, more rigidity, reduced wastage of fittings, less eccentricity of loading and more predictable structural behaviour. These systems were used to provide access, and, where fitted with suitable top and bottom adjustable screw jacks, support scaffolding.

There continued increased development of more systemised, standardised components and systems with the primary objective of reducing labour costs (time and skill). These developments were made by the emerging formwork equipment suppliers and scaffolding suppliers. It is perhaps worth noting that this equipment could be re-used and hired by the contractor.

Whilst frame systems continued to be developed and used extensively in other countries for access and support (For example Lightfoot and Oliveto (1977), Christian (1981), Bennett(1984) and Bennett and Ratay (1984)),the Kwikform Company pursued a development which drastically changed the provision of access and support work. 'Kwikstage', in 1961, was the first of many 'pocket' scaffolding systems where individual tubular members were still retained but connections made by welded lugs fitting into pre-formed pockets welded onto the vertical member. Thus there was a modular system of scaffolding incorporating a good deal of the flexibility of tube and fittings but with better load and moment carrying capacity. The prime advantage, however, was in the labour and skill required. For example, erection times of systems can be up to one half of those with tube and fittings. Material costs and fabrication costs tend to be more expensive than tube and fittings by about 30%.

In 1980, systems scaffolding of this type accounted for 30% of all scaffolding, with Kwikform accounting for 80% of this figure (Contracts Journal (1980)). Tube and fitting scaffolding tends only to be used nowadays for jobs which are complex (in relation to geometric layout) or where they are needed for long periods (the consideration of equipment costs or hire costs then outweighing the labour costs). For these reasons one is less and less likely to encounter tube and fittings support as falsework, where it is required for a relatively short duration. Complex shapes usually occur in building work where systems are supplemented or replaced by adjustable props. As tube and fitting stocks become old and unusable they are more likely to be replaced by pocket systems.

In the United Kingdom, in contrast to other countries, these modular pocket systems have become the dominant form in comparison with frame systems which are thought less suited for higher structures and heavily loaded structures since they need stabilising by bracing and lacing members. Since the Bragg Report and BS 5975 the requirements for lateral stability mean that traditional frame systems receive less and less favour. No supplier sells or hires this equipment any more for use in support work, but some offer special heavy duty trestling systems or rigid alloy, tower systems which bear little relationship to the old form of frame system. It is possible to see frame systems used (owned) by contractors (sub-contractors) in building operations as evidenced by the study.

Developments have continued in making system scaffolding and formwork more 'idiot-proof', requiring less skill and time to erect, and in extending applications into heavier loading conditions. Loading on each vertical member (standard) is often limited by the span of the primary beam or runner connecting the formwork. With developments of steel and aluminium beams for these applications, loading on a standard may be increased. Suppliers have introduced stronger systems, either by incorporating horizontal restraint (via lacers, ties or braces) at more levels thus reducing the effective length or using stronger tubes or connections. Stronger or larger tube has disadvantages of needing special connections and problems of confusion with lighter tube.

The prime incentive has always been to save labour costs and since steel and alloy scaffolding became established, efforts have been made to facilitate erection and dismantling. Systems were developed which incorporated decking as an integral part of the falsework and formwork, which could enable larger spans and better utilisation of the structural properties. In 1945 it was again Acrow who developed telescopic floor centres for use with props and further developments came whereby a complete proprietary system of props, beams and decking panels could be hired or purchased. (Acrow U-form in 1964.) The formwork carpenters on buildings using these systems were becoming assemblers of 'Meccano-like' structures. Formwork and scaffolding suppliers followed, introducing proprietary systems which could support a variety of floor or soffit types and which offered a quick-stripping facility whereby primary and secondary beams and even decks could be removed whilst the propping remained as backpropping for subsequent pours. Larger quantities of formwork were thereby released for use elsewhere on site. Recent developments in the United States and the United Kingdom have resulted in larger scale 'flying forms' systems of tableform structures using steel and aluminium.

It is therefore possible to see a variety of support types to concrete slab structures in the United Kingdom and a variety of organisations involved. (Chapter 14).

The main types of support to be encountered in the United Kingdom and examined in this study are:-

i) Tube and fittings.

ii) Adjustable steel props.

iii) Proprietary systems.

On any one of these support structures a mixture of formwork or decking types may be used:-

i) Traditional decking of plywood sheets on timber or aluminium secondary and primary beams.

ii) Proprietary decking consisting of plywood sheet or steel or aluminium framed panels with plywood or steel facing, trough and waffle units, permanent soffit shuttering of concrete, expanded metal, profiled steel sheeting, glass reinforced plastic etc. These may be supported on proprietary floor centres, steel or aluminium beams connected and integral to the support system of props or systems.

There is thus a multitude of arrangements but for the purpose of this study there was only a need to define whether the formwork (ie. the primary members) was integral to the support system or not. For example, floor centres may be used as secondary or primary members, simply supported on timber bearers or in the head of the prop or standard; in this case the decking is classified as 'traditional' and separate from the falsework support structure.

With such a variety of proprietary formwork and falsework systems which often can be interchanged and mixed, contractual liabilities of the suppliers become blurred and the potential for abuse of materials, and equipment is increased.

This thesis does not address those structures involving heavy structural support systems using military trestling or Bailey Bridge panels, prefabricated steel girders etc. necessary for large scale bridge crossings, for example over navigable waterways, railways or motorways.

Wilshere (1983a) states that the falsework has to meet three main requirements.

> "It should provide a safe support, that is to say there should be neither failure nor risk of one. The second is that it should provide this support without undue movement, that is to say the permanent structure should be within the tolerances laid down and without locked in stresses."

(The author would add provision of safe access to check and adjust the falsework and access to lay concrete).

> "Thirdly, the cost should be as small as possible. In many ways the first two are contradictory to the third and satisfactory falsework has to be a reasonable compromise between these opposed arguments."(pp1-2)

It would seem that the studies of failures by Bragg(1975), and the Health and Safety Executive (1985), and this one would suggest that a satisfactory compromise is not being reached, as discussed in Chapter 3 and subsequent findings of this study (Chapter 8).

More details of proprietary systems are to be found in, for example, Brand (1975), Irwin and Sibbald (1983), Christian (1981), Wilshere (1983). Figures, and photographs, are included at the end of this chapter to illustrate the different types of structure and some of the technology. A glossary of terms appears in the appendix.

The main suppliers and manufacturers of formwork and falsework equipment in the United Kingdom are:-

G.K.N/Kwikform

S.G.B

R.M.D(Rapid Metal Developments)

Aluma Systems.

Acrow went into liquidation in 1983 but there is still a wide range of equipment held by suppliers and contractors alike.

Conclusion

Falsework can comprise a wide variety of support structures. In this thesis, only those structures used to support the soffit to traditional reinforced concrete beam and slab structures in bridges and buildings are considered. Falsework cannot be totally divorced from the formwork it supports. These temporary structures can use a variety of equipment and material types. These have been described together with their development.

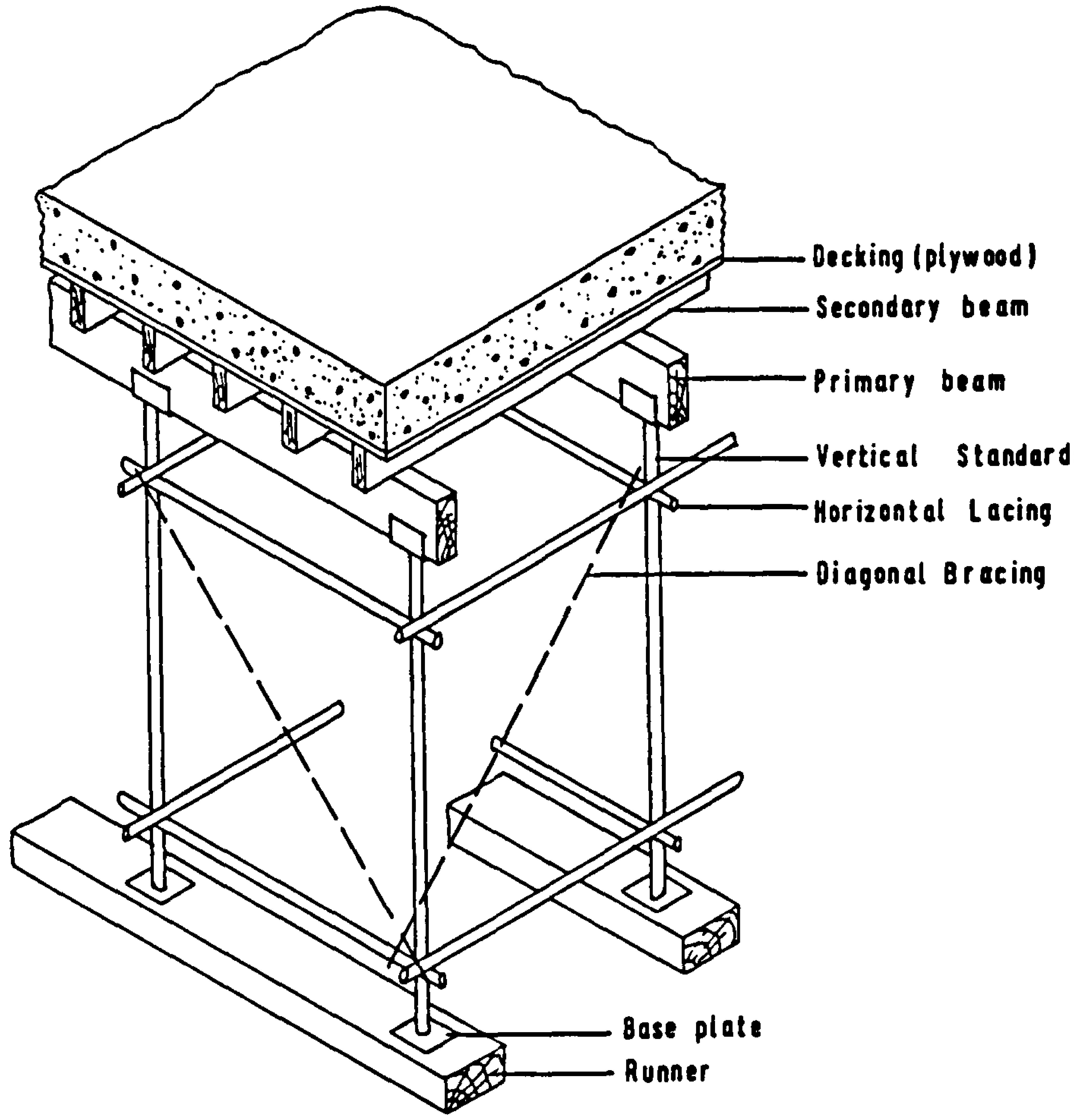


FIG.1: Tubes and fittings falsework with traditional decking

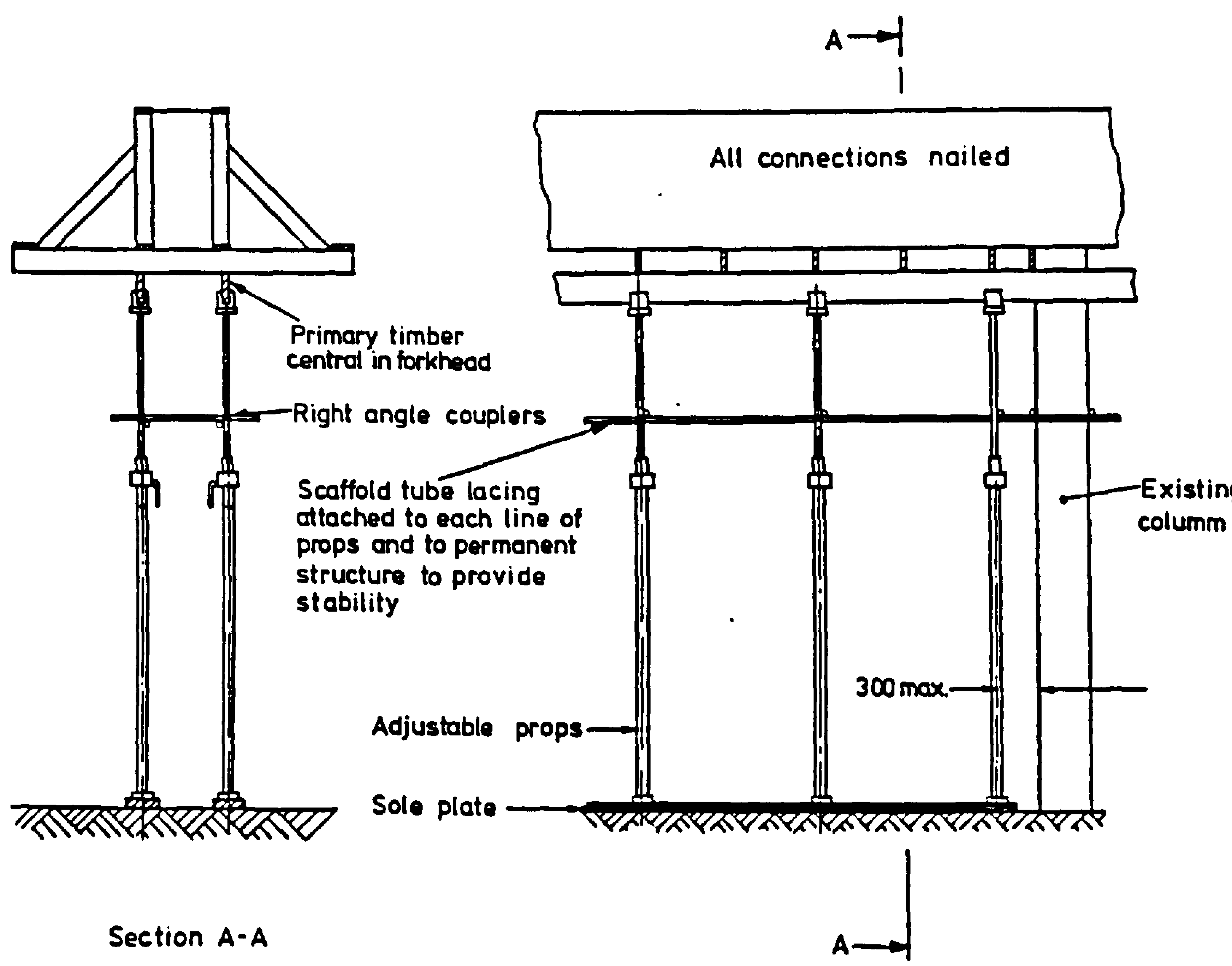


FIG.2: Adjustable steel props for typical beam support

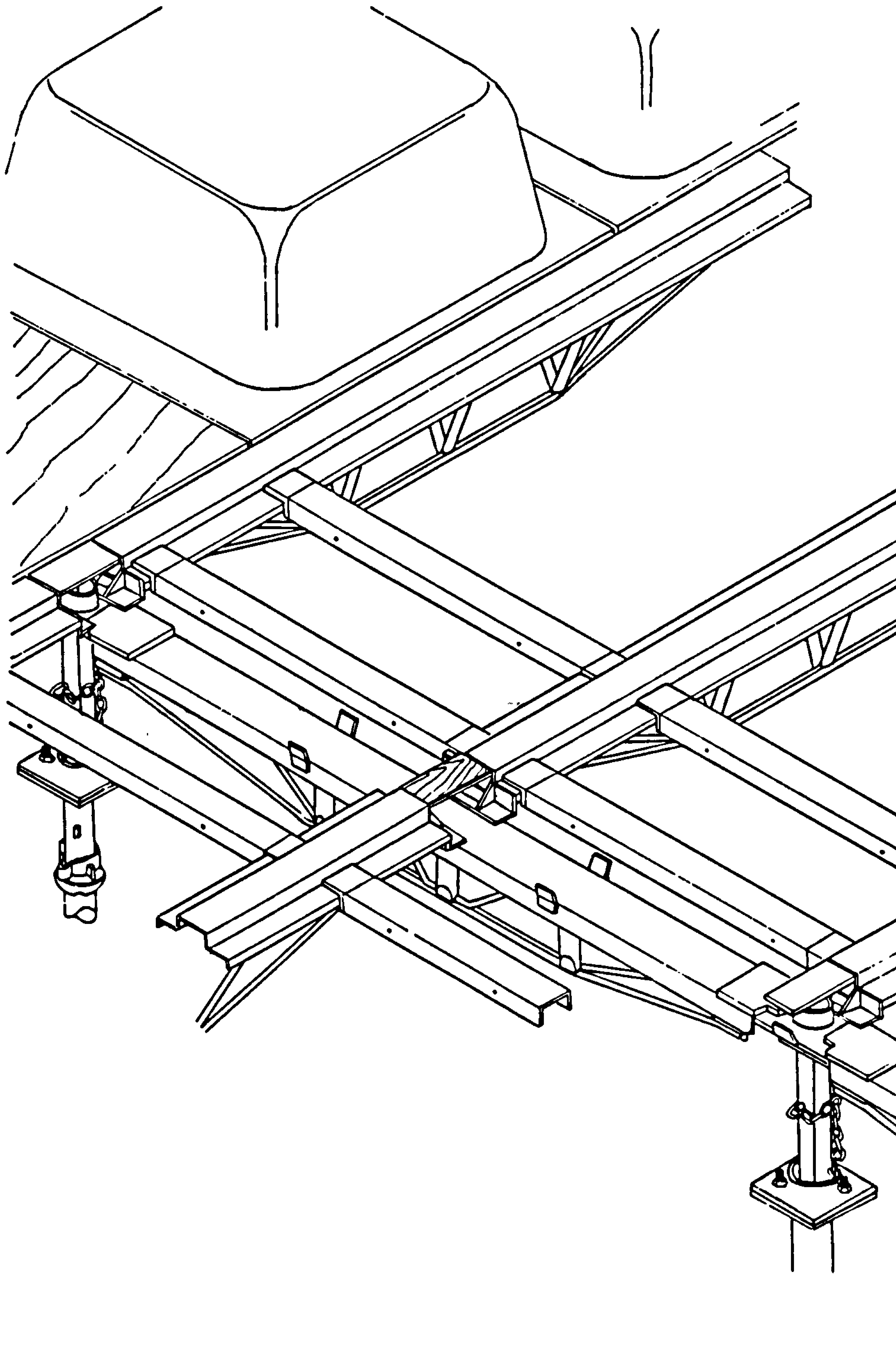


FIG.3: Proprietary systems and proprietary decking -

waffle moulds on decking system beams

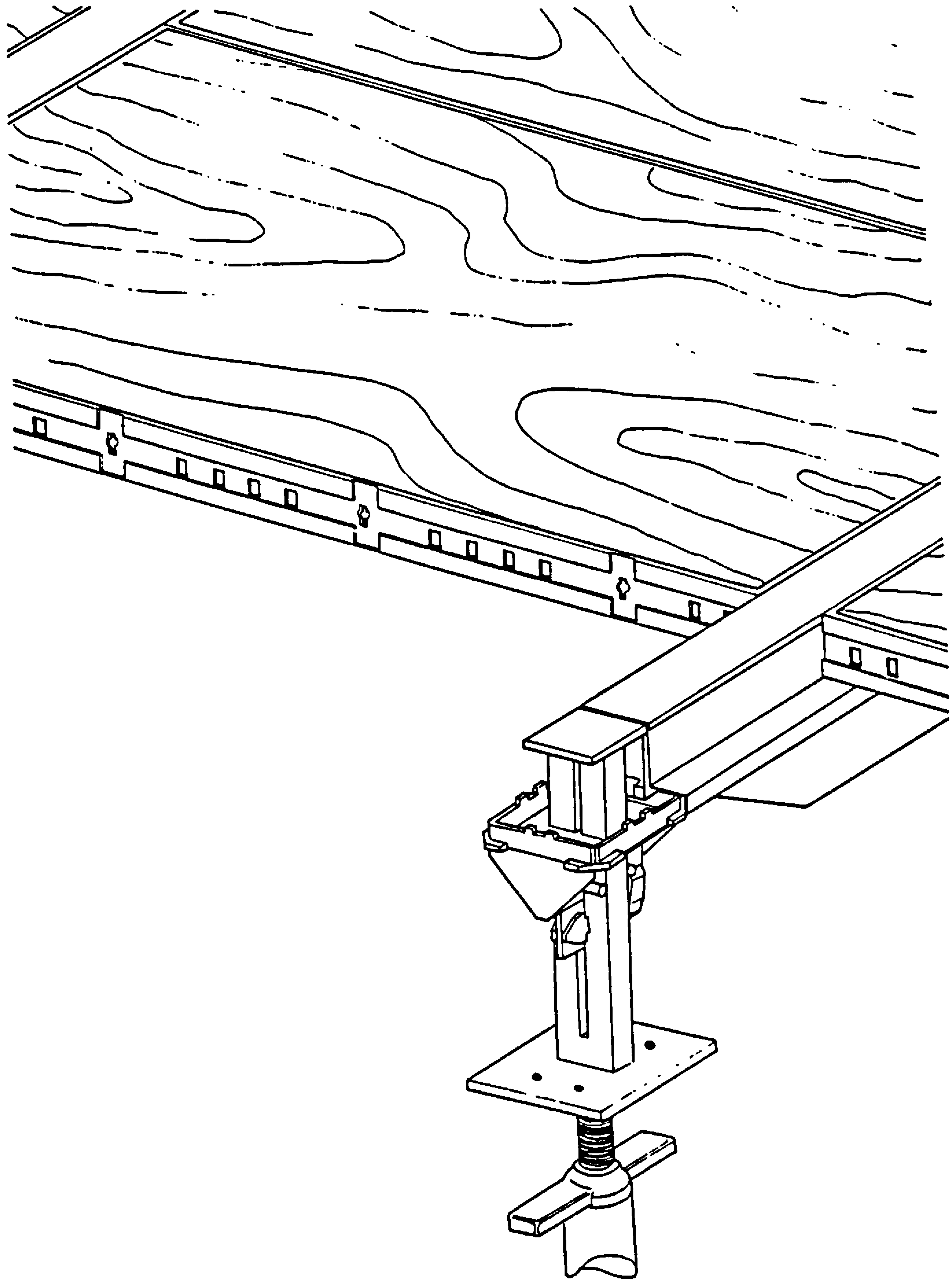


FIG.4 :Proprietary systems andproprietary decking -

aluminium and plywood panels on aluminium primary beams

Photographs of Falsework Systems

In the following plates, acknowledgement is given to the following suppliers for their material and permission to include them in this thesis.

Rapid Metal Developments (R.M.D.) PLC

Plate Nos. 1, 6, 8, 9, 11

G.K.N./Kwikform PLC

Plate Nos. 2, 7

Scaffolding Great Britain (S.G.B.) PLC

Plate Nos. 3, 4, 5

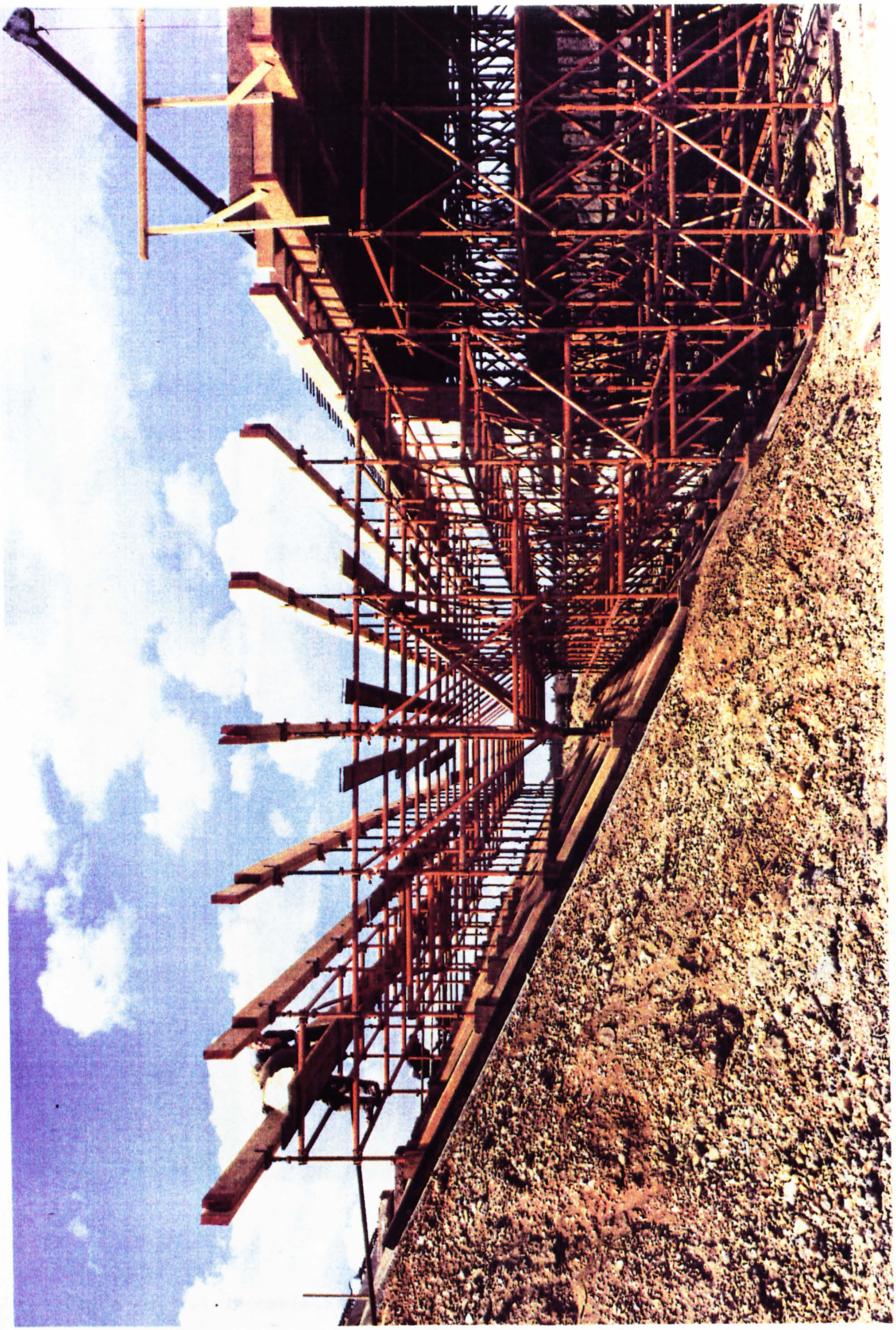


Plate No. 1.   Proprietary system with traditional timber decking.

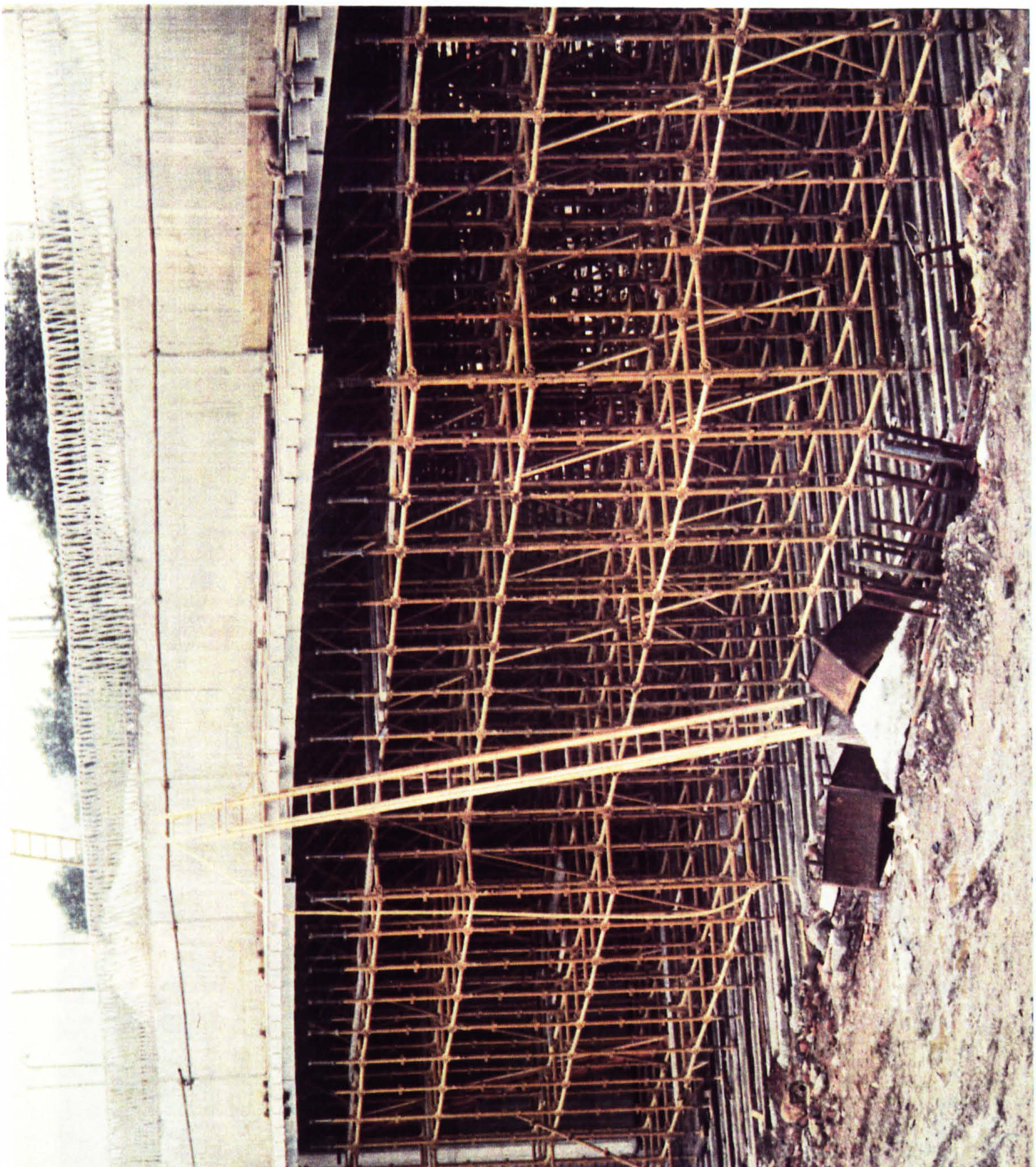


Plate No. 2. Proprietary system with aluminium beams.

Plate No. 3. Proprietary system with proprietary decking and waffle moulds.

Plate No. 4. Adjustable steel props and proprietary decking.

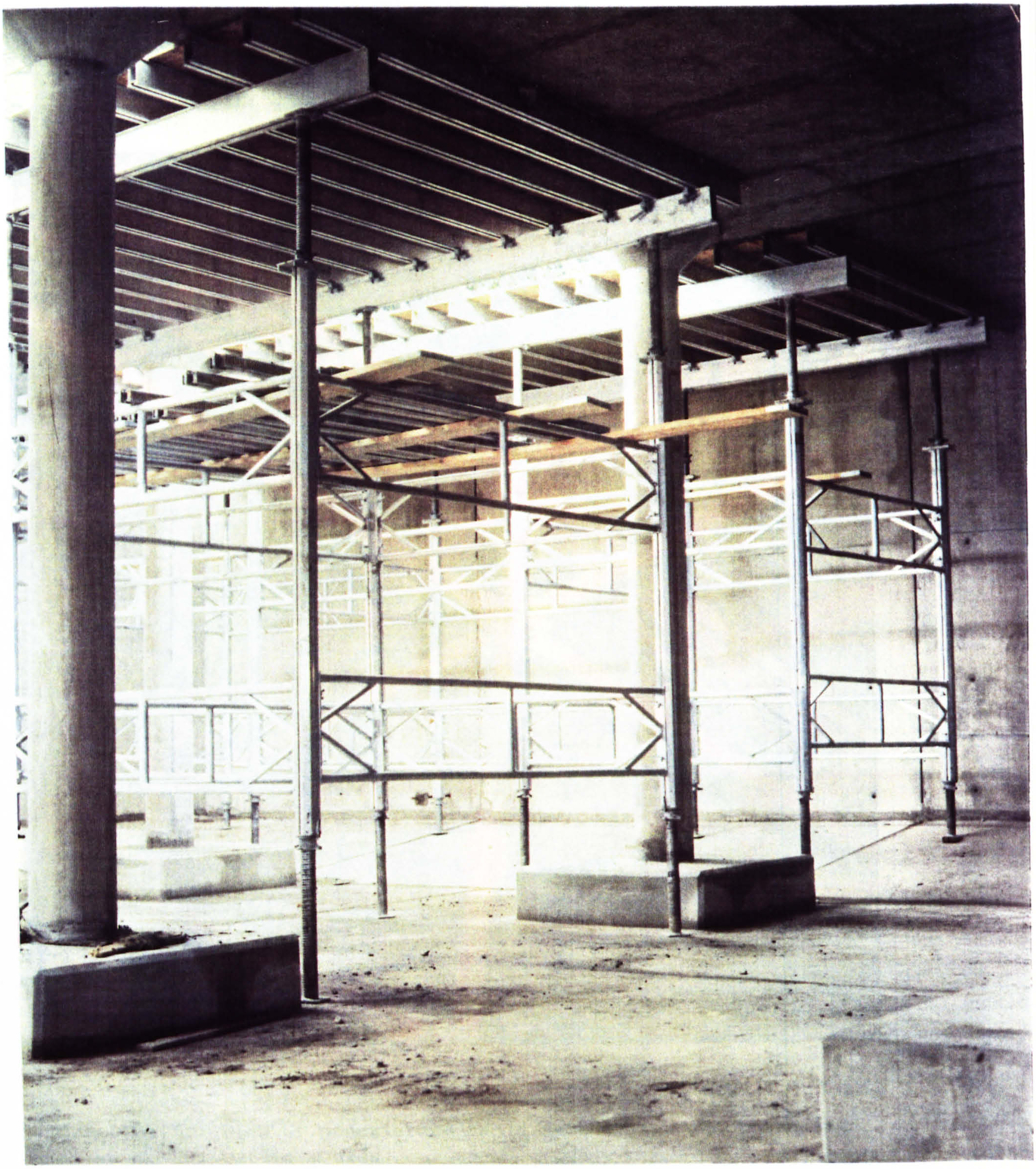


Plate No. 5. Heavy duty frame system and aluminium beams.

Plate No. 6. View of proprietary rapid deck system incorporating waffle moulds.

Plate No. 7. View of heavy duty proprietary system showing trigger-brace and coincident node connections.

Plate No. 8. Flying form proprietary system and two other support systems.

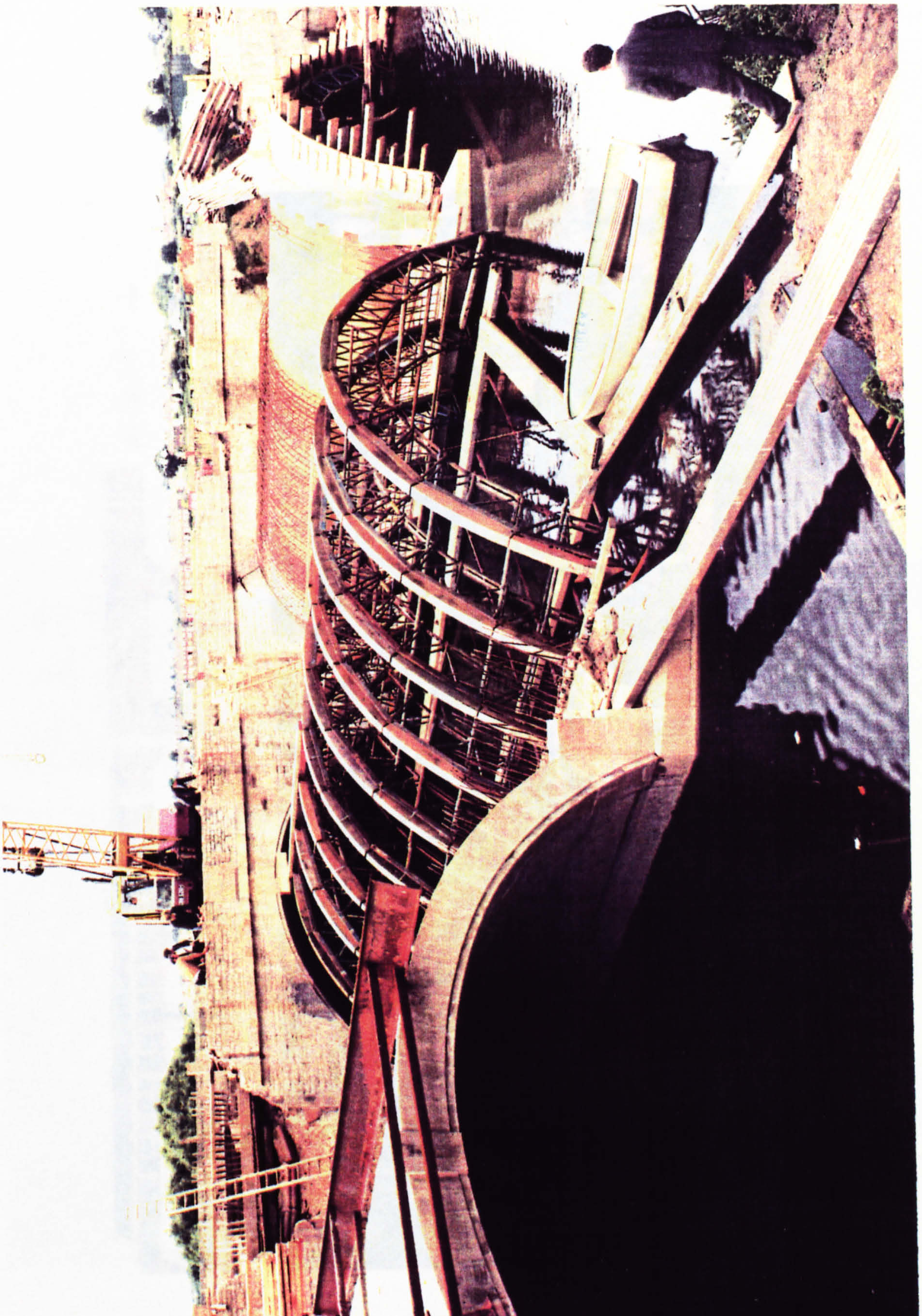


Plate No. 9. Proprietary system for use in centering.

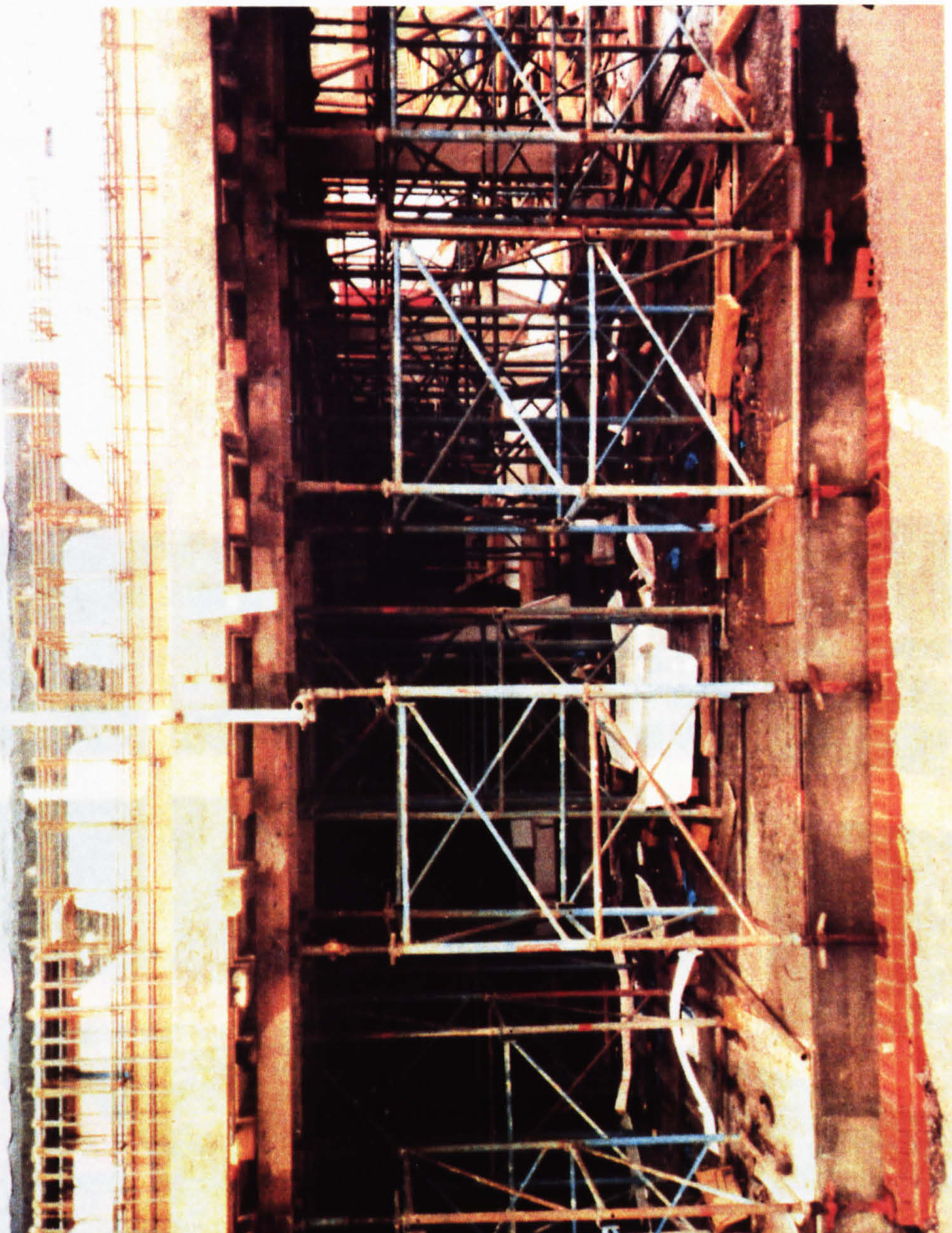


Plate No. 10. Proprietary frame system (supply now discontinued) and traditional timber decking.

Plate No. 11. Proprietary system and proprietary decking.
Adjustable props as back propping.

CHAPTER 3

Background to The Problems of Falsework Construction

Introduction

In this chapter the background to the concern for the problems of falsework construction and quality and the efforts and studies made to remedy them, will be addressed.

Much of the concern arose during the space of a few years between 1970 and 1974 where a series of dramatic failures occurred worldwide (some of these are discussed in Bragg (1974,1975a)); and in a climate of increasing Government and Trades Unions concern about safety.

By the time BS 5975 was published in 1982, interest in falsework was beginning to wane. The construction industry representatives claimed that they recognised the problems and had instigated policies and that there was no need for political intervention or more policing by the Health and Safety Executive. (H.S.E.)

From the interest shown by many organisations and practitioners in studies carried out by the author and their unqualified support to the S.E.R.C. study, interested parties were still concerned with the quality of falsework and standards of safety being achieved. Although in the words of one senior H.S.E. representative engaged in falsework and formwork:-

> "Investigation in falsework today (1986) is a dead duck. Since the Code of Practice it has run out of steam. We have produced a guidance book to supplement the Code and other books and that is all we can do now. We have to concentrate our meagre resources on more important areas."

With only 90 inspectors to cover the whole United Kingdom construction industry and who have to find time to prepare their own prosecution cases, one can see his point.

The following chapters of this study suggest that there is still cause for concern for the quality of falsework construction.

<u>Previous studies</u>: **The Background.**

Prior to the publication in 1971 of the Falsework report by the Joint Committee of the Concrete Society and the Institution of Structural Engineers (1971) there was no single self-contained published document giving guidance on the design or construction of falsework structures. Some British Standards gave rule of thumb methods for shoring, underpinning and support works as did various company brochures.

Shortly after its publication, on 23 March, 1971, the Birling Road overbridge in Kent collapsed killing one man and seriously injuring five more. There was growing concern within and without the construction industry, fuelled by the collapse in Pasadena, California of the Arroyo Seco Bridge on 17 October, 1972 and nearer home the frequently reported collapse of the viaduct over the river Loddon in Reading, just eight days later, killing three men and injuring ten others. Falsework designers were in serious danger of losing their credibility and falsework suppliers and contractors their reputation in the light of such publicity. Interested parties were keen to maintain control over the provision of falsework. There were also fears that the awesome powers of the new Health and Safety Executive proposed by the Robens Committee (1972) and subsequently established in the statute the Health and Safety at Work Act 1974 (1974) would impose undesirable measures if the industry could not demonstrate that it was remedying the situation.

In the event the Government acted and the Secretaries of State for Environment and Employment jointly set up the Advisory Committee on Falsework on 13 March,1973 under the chairmanship of Professor S.L. Bragg. The committee comprised members from contractors, consulting engineers, Health and Safety Executive and the Trades Unions and was welcomed by the Falsework designers.

Bragg committee

To quote in full the terms of reference of the Committee (Bragg 1974, 1975a):-

> "To consider and advise on the technical, safety and other aspects of the design, manufacture, erection and maintenance of temporary load bearing falsework used to support formwork or permanent structures, *particularly bridges*, during construction, and, in particular to:-
>
> a) identify any inadequacies in present knowledge, standards and practices, recommend such steps as may be needed, and indicate an order of priority;
>
> b)draw up interim technical criteria; for use in advance of the publication of a British Standard Code of Practice; together with such procedural guidance as the Committee may consider appropriate.
>
> c)recommend what research and development should be carried out in the short and long term; and
>
> d) advise as to the training, organisational and manpower implications of the Committee's recommendations."
>
> (author's italics)

It should be noted here that attention was focused upon the more spectacular form of failures of bridges which hit the headlines while recognising that the greater number of 'minor' failures on building jobs resulted in as many,if not more, deaths and injuries.

Reference is also made in the above quotation to the preparation of a Code of Practice; at the same time of the setting up of the Bragg Committee (as it became known), the British Standards Institution (B.S.I.) who had been deliberating for some time, announced its intentions of setting up a Code of Practice. (see below). This, again was welcomed by those interested parties.

The Bragg Committee produced its interim report in 1974 (Bragg, 1974) and its final report in 1975, (Bragg, 1975a). These documents represented a most thorough, perceptive and penetrating investigation.

The Committee started work by studying evidence from known collapses in the United Kingdom and overseas in the United States, Canada, Australia, South Africa, Germany and France. They also studied evidence from smaller jobs and more 'minor' failures. Far more failures and accidents occurred, the Committee believed, on building jobs than on major works of engineering construction.

The Bragg Committee found difficulties in estimating the size and scope of the problem. They could only estimate that approximately 12,000 jobs involving falsework are erected each year. (The market size and type of work during the period of study related to this thesis do not suggest any modifications to this figure which is as good as any.) What constitutes 'failure' is also a matter of debate, as only failures which constitute a collapse and injuries or fatalities reportable by law (Health and Safety at Work Act 1974- H.A.S.A.W.A.) are reported. The number of failures that occur daily where no reportable accident occurs and result in economic loss for the contractor or sub-contractor in the form of remedial works or re-construction works can only be surmised. Popular opinion in the industry by practitioners, and H.S.E. would suggest that such failures are 'common'.

Part of the recommendations of the Committee was a strengthening of the role of the Health and Safety Executive (H.S.E.) and a more thorough reporting of accidents. This was rather a Utopian vain hope, however, bearing in mind the industry's dislike of external controls, shared by the Government at the time of publication of the Code of Practice.

Part of the problem of falsework quality, claimed the Bragg Committee, lay in the fundamental nature of the Construction Industry in general and the role of temporary works in particular.

The structure of the industry in relation to the unique project is examined later in part 3 (Chapter 14) but the Committee commented upon the fragmented nature of the industry and the traditional separation of design and production which made communication and coordination difficult. Furthermore falsework and temporary works were exactly that; temporary and transient and part of the contractor's preserve and risk. As commented earlier, seldom is there separate provision in the Bill of Quantities for falsework (or temporary works except in the case of special falsework, cofferdams or caissons) and it is enshrined in the usual conditions of contract (for example I.C.E.,1979,J.C.T.1980,G.C.Works 1977) that the contractor is responsible for temporary works with a relatively minor role for the client's representatives. The client's representative may call for designs to be furnished, checks made and for their consent to be given before temporary works are executed. In certain cases particular structures may be specified for an independent check to be performed and a certificate of such a check be submitted by the main contractor, as in the 'Clause 8A' provisions in some I.C.E. contracts. The client's representative has always discretion to stipulate or request such information; this might be construed as part of the express terms of the contract (as, for example, in the I.C.E. conditions, or where additional clauses are inserted in any other conditions) or construed as a variation. All standard contracts clearly affirm that contractual responsibility for temporary works and permanent works construction lies firmly with the main contractor, irrespective of any requests, consents or 'approvals' made by other parties. (Responsibilities in Tort and under Statute still apply to the client and his representatives or any other parties on site.) Contractors and others did not have to comply with any Codes of Practice for temporary works or falsework, (none were in existence at the time) and safety in these areas was subject to erosion in contrast to the permanent works.

It is in the contractor's economic interests to minimise cost and duration of falsework which is only one of his tasks and area of risks. The Committee commented on the increased fragmentation of falsework, in particular, where suppliers, sub-contractors and other organisations may be providing several design and construction services on any one job.

In spite of these difficulties the majority of falsework is designed, constructed and dismantled without accident. The Committee said, however, that ultimately the costs of any failure whether minor or major are passed on to the client and that the client should take an interest.

This, of course, sets the scene for a discussion of competition and economic policies mentioned in the introduction and explored in detail in the main body of the thesis.

Having commented upon these fundamental problems (and addressing them later) the committee investigated the reasons why accidents occurred and why errors were made in design and construction.

> "Failures arise from many different causes. Each one has two elements: the technical cause which led to the collapse; and procedural errors which allowed the faults to occur and go undetected and uncorrected."
>
> (pg.7 Final Report)

and

> "In hardly any case did we find that failure was the result of a problem beyond the scope of current technology"
>
> (pg.7-8*op cit*)

Problems were not therefore due to a lack of technical knowledge *per se*, in that the industry was operating in uncharted territory, but due to organisational problems partly due to the structure of the United Kingdom construction industry, and the problems, caused by fragmentation, of communication and coordination.

This view is echoed by Mott (1975), a member of the Committee who stresses that the problem is largely an organisational one.

Returning to the findings and recommendations of the Committee these can be divided into four main areas:-

Technical

Procedural

Training and Research

Legal and Client Issues

Technical problems did not usually originate from a lack of knowledge but a lack of dissemination of that knowledge down to the falsework designers in the design offices and on site (hence the need for training, a Code of Practice and a handbook or textbook suggested by the Committee). There was also a coordination and communication problem between the designer and site and the various organisations serving these two.

> "There seemed to be no wide areas of ignorance in falsework design awaiting a vast programme of applied research for their elucidation. What is needed is to ensure that designers do apply all the knowledge already available."
>
> (pg. 86 Bragg 1975b)

One particular technical area singled out is one of lateral stability against horizontal forces.

> "In particular there seem to be some characteristic blind spots which we met many times in the detailed consideration of falsework failures. Foremost is the neglect of the effect of possible lateral forces."
>
> (pg. 86 *op cit*)

These lateral forces may arise from errors in workmanship, and some of the effects are reported by Birch *et al* in the C.I.R.I.A. studies of adjustable steel props (1971,1977a, 1977b). The assessment of the quality of workmanship standards undertaken in the studies reported in this thesis has obvious consequences upon the method of design of falsework structures.

Apart from certain faults and recommendations involving details of connections and local stability in composite and grillage construction and the need for attention to material properties, lateral local stability accounts for the vast (80%) majority of the whole technical content of the report, the other main concern being the use of proprietary equipment which was highlighted by the C.I.R.I.A. study reported (1971) below.

In undertaking the study of quality of workmanship reported in this thesis, the main problem areas in workmanship were always envisaged to be the provision of adequate bracing, lacing and tying-in to ensure lateral and local stability of the structure and its elements. The results would confirm these expectations (Chapter 8).

The research also confirms that there is still a lack of adequate information and data widely available on the use of proprietary systems and the necessary workmanship standards. The Code of Practice offers little assistance since the committee were limited by problems of commercial confidentiality of test results and equipment capacities. It was also impractical for the Code to address all of the many different types of systems which were changing and being constantly developed.

Failures which result in collapse are usually due to lateral instability which is clearly a problem of overall structural quality. This thesis relates to measurements of quality of workmanship and not necessarily structural quality but it could be argued that since it is the single fault that could cause collapse, and not local failure, the assessment of errors regarding lateral stability should be penalised more heavily. Chapter 9 deals with a scoring system for evaluating severity of errors in workmanship.

Since these areas of lateral and local stability and uncertainties of proprietary system behaviour and capacities are the main problem area for design it is not surprising that they are the main sources of ignorance, disbelief or even suspicion (of overdesign and extra equipment costs) in the construction personnel (supervision and erectors) on site.

Apart from these technical recommendations the main thrust of the Bragg report is on organisational failings either due to the intrinsic nature of the industry, or the transient and perceived minor role of falsework and its fragmented production process (Part 3).

Bragg asked:-

> "What were the failures in procedure or communications or inspection that allowed them (the technical faults) to happen........

> ....The first is *failure of communication*: the designer was not given a proper brief by the client; or the designer's drawings were inadequate or liable to misunderstanding; or there was no feed-back to the designer when conditions on site were found to be different from those assumed. The second is *failure of inspection*: the design was not checked by a competent authority; or the structure was not inspected after erection."
>
> (pg. 38 Final Report)(author's italics)

These features of communication and coordination of checking activities feature largely in the report and subsequent commentaries by the Committee (Bragg 1975b, Mott1975 for example). Further, the report goes on to say:-

> "We are of the opinion that if adequate and proper attention was paid to communication of information which is already available somewhere, this could possibly be the *greatest single contribution to improved standards of falsework construction*."
>
> (pg. 39 *op cit*, author's italics)

It is hardly surprising that this thinking, already with a strong grounding in the interim report, should lead to strong recommendations for detailed procedures for the design, construction and dismantling of falsework.

Bragg suggested that these procedures should furthermore be formalised and administered by a specifically nominated person, the Temporary Works Coordinator (later the Falsework Coordinator in the Code of Practice). More details of the procedures and role of the Coordinator are described in Part 3, but in the Bragg report and the draft Code of Practice (see below) the role of the Coordinator is delineated closely.

To implement the recommended procedures, perform the role of coordinator and incorporate and disseminate relevant technical knowledge requires training. The Bragg report prescribes training of personnel ranging from falsework designers to operatives. The Construction Industry Training Board (C.I.T.B.), the Cement and Concrete Association (C.& C.A.) and suppliers' and contractors' organisations responded but the effects were minimal (see Appendix L). The committee clearly felt that the perception and respectability of temporary works should be raised and suggested that falsework should be a compulsory component of all education courses in civil engineering and architecture and part of the Institution of Civil Engineers training scheme. There was also need for a handbook and a textbook on falsework in order that the body of knowledge could be identified.

It has been mentioned earlier that the committee recognised the problems due to the traditional contracting system used for construction in the United Kingdom (and elsewhere) and whilst it respected and understood the views of the client and consulting organisations it was nonetheless critical of their role and attitude to falsework. There were still duties under common law and statute and these should be made clear to the participants. It supported the use of statute law and called for similar rules as are applied to access scaffolding (via a compulsory register) and that Government should insist upon fully trained, certified operators and site personnel on all of its contracts involving falsework.

The Code of Practice

At the same time that the Bragg committee was carrying out its investigations and reporting its recommendations, the Code of Practice Committee was pursuing the lengthy process of drafting a Code of Practice for Falsework. Work began in 1973, a draft published for comment in August 1975 (1975) leading to the publication of the final code BS 5975 in March 1982. It was intended that much of the philosophy and scope of the Bragg inquiry would be incorporated into the Code of Practice. The process was facilitated by appointing as Chairman of the Code Committee, the respected C. Wilshere, who was also a member of the Bragg committee. To expedite writing of the draft code this work was let on a Department of the Environment contract to another leading practitioner, D.W. Quinion.

The resulting draft Code of Practice was swiftly prepared and was a most comprehensive document.

Much of the thinking by the Bragg committee was incorporated into this draft; in particular the need for formalised procedures and the appointment of a Temporary Works Coordinator. It is also suggested that the permanent works designer should nominate a structural designer to oversee temporary works. The requirements for competence of staff and operatives and the responsibilities of the temporary works coordinator, designer and supervisor are described in considerable detail echoing the sentiments of the Bragg committee and given precise setting in actual work situations. As a Code of Practice these organisational and indeed managerial prescriptions broke new ground and were quite ambitious.

The bulk of the draft code was a design handbook which included reference to other branches of design, for example the determination of earth and wind pressures, foundation loading and so on. The intention was that the resulting Code of Practice could be used by a wide range of personnel who did not have access to libraries or computing facilities; to these ends standard situations were included. This drew criticism from engineers who claimed that this led to some elements of design such as geotechnics being trivialised and over-simplified. The draft code (and subsequent code) also included reference to workmanship standards, and tolerances. It was noted earlier that the Bragg committee drew attention to horizontal loads caused by workmanship standards. Where these horizontal loads could not be estimated then a figure of 3 percent of the total vertical load would be used in assessing local or overall lateral stability. This figure was carried through to the draft Code of Practice and subsequently reduced to 2.5 percent in the final code; it was expedient to do this to match up with the requirements for node stability and the Code of Practice for Steel: B.S.449 (1969). The derivation for the value 2.5 percent used for node stability is obscure and is discussed by Medland (1977) in relation to column bracing.

There was a great deal of confusion and discussion over what standards of workmanship should be assumed in design or prescribed in a Code of Practice. For example, the work by Birch *et al* for C.I.R.I.A. (1971,1977) pointed to serious problems.They reported that safe load recommendations for props derived from existing tests did not reflect the loading conditions and workmanship standards on site.

The Building Research Establishment was persuaded to assist the code committee and commissioned a study by Tarmac Construction Limited (Quinion and Ward 1975) to investigate standards of workmanship of falsework.

> "This investigation was commissioned to examine the practices and results achieved by a variety of contractors of different size and technical capability and on a variety of types of falsework. The aim is to identify current practices and to gain an indication of where deviation occurred from good and satisfactory practice. In the Code of Practice it is intended to draw particular attention to all the items which should be checked before the safe and proper use of falsework. The code must establish the maximum acceptable deviations which can be safely permitted from the strict requirements of the design. These tolerable deviations must have a relevance not only to the safety of the falsework but also the ease and economy with which it can be erected and satisfactorily checked."
>
> (pg. 3 B.R.E. report).

Their report published in September 1975 coincided with and was used in formulating standards and tolerances in the draft. This report also draws upon data from the C.I.R.I.A. studies, which carried out inspections of forty sites.

These tolerances and standards which were eventually incorporated in BS 5975 are discussed in the next chapter. It should be noted that Tarmac's research was hindered by the very fact that they were a major contractor and there were commercial problems of inspecting competitors' sites. They relied upon the cooperation of other interested companies. In the main the forty two sites were drawn from their own or from four or five large contractors with links with either the Code or Bragg committees. Frequently the standards reported were the result of several checks and where remedial action had already been taken. The standards of workmanship thus reported therefore represent largely the best that could be achieved and what could be striven for; but the survey nonetheless confirmed the type and severity of error that could be found. It is fair to say that the only design parameter that was linked to any statistical treatment of workmanship was that relating to adjustable steel props and the C.I.R.I.A. studies.

The early seventies was a fruitful period for research which was incorporated into the draft and subsequent Code of Practice, for example the work of Holmes (1979), and Lightfoot (1976).

After a long period of consultation and comment the Code of Practice BS 5975 was published in March 1982. Reference should be made to the paper of Wilshere (1982) and subsequent discussions (1983b,1983c) for an indication of the flavour of the debate that took place during and after the publication.

The drafters of the Code certainly faced the problem of treating a wide variety of falsework types erected in a variety of locations by fragmented temporary organisations.

> "The Code should cover all but the most infrequent applications of falsework and the assembly of the components should take place to standards of accuracy related to the working performance of the members, irrespective of the nature of the work to be supported. Since similar members are used in most types of falsework and there is no justification for applying different standards of accuracy in the erection, the Code recognises only one class of falsework, but that it could be used by organisations of differing sizes, competence and technical capability."
>
> (extract from lecture given by Wilshere, October 1985).

The Code broke new ground by giving guidance on how to deal with falsework as a total entity. On the one hand it serves a comprehensive handbook of design, repeating data from other sources and British Standards, and provides standard solutions. This facilitates design to be performed on site by a variety of personnel. On the other hand, and in this respect the Code was quite unique in its approach, it describes the falsework process and organisation and prescribes management action in the form of formal procedures and the appointment of specific personnel, i.e. the Falsework Coordinator.

These procedures and responsibilities suggested by Bragg and detailed in the draft Code were severely diluted in the final Code owing to various political and legal reservations expressed for example, by B.S.I., I.C.E. and the Department of Transport. Much of Appendices J and F appearing in the draft Code disappeared, along with references to the permanent works designer and the Health and Safety Executive.

For reasons of commercial confidentiality and continued innovations in design and manufacture, the Code could only offer broad recommendations on the use of proprietary systems. Analysis later shows that this is still a problematical area in disseminating design and required workmanship standards to sites.

After the publication of the Code of Practice, interest in falsework appeared to wane. The climate in the industry changed. The dramatic collapses of the sixties and seventies were not repeated, and received less attention; although accident figures in the United Kingdom worsened and have not improved. There is no need here to discuss the appalling record of the Construction Industry regarding safety. Statistics are widely available from the H.S.E.(1986) and are reported, in many journals from the New Civil Engineer (1987) to the Nursing Times (Jones 1986), which make disturbing reading. The situation in the past decade (where workload and employment decreased) has got steadily worse. Of interest to this study is that typically 70% of fatal accidents are due to falls of men or materials,(H.S.E.1986,1988). During the time of the preparation of the Code of Practice, certain members of the industry feared their reputation was being eroded, and feared the draconian rules being proposed by the newly formed H.S.E. As a result a number of the larger contractors formulated very comprehensive temporary works policies between 1974 and 1975 (samples appear in the Appendix) which detailed procedures and responsibilities of the temporary works designer, supervisor and coordinator. These threats, however, did not materialise and the subsequent Code of Practice was not made an approved document by the H.S.E. (This is due to the management content included in the Code). The H.S.E. has severe resource problems but it is likely that in the near future renewed efforts may be targeted on offending falsework sites.

The effects of Bragg and Codes of Practice

It was noted earlier that Bragg recommended comprehensive training courses for designers, supervisors and operatives. Organisations such as the C.I.T.B. and the C.& C.A. responded quickly to a perceived demand and devised a series of courses. The actual takeup by industry was extremely low (Chapter 19). Falsework is included as a compulsory element of the training under the Scaffolder Certification Scheme (C.I.T.B. 1979), however the majority of trainees and certificated scaffolders work in access scaffolding.

Government contracts for the Department of Transport (DTp) began to incorporate 'Clause 8A' checks, referred to earlier, whereby the design of significant elements of falsework were to be checked by an independent source. Such procedures were welcomed by Bragg. However as Wilshere(1983c) points out in his article in *Concrete* (May 1983) such arrangements may lead to a further blurring of legal responsibilities, rising professional indemnity insurance premiums and not, if the experience of the 'prufingenieur' system in Germany is much to go by, a prevention of catastrophes.

An unofficial study made by the H.S.E. of 70 sites in 1985, indicated that problems in workmanship were occurring relating to eccentricity of loading, verticality and excessive spans and that 25% had no designs. Studies by the author, commencing in 1983 also confirmed these findings. There was still cause for concern but this was restricted to those practitioners in the falsework industry, the designers in contractors and suppliers and the H.S.E. and Trades Unions personnel. They gave their unqualified support to the subsequent S.E.R.C. proposal in 1984.

<u>Conclusions</u>

This chapter has addressed the relevant literature and studies which highlight the concern about falsework construction and the problems of quality and safety.

Some of these problems arise from the lack of technical knowledge, or more correctly lack of dissemination of the knowledge already available. The technical recommendations of the Bragg and Code committees on, for example, lateral stability and horizontal loads have been discussed. By far the greatest contribution to the problem of quality of falsework construction was recognised to be an organisational one. The opinion of many practitioners in the industry was that quality standards were still unacceptable. There was support, therefore, for a study which assessed the levels of quality being attained on sites and the type of organisational control that was being exercised. The first, fundamental task was to obtain a measure of the quality standards. The applicable tolerance requirements are discussed in Chapter 4.

CHAPTER 4

Standards of Workmanship and Design Assumptions

Introduction

This chapter addresses the standards of workmanship and tolerances listed in the Code of Practice and their derivation. These are supplemented by knowledge of the proprietary systems and construction practices and are presented in a comprehensive list which appears as an appendix to this chapter. The list forms the basis for the checking and subsequently the scoring of quality of workmanship. Figures are presented but in the event of confusion over terminology the reader is directed to the glossary of terms in the appendix.

The design of falsework assumes certain workmanship standards and loading conditions. The concern of this study is to determine whether these standards are attained on site. The studies reported in this thesis were performed to assess the degree to which standards of workmanship advocated by the Code of Practice, and other studies, are being adhered to; and the degree of conformity or acceptance of some of the design requirements (in particular those of stability). Furthermore, these studies examine the organisational factors that determine the quality of workmanship.

Firstly, it is necessary to discuss some of the design recommendations made in the Code of Practice.

Design

Falsework is normally designed so that individual members do not fail since this could lead to a progressive failure or collapse, and even if it does not, it is likely to lead to local deformation which may have to be remedied, thereby incurring economic loss. Prime consideration is given, of course, to the overall stability of the structure, and the concerns of the Bragg and Code committees on the prevention of lateral instability due to horizontal forces are given high priority in the Code of Practice. Falsework design is based upon deterministic, permissible stress theory; information necessary for a probabilistic or limit state approach is not yet available and bearing in mind the wide variety of very temporary, highly indeterminate structures, limit state design is unlikely to be thought warranted in the future for all but the largest structures. A factor of safety of two is normally used in the design.

Clause 41.2.1. states that:-

> "the maximum allowable construction tolerances should be taken into account in the final design."

Also as reported in Chapter 2,Wilshere states that any design must

> "apply the same standards,.....irrespective of the nature of the work to be supported."(Wilshere 1985)

In other words bad workmanship cannot be sanctioned even in situations where it will not lead to problems of collapse or quality of concrete finish.

The derivations of the tolerances will be discussed below; for the moment one particular feature, Clause 42.1.3.2. which relates to *forces resulting from erection tolerances*, will be addressed.

> "the acceptable erection tolerances in nominally vertical members.....result in horizontal reactions."

The clause goes on to mention moments induced by eccentric loading.

This leads on to the whole notion of lateral and local stability and the whole of Clause 43 is devoted to lateral and local stability and the provision of bracing, lacing, or tying in to transfer horizontal forces.

Clause 43.4.1. states that falsework should be designed to resist at each phase of construction, the applied vertical loads and the greater of either:-......

a) horizontal loads equivalent to 2.5% of the applied vertical loads (reduced from the 3% figure advocated by the Bragg Committee) or

b) the known horizontal forces that can result from, for example, wind, concrete pressures plus those due to impact plus those arising from erection tolerances, (normally taken as 1% of the vertical loading).

Clause 43.4.2. refers to the bracing and lacing requirements to resist these forces. Such bracing will normally satisfy Clause 43.4.3. which details the bracing necessary to maintain the node point positions for struts. Where stability is derived from tying in to parts of the permanent structure, bracing and lacing may still be necessary to stabilise the strut at the node points and validate the assumptions made in determining the effective lengths of the struts given in Clause 46.2.

These rules for the determination of effective lengths can lead to severe restrictions on the local capacity of cantilever projections and where nodes cannot be restrained in position or direction.

Clause 45.2. relates to independent towers and the need for bracing and lacing between towers to overcome horizontal forces, notional or otherwise. Discussion amongst practitioners subsequent to the Bragg committee and during the comments stage on the draft Code of Practice and the subsequent inclusion of this clause has meant very few designs incorporate tower systems. The only tower systems supplied today are the heavy duty, fully braced military trestling systems, purpose designed structures and rigid heavy duty alloy towers (see plate number 5 chapter 2). In the rest of Europe and the U.S.A., energies are still concentrated on developing heavy duty proprietary tower systems, as opposed to 'pocket'-type systems.
The assumptions of good workmanship could be summarised as being based upon choice of good materials, tight connections near to node points (thereby not inducing moments), good fixity at the top and bottom with minimum eccentricity, and reasonably vertical and horizontal frame members. It is the requirements of lateral and local/node stability which are least likely to be understood or accepted by the

construction and perhaps the design personnel. The majority of practitioners accept the need for lateral stability, but frequently point to the inherent rigidity of the structure and fixity of the decking, which may provide horizontal restraint against walls and columns for example. This rigidity cannot be legislated for in the Code but leads to some erection personnel deriving their own measures to assure lateral stability. The provision of adequate node stability is an even more problematic issue.

Many designers, simply following in-house design procedures, are not fully aware of the reason for considering node stability and local stability of webs of beams for example. Many site personnel would take some convincing of the need to provide bracing in structures which are fully tied at the top, unless the structure felt inherently unstable and 'live'. They are not usually aware of the sometimes drastic reductions in load carrying capacity caused by lowering the top level of lacing to facilitate access. The construction personnel are frequently sceptical of the designs which incorporate masses of bracing and lacing assuming that it is another commercial ploy by the supplier to derive extra revenue. In fact although some over design may be likely due to the modular design of systems, the suppliers exist in a highly competitive environment and are unlikely to risk losing an order by stipulating extra equipment.

These requirements for stability are also likely to be variably accepted by different work groups. Scaffolders erecting independent access scaffolding are aware of the need for bracing, but may relax their standards on falsework; on the other hand joiners used to erecting timber or adjustable steel props in 'closed' buildings may not accept or be aware of the need. The designer or checker has always to counter the statement that:

> "This is how we've always done it and we've never had a collapse."

What is important, of course is that the probability of collapse is increased when standards of workmanship deteriorate. It is in these areas of lateral and local stability where the requirements of the Code of Practice are least likely to be understood and accepted by site personnel.

Derivation of Code Tolerances

Before dealing with the tolerances in detail it is apposite to discuss the derivation of these workmanship standards and tolerances so fundamental to design and in any assessment of quality standards on site. The standards are derived from studies such as that sponsored by the B.R.E.(Quinion and Ward 1975)and C.I.R.I.A.(Birch et al 1971, 1977) and what practitioners believe to be normal or reasonable 'trades practice'. Sometimes this trades practice is embodied in company brochures or training courses or as empirical rules in British Standards, for example the empirical rules for bracing in BS 5973 (1981) and many brochures. It was noted earlier in Chapter 3 that the B.R.E. study did not describe the range of workmanship to be encountered on sites but the best standards that could be achieved, and so the standards advocated in the Code and the resulting design assumptions can in no way be described as being based upon statistical, probabilistic, analyses. The safe working loads recommended for adjustable steel props (Clause 23.6) are related statistically to workmanship in the form of eccentricity and verticality (Clause 49.2.2.) and distribution of loading drawing upon the studies of Birch *et al* for C.I.R.I.A. (1977). The standards of workmanship prescribed in the clause are "a maximum eccentricity of 25mm and verticality within 25mm in 1 metre."

To a certain extent load capacities for tube and fittings (Clause 22) are related to workmanship (Clause 49.2.3.) using the work of Lightfoot (1977) among others.

The tolerances used for the erection of tubes and fittings (Clause 49.2.3.) are largely based upon the trades practice of scaffolders and what they can achieve in terms of access scaffolding (see BS 5973 (1981)). The tolerance of 25mm eccentricity is based upon loading applied to ledgers in access scaffolding, site practices (eg. B.R.E. study) and again the work on props by C.I.R.I.A. The modifications on effective length (Clause 46.2) has already been discussed but it is an area where the designer's intentions must be clearly transmitted and adhered to. The requirements for verticality to be "within 15mm over 2 metres height subject to a maximum displacement from the vertical of 25mm" are far more severe (over three times) than those for props. It is to be presumed that the safe working load of tube scaffolding assumes the standards of Clause 49.2.3.; and that operatives are capable of achieving the standards. Scaffolders usually erect tube and fittings and it is implicit that they are either more careful or competent than those erecting adjustable steel props; or that the trade practice of erecting adjustable steel props adopts different standards. Personal experience suggests that it is more difficult to erect props than tubes and fittings.

For the reasons that they are constantly changing, have a variety of types and load capacity, commercial confidentiality and legalities, the Code of Practice does not stipulate detailed erection tolerances for proprietary systems. Manufacturers must perform necessary tests (Clause 23.2) as described in Appendix C in the Code of Practice in order to establish that their systems conform to the Code's general requirements for loading design and so on. Appendix C does not detail particular tests but offers vague guidance in the form that the tests should reflect the loading conditions and erection standards likely in a certain application on site. There are no universal testing criteria therefore applicable to all manufacturers. The manufacturers, in the author's opinion, should stipulate in brochures and drawings any particular workmanship standards necessary or assumed. Such information is normally absent, therefore for the purposes of this research: *the workmanship standards prescribed in the Code of Practice for tube and fittings will be assumed to apply to the use of proprietary systems in the analysis of quality reported in this thesis.*

It may be possible that equipment capacities claimed by suppliers may be achieved under conditions of greater eccentricities, out of plumb or cantilever projections (for example jack extensions); on the other hand, tolerances used in the testing of assemblies may be unreasonably small as was the case in the C.I.R.I.A. studies. Hitherto, tests on adjustable steel props were carried out upon concentrically loaded, vertical members. Thus the factors of safety on the safe working load (S.W.L.) determined from such tests were severely eroded to almost unity, when props were erected to the standards of workmanship found on sites. The studies for C.I.R.I.A. resulted in revised B.S. tests for props and the derivation of S.W.L., which reflected the loading and workmanship standards on site.

It is often claimed that systems are 'idiot-proof' in that they can be easily assembled to the required standards of verticality and horizontality, or that features such as eccentricity are obviated 'by design', using proprietary decking beams or 'trigger-braces'. This study will show (Chapter 8), that the standards for proprietary systems assumed in this thesis can be achieved. There is no universal acceptance however, that these standards are necessary. It is sometimes presumed that the erection of proprietary systems requires different and lower levels of competence (body of knowledge). The tolerances in the Code of Practice reflect the overall standards of workmanship that can be achieved by competent personnel. There is implicit, therefore, an assumption of some level of competence in the Code recommendations.

Training is necessary to achieve or continue this assumed level of competence and although the Code of Practice makes no mention of it, the draft Code and Bragg reports make specific recommendations on training of the workforce and their supervision.

Workmanship standards cannot be changed depending upon the type of system, unless different standards are widely disseminated, via the drawing or brochures. It is unreasonable and impractical to expect operatives and supervision to have such a wide knowledge of individual system types.

Basic workmanship regarding erection standards and reading of drawings are universal requirements and not subject to adjustment, depending upon circumstances.

Tolerances and sources of error are now examined and explained in detail. The Code of Practice is used extensively, supplemented by the knowledge of systems and construction methods.

<u>Erection tolerances</u>

The clauses in the Code of Practice of relevance are 49, 50, and 53, from'general workmanship', 'checking falsework', 'maintenance', 'inspection and identification of materials', and clauses 54 to 57 on 'standard' solutions.

Clause 49.1 'critical factors of workmanship' gives a broad list of requirements, of little help in formulating an actual list to assess workmanship on site:-

a) the foundations should be satisfactory;

b) the falsework should be in accordance with the design, particularly regarding quality and quantity of components and setting out;

c) tolerances should be in accordance with 49.2;

d) all connections should be properly constructed;

e) there should be adequate safe access and working places.

The pages of tolerances and standards provide comprehensive, but confusing details which are of limited use in conducting an actual check on workmanship. Many of these standards are duplicated in the section on 'Standard Solutions' to enable 'Section Eight' to be used as a self-contained handbook for repetitive, common applications. However when one considers that the section is intended for 'the man in the hut', some of the explanations (for example, on bracing and lacing and tying in) are surely confusing in that they are written in engineering terminology assuming knowledge and understanding for example of strut behaviour.

To enable checks to be made on falsework the Code requirements (and supplementary knowledge) must be assembled in a more straightforward manner. Inevitably some of the requirements are neglected or subsumed under one heading.

For typical beam and slab soffit construction workmanship can be assessed under the following seven headings:

1) Head condition
2) Base condition

3) Vertical members

4) Bracing

5) Tying-in

6) General conditions of materials

7) Access and safety.

Details of individual tolerances, and errors of workmanship together with explanatory references to the Code of Practice or current trades practice are given in the Appendix to this chapter for each of the seven headings.

This list was used as the source of the checklist and scoring mechanism of Chapters 7 and 9.

Conclusions

This chapter has dealt with the technical recommendations of Bragg and Code of Practice. The derivation of the erection tolerances listed has been described. Workmanship standards are also prescribed in the form of rules concerning bracing, lacing, tying in and so on. The purpose of this study is to measure quality of falsework construction. The next chapter will explain that the definition of quality for the purposes of this study concerns quality of workmanship on site and under the control of site. The various clauses and standards listed in various parts of the Code of Practice, together with supplementary knowledge of proprietary systems and construction practices have been assembled in order that such measures of workmanship standards can be performed. The detailed list appears as an appendix to this chapter and forms the basis of the checklist and subsequent scoring mechanisms addressed in Chapters 7 and 9.

The organisational recommendations of Bragg and the Code of Practice are addressed later in Part 3.

Appendix to Chapter 4

Workmanship factors and erection tolerances used in the study.

Reference may be made to the glossary in the main appendix and to figures included at the end of this appendix.

A.HEAD CONDITION

1) Eccentricity greater than 25mm - Beams not centrally loaded.

   This error typically occurs when traditional formwork decking is supported by the falsework and the timber or aluminium primary bearers are placed eccentrically in the forkhead. See Fig.1. This may be due to incorrect setting out, simple lack of care, or where overlapping single primary bearers are used. It is not practical to stagger the line of vertical standards in order to achieve concentric loading (since lacing and ties must be fixed along the same centre line) and therefore the primaries should be laid as shown in Fig. 2. Where single primaries are butted together within the forkhead (which may waste material in cutting) consideration must be made of the bearing and fixity (below). The error is very rare when proprietary decking systems are used since the decking beams fit directly onto lugs at the top of the heads. The error may occur where two different equipment types are used for the support and decking which have incompatible connection arrangements.

   Clause 49.2.2(c) and Clause 42.2.3(c) requires that props and standards should be placed centrally under the member to be supported and any member supporting the prop or standard with no eccentricity in excess of 25mm. (Measured between centre-lines of forkhead and centroid of primary member(s.)

2) Clips/wedges missed out for beams smaller than forkheads.

Clips and wedges are essential to ensure that the aluminium and timber beams in forkheads do not topple over due to excessive horizontal force (Clause 50.2(c)(8).

3) Joints in beams not located centrally on forkheads (more than 15mm).

Clause 49.4 suggests that where timbers butt in a forkhead, the joint should be within 15mm of the centre of the forkhead.(Figs.3 and 4).

4) Jack extension beyond limit and no bracing.

Clause 49.2.3.(d) notes that adjustable forkheads and base jacks should be adequately laced and braced where their extensions exceed 300mm. With proprietary equipment there are standard charts showing details on jack extension limits and provisions of bracings with respect to different combinations of horizontal and vertical loadings.

5) Timber beam seatings on propheads not secured.

Clause 50.2(c)(8) requires that the bearers are correctly spliced, centralised in forkheads and, if required, nailed and wedged in the forkhead. Clause 57.5.3. denotes that the wedges and timbers should be nailed to the top plate of the forkhead. Usually two nails on propheads should secure the timber bearer against over-turning.

6) Load bearing wedges not wide enough.

Where the ground and/or soffit is sloping, load bearing wedges and/or rotating (about the horizontal axis) forkheads or baseplates are required.

Clause 49.5 suggests that they should be as wide as the member above to develop full bearing of the members in contact.
(Figs.5 and 6).

7) Load bearing wedges of inadequate material (especially on sloping soffits).

Again Clause 49.5 requires load bearing wedges should be selected to be of uniform sound quality. The material (refer to Clause 18.1.3.) from which the wedges are formed should be appropriate for the stresses to which they are subjected. For load bearing wedges and packings, the higher strengths available only from the denser hardwoods will be desirable.

8) Condition of forkheads/bearing plates of standards and adjustable steel props.

Clause 53 requires that the equipment and materials used in falsework should always be examined prior to use. Before they are used again they should be cleaned of deposits of soil, concrete or such unwanted material.

Clause 16.2. notes that a careful inspection is essential in preventing unfit, secondhand material being used. Welds should be checked and material that is bent, distorted or badly corroded should be scrapped or sent for repair. Items made from steel should be kept in a well-painted condition.

9) Undersize timber - primary and secondary runners.

Clause 50.2(a)(2). requires that only correct materials in serviceable condition have been employed, especially if specific types or qualities were required as will normally be the case with structural steel or timber.

10) Light instead of heavy duty jacks/propheads.

Again Clause 50.2(a)(2) is applicable here. Only correct types of propheads should be used because light duty instead of heavy duty propheads will not be sufficient to take the design load.

B. BASE CONDITION

1) Light instead of heavy duty base jacks.

Comments in A(10) above apply, plus Clause 49.7 indicates that "when equipment such as a proprietary framing system is used, all the recommended components should be used; no changes should be made without further consideration of the original design."

2) Conditions of foundations and soleplates.

In accordance with Clause 50.2(b)(2), the ground should be adequately prepared and at a satisfactory level. Section 5 of the Code should be referred to in order to understand the correct ground requirements to support the falsework. Clause 57.1 briefly explains the Code requirements for ground preparation and anything beyond these requirements should be specifically designed. Sole plates, if used, should have a minimum cross-section of 250mm X 125mm. No upright should be within 300mm of the end of the sole plate. Where ground is sloping, load bearing wedges or rotating baseplates are required (as above) plus an arrangement to cater for horizontal thrust down slope.

3) Base plate seating inadequate.

With reference to Clause 50.2(b)(5,6 &8) care should be taken that the base plate is sitting on a sound base and not on the edges of foundations or channels or have any voids underneath it.

Timber soleplates should be used to protect concrete floor slab or to distribute the loading into the foundation. See Fig.7.

4) Incorrect pins used on adjustable jacks (on certain types).

On certain base jack assemblies heavy duty pins may be replaced by mild steel bars and nails. This is totally inadequate. Compare Clause 23.6. for use in adjustable steel props.

5) Excessive jack extension greater than 300mm.

Comments in A(4) above apply. Reference must be made to proprietary suppliers' brochures for further information with respect to bracing.

6) Base plate conditions.

Reference should be made to Clause 53. The material used on site should be of good quality, i.e. not bent, corroded etc.

C. VERTICAL CONDITION

See Figs. 8 and 9.

1) Lift height excessive.

With respect to Clause 50.2(c)(4), the spacing and the level of each lift of lacing members must be correct.

If the level is increased, the effective length of the standard is increased (Clause 46.2) which in turn decreases the load carrying capacity of that standard. This is particularly problematical when lacing is lowered to facilitate access to adjust or strip formwork and indeed to check the structure.

2) Lacing missing (check in both directions).

In accordance with Clause 57.2.2(f), the tubes should be laced at head and foot and intermediate levels so that the vertical distances between levels of lacing do not exceed 2 metres. Lacing is important to ensure stability of the falsework structure. For props Clause 57.5.2 should be noted where it indicates that any prop beyond 2.75 metres of extended length must be laced. Again lacing may be missed out in one or more bays to provide walking access beneath structure. Note the requirements under (1) and (2) also apply to proprietary systems unless proven otherwise.

3) Incorrect pins on adjustable steel props.

With respect to Clause 57.2.1(c), and Clause 23.6 the props should have the high tensile steel pins provided by the manufacturer and only these should be used.

4) Conditions of materials.

Clause 53 states that good quality material is to be used on site.

5) Excessive inclination.

For any steel prop, Clause 49.2.2(b) recommends that it should be plumb within 1.5 degrees of vertical (ie. not exceeding 25mm out of vertical over a height of 1m).

For tubes and fittings, Clause49.2.3(b) notes that verticals should be plumb within 15mm over 2m of height, subject to a maximum displacement from vertical of 25mm. This means that the verticals should be plumb within approximately one half degree of vertical.

For proprietary systems the Code does not give any particular figures and since the proprietary suppliers cannot give accurate figures based upon their own tests the tubes and fittings requirements are adopted for this project.

An inclinometer of the required accuracy was used to measure the verticality of the props and standards on site.

6) Light instead of heavy duty standard.

Correct type of standards should be used in accordance with Clause 49.7 and 50.2(a)(2), eg.A 30KN standard should not be used if 55KN is specified on the drawing. This is obviously a potential problem in proprietary systems and mixing of different types of system and could apply to wrong size adjustable steel props being used (see Fig.1 in Code).

7) Fixing at all node points.

In accordance with Clause 50.2(c)(11&12) make sure that all couplers, wedges, clips etc. are fixed adequately for bracing and lacing at node points. In some systems fixing is automatically coincident with node. See Fig.10.

D. BRACING

Reference should be made to the whole of Clause 43.4.

1) Correct type of bracing.

With respect to Clause 50.2(a)(2), the correct type and length of bracing should be used, otherwise inferior type means that the load carrying capacity of the bracing is diminished, or if the wrong length, the connections may not be close enough to the node point (below).

2) Distance from node points.

Clause 57.2.2(j) requires that the position of bracing should not be more than 150mm from a node point. In certain systems this is obviated by the equipment design, in others scaffold tube must be used. Problems may occur where the grid size is changed or the lift heights changed on site and thus the supplied bracing members are the wrong length to be fixed adjacent to the node. See Fig.10.

3) Position, proportion and distribution.

In the absence of a design or drawing the standard solutions of section 8 apply.

Clause 57.6 explains clearly the importance of bracing and minimum requirements in various conditions of falsework. When bracing falsework utilising adjustable props as the vertical load bearing members, at least every sixth prop in a row, a diagonal brace should be fixed in the direction of the row and connecting with an adjacent row. Similar bracing should be provided for all rows at right-angles to the first direction of bracing.

Where using tube and coupler falsework, and no drawing is available, diagonal braces should be provided at a minimum frequency of one brace every sixth standard, in each line of standards.

4) Condition of materials.

Clause 53 again addresses these requirements.

E. TYING-IN

1) Replacing bracing for lateral stability in part or in total by tying-in.

Clause 43.4 and Clause 57.6.3. explain the situations where falsework is restrained by existing structures such as walls and columns. The tying-in should be in accordance with the Code of Practice and checks should be made that all fixings for tying-in are adequate as far as load bearing requirements are concerned, plus the stability of structure is maintained ie. tying-in should be adequately provided at all levels of lacings.

2) Check bracing for node stability.

If tying-in is introduced instead of bracing, the requirements of Clause 57.6.3. and 4 should be still adhered to for both the lateral and node stability. No vertical member should be more than 4 members away from such a strong point unless otherwise stabilised. ie. by bracing.

F. GENERAL CONDITIONS OF MATERIALS

1) This section is included in the checklist to obtain an overall assessment on the condition of falsework materials in any given sample area. In each of the previous conditions, the quality of the falsework material is examined separately and under this heading different categories of conditions of material can be identified:

a) No serious comments.

b) Rusty, bent etc. but no structural problem.

c) Rusty, bent etc. but may cause local structural problems.

G. ACCESS AND SAFETY

1) This section refers to Clause 50.2(c)(13). where it is briefly described as the type of access to be provided for workmen ie. if ladders, platforms, guardrails and toeboards are fixed adequately and comply with the requirements of the construction regulations. In the latter part of the interviews with the designers it became evident that more items under the Health and Safety at Work Act 1974, will be required to be included on the checklist. Three clear points can be selected:

1) Adequacy to check edge formwork.

2) Adequate and safe access to concrete.

3) Site tidiness.

On a few sites this list was extended to 10 No. definite checks under this heading. These checks were as follows:-

1) Is safe access provided to reach all parts for works,ie. ladders and safe access scaffold?

2) Are all walkways level and free from obstruction?

3) Are there adequate guard rails and toe boards?

4) Are all access materials in good condition and free from obvious defects?

5) Are all ladders secured at the top and bottom?

6) Are there sufficient boards at all working platforms in use?

7) Are the ladders properly positioned for access?

8) Ladder rise must be at least 1.07m above the place of landing. If not, is there adequate hand-hold at the place of landing?

9) Is the site tidy and are materials stored in safe positions?

10) Is somebody responsible for the inspections and are they carried out and recorded?

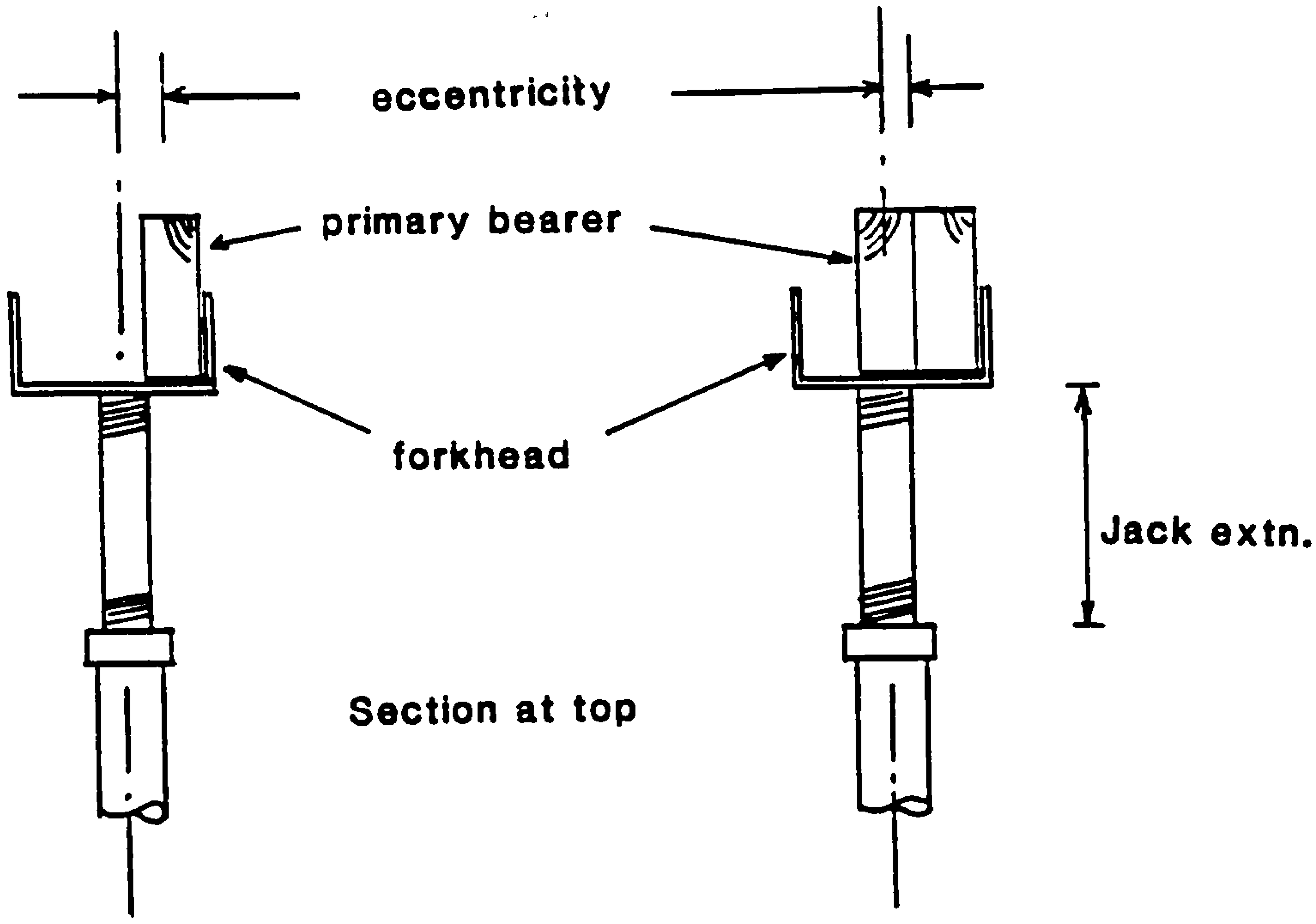


FIG. 1 :Eccentricity at forkhead

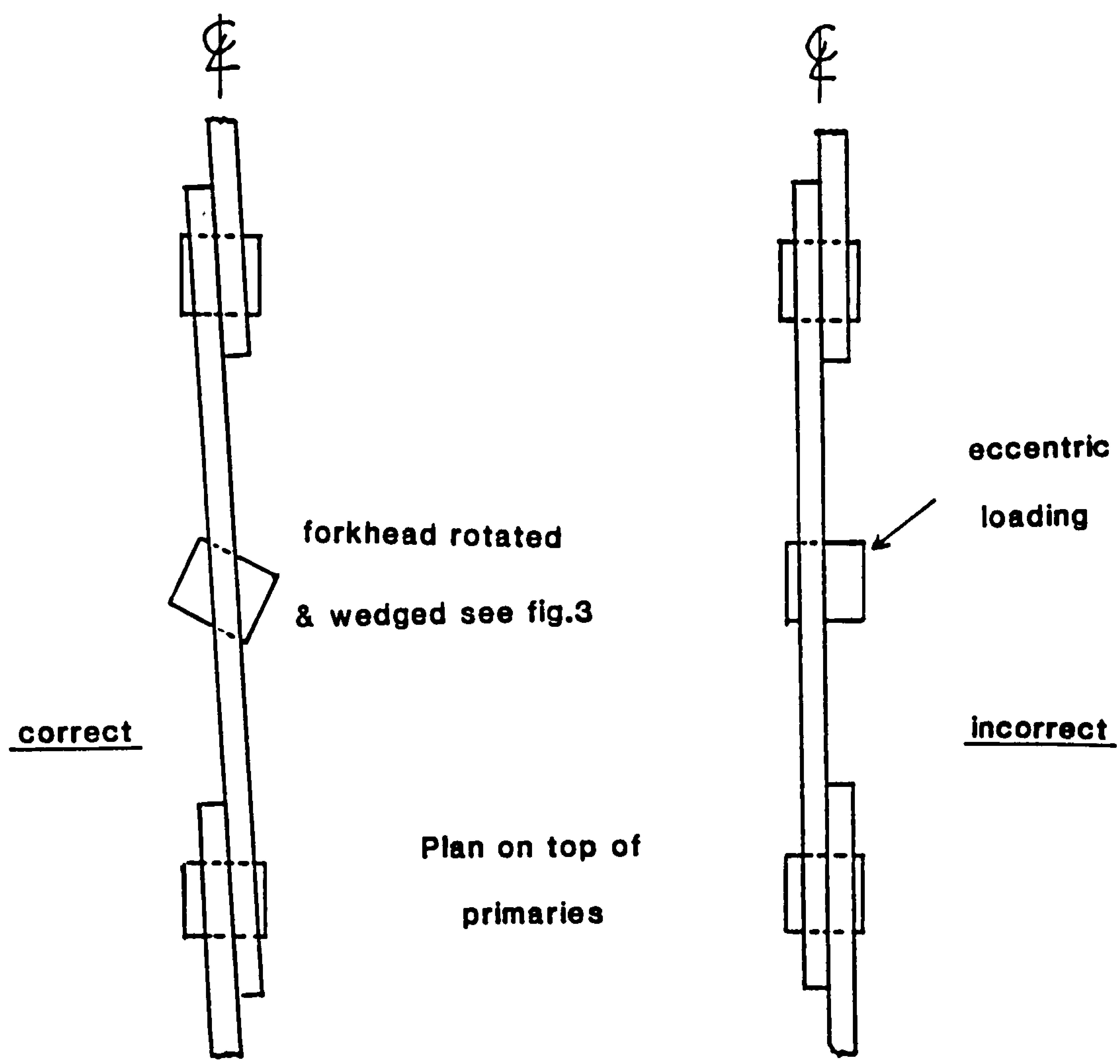
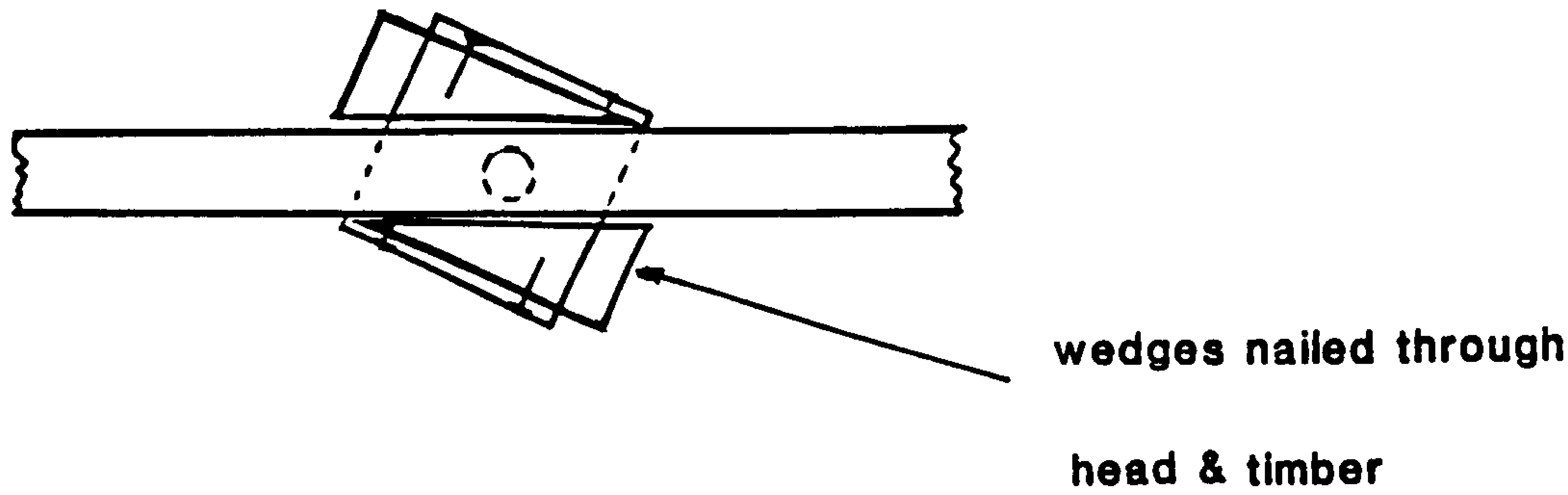
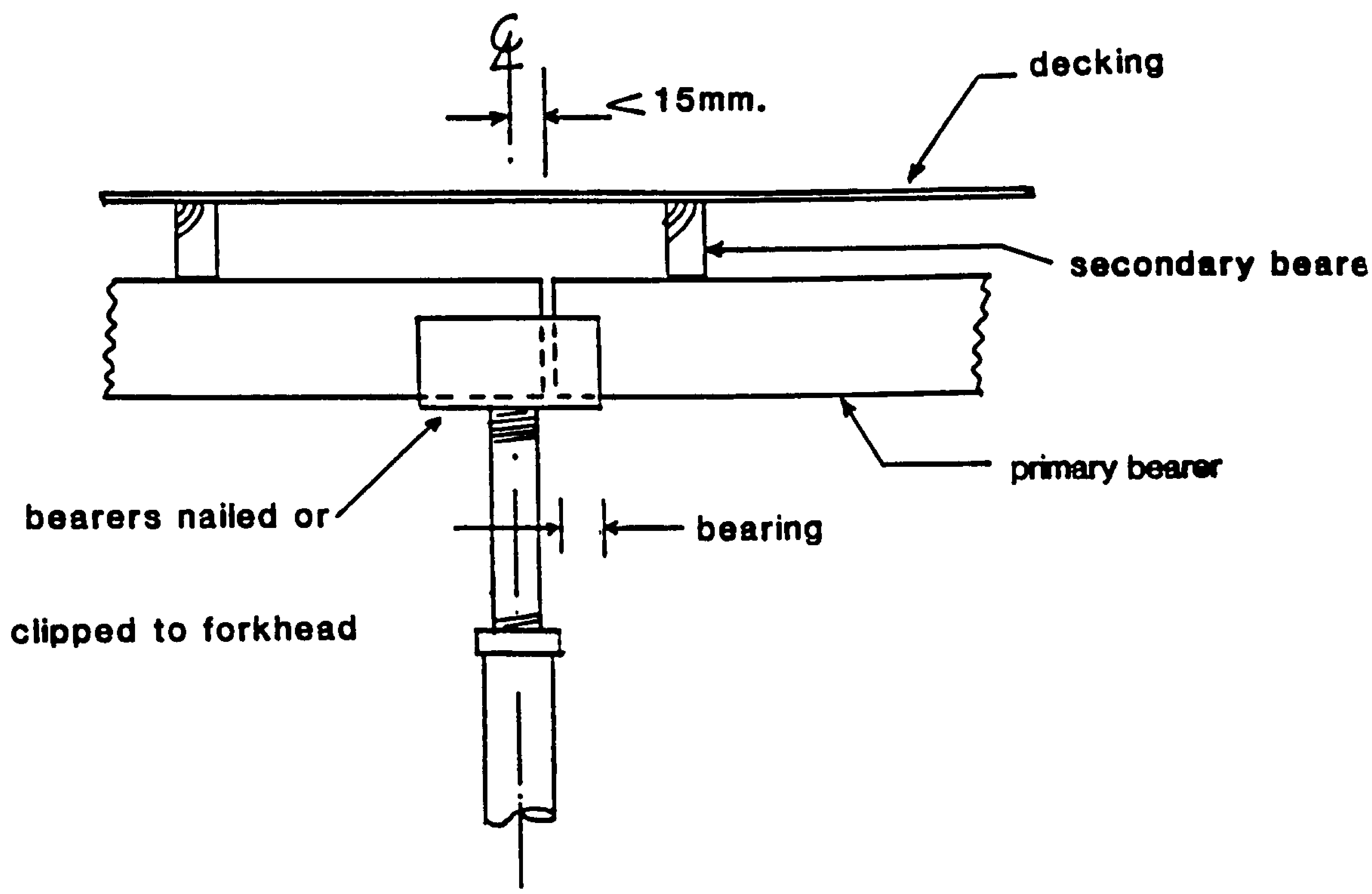


FIG.2: Method of reducing eccentricity when using single overlapping primary bearers



Plan on top of primary

FIG.3: Rotation of forkhead and wedging to ensure min. ecc. and adequate fixity



Section at top

FIG.4: Eccentricity, bearing, fixity in butted primary bearers

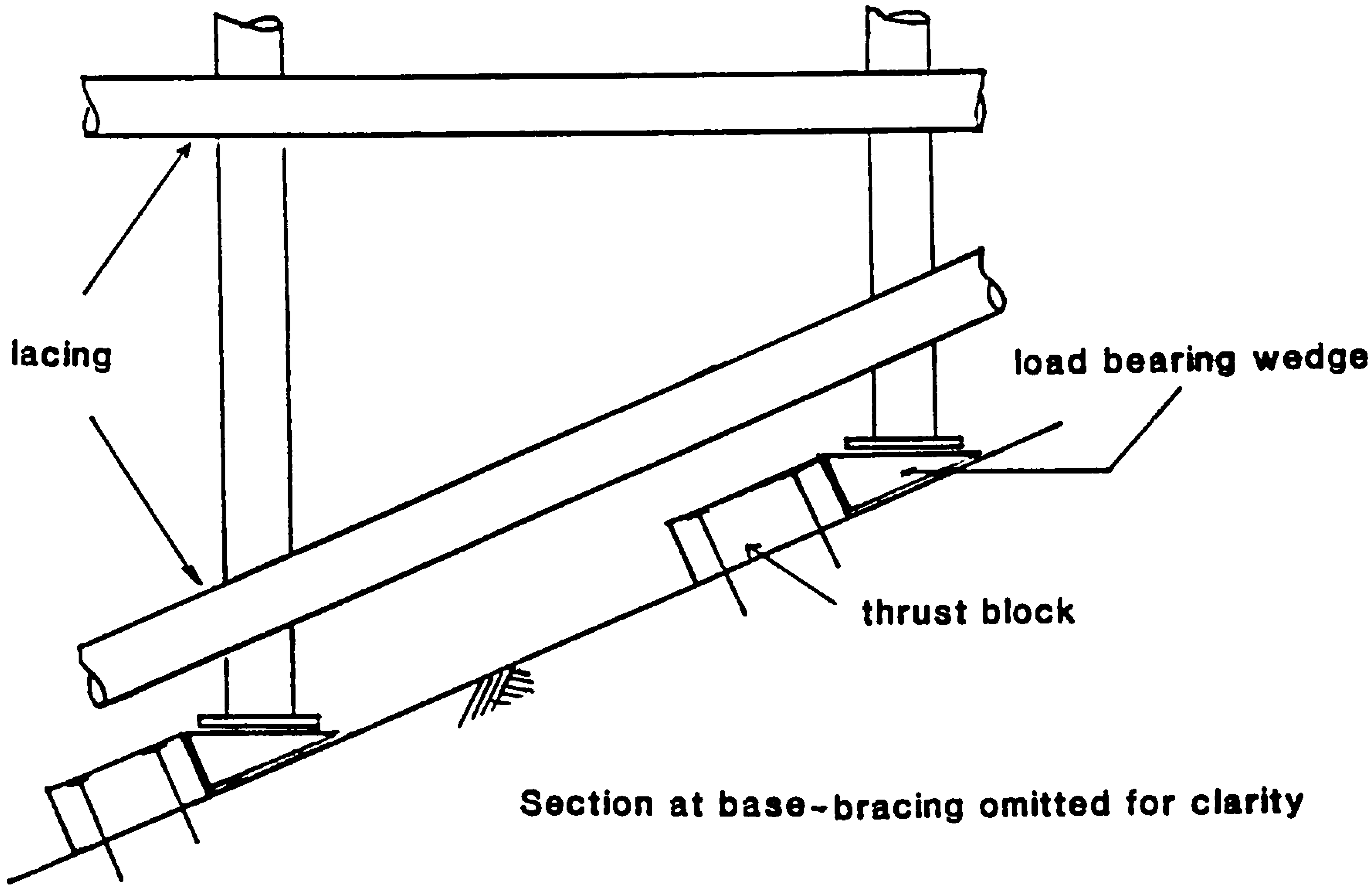


FIG.5: Load bearing wedges on sloping ground

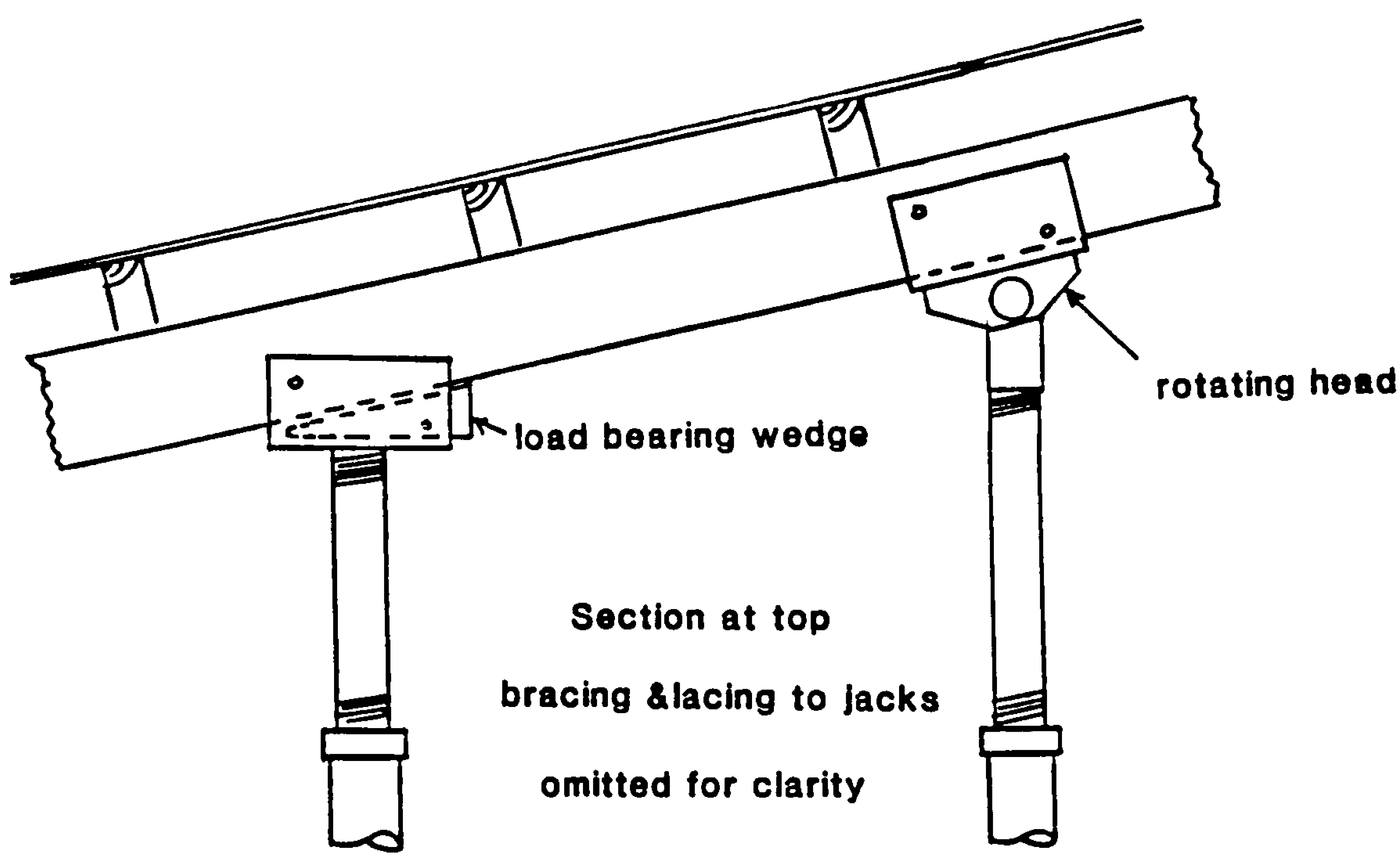
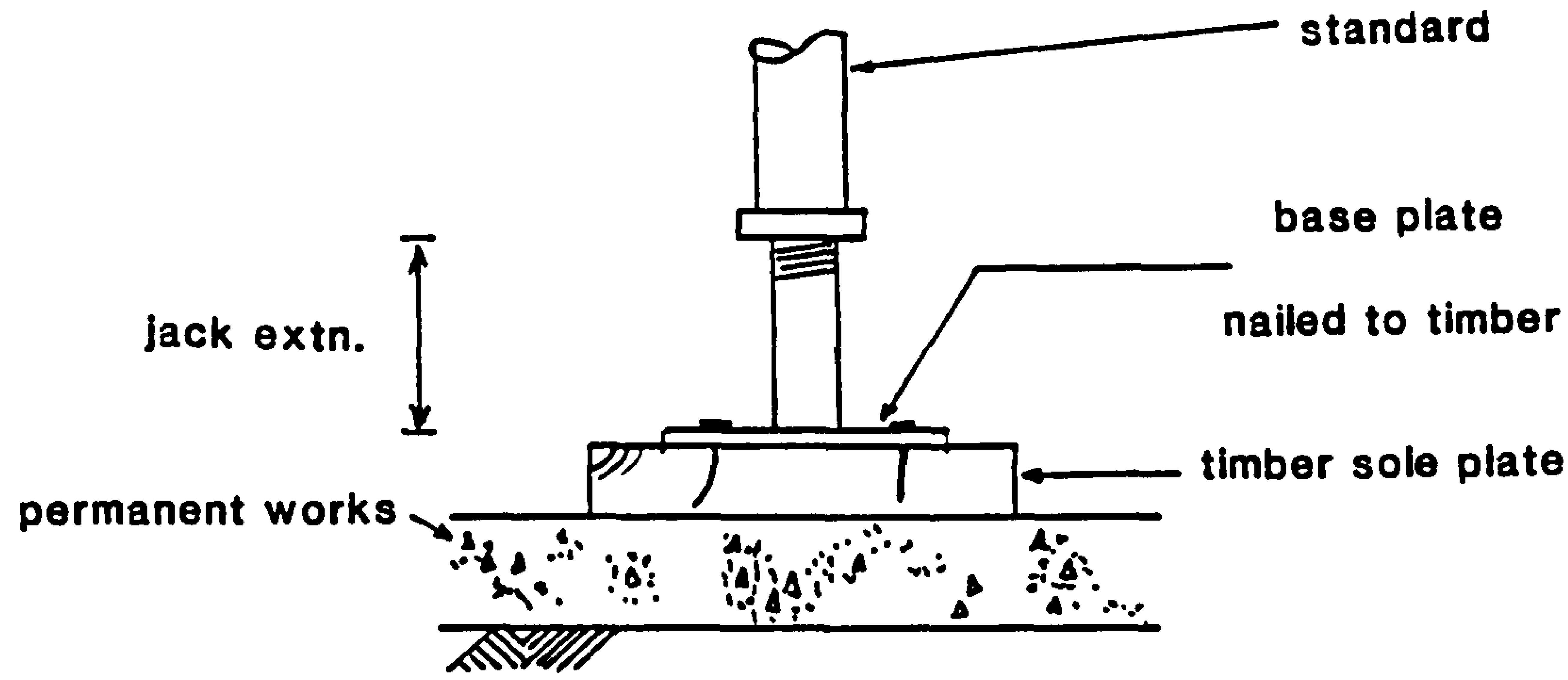


FIG.6: Sloping soffit using load bearing wedges or rotating forkhead



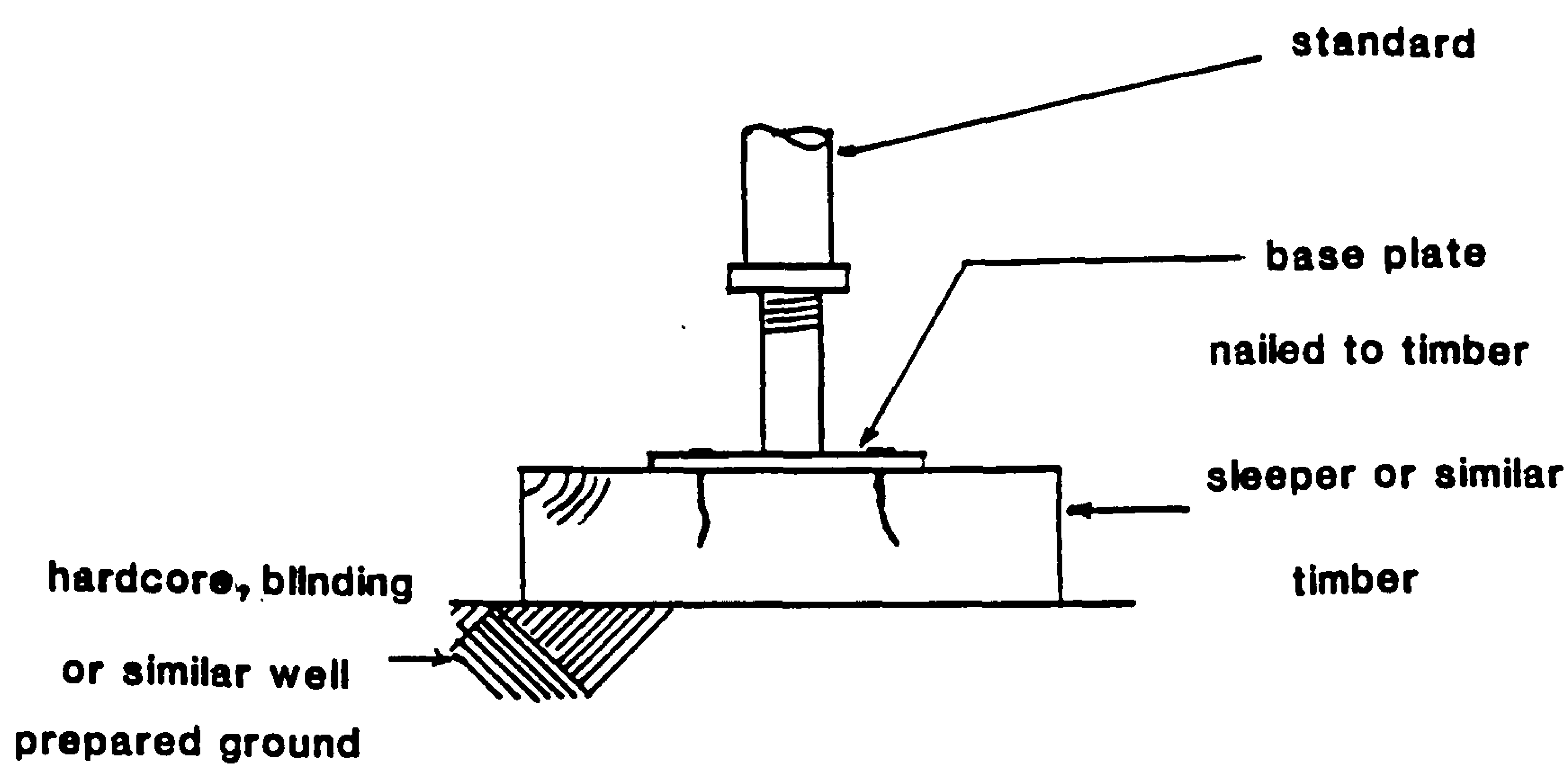


FIG.7: Base details on slab or prepared ground

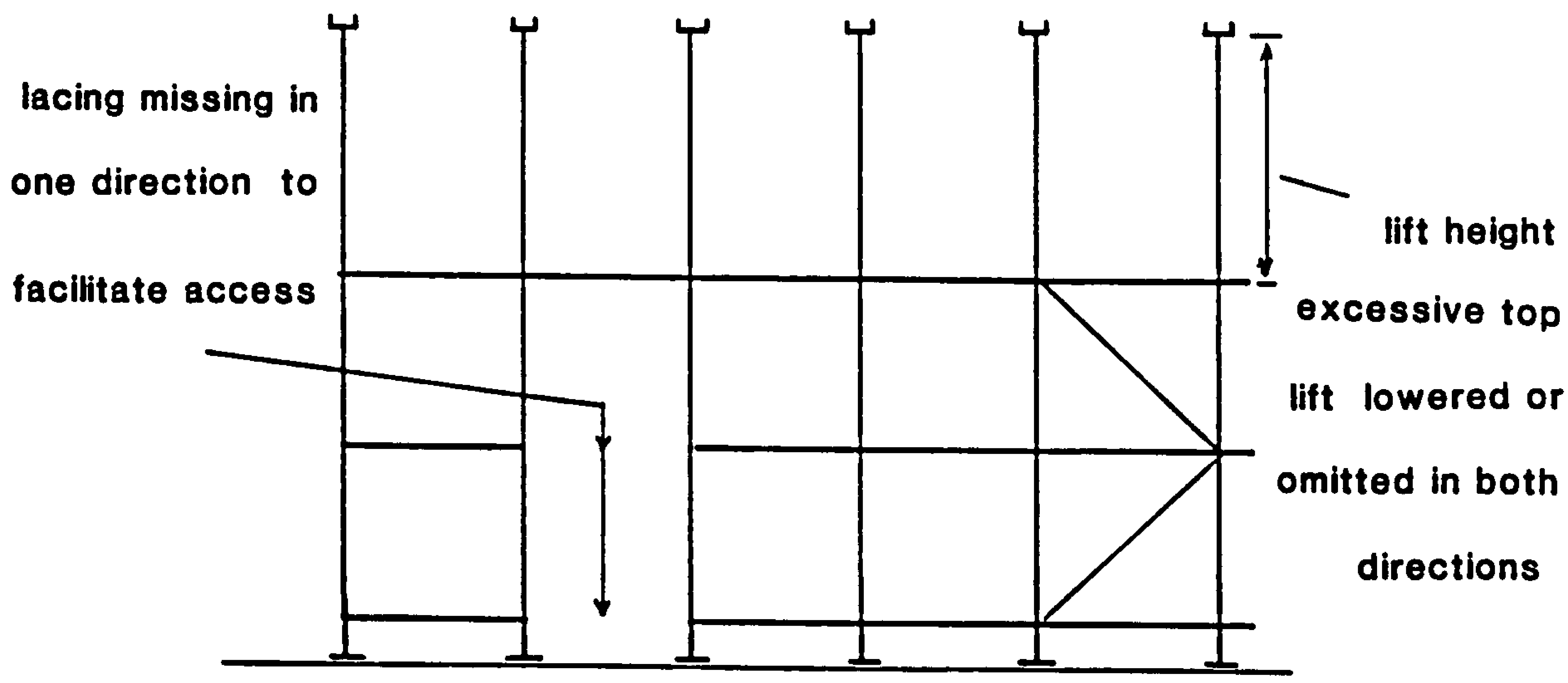
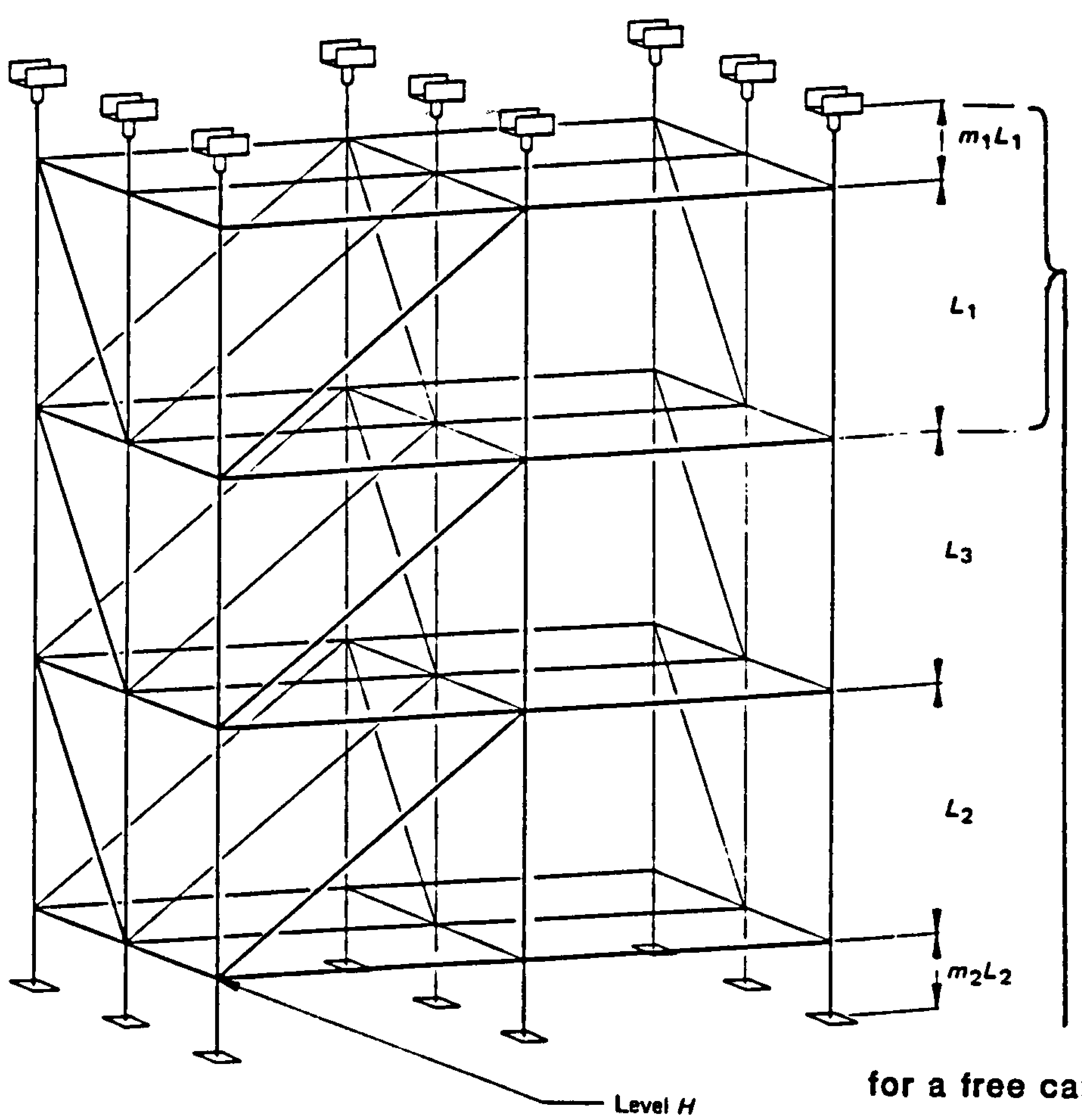


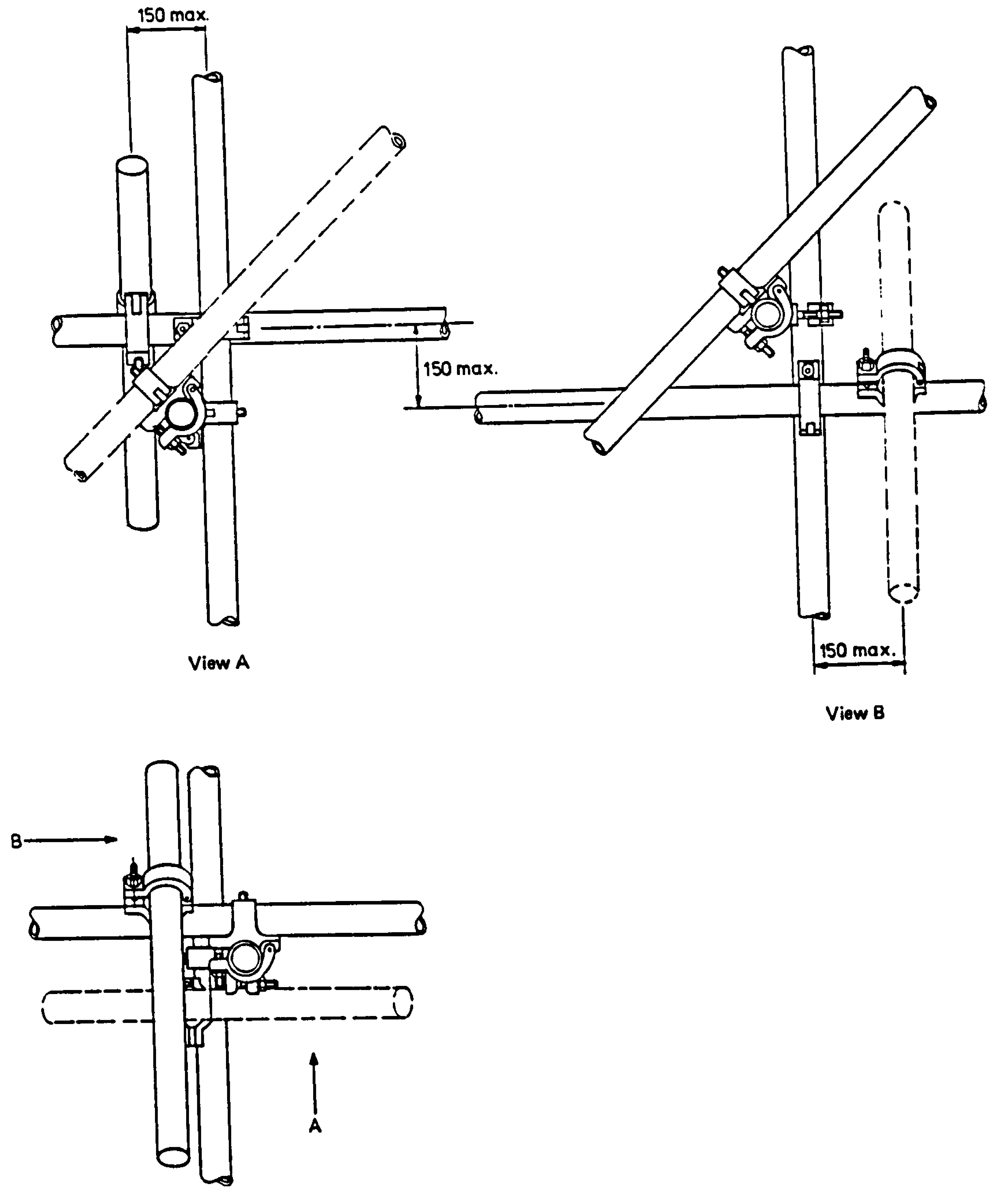
FIG.8: Vertical condition lacing missing



NOTE. Configuration of scaffold is diagrammatic only.

for a free cantilever effective length of this member is $l = L_i + 2m_iL_i$

FIG.9: Effective lengths in tubes&fittings



NOTE. One diagonal is shown dotted for clarity.

All dimensions in millimetres.

FIG.10: Eccentricity at nodes (Taken from B.S. 5975)

PART TWO

Measurement and Findings on Quality

CHAPTER 5

The Assessment of Quality

Introduction

In this chapter the phenomenon of quality is briefly discussed and also the procedures adopted by other industries. Today, the issue of Quality Assurance (Q.A.) in the Construction Industry is receiving much attention. The procedures involved in implementing Q.A. imply that quality is measurable. This study, in a microcosm of the industry, of quality and management of falsework construction by procedural means, therefore has relevance to these wider issues. It was of fundamental importance that some measurement of quality of falsework had to be devised in order to proceed with the discussions on the relationship between organisational control and quality. The methodological problems in determining this measure and definition of quality of falsework are presented.

Definition of quality

Quality is a phenomenon difficult to define or describe and is more of a philosophical and ideological issue. Such discussions are beyond the scope of this thesis. Quality is defined in typical British Standard terms in BS 4778 (1978) as:

> "The totality of features and characteristics of a product or service that bear on its ability to satisfy a given need."

It gives little help on how it can be judged, but 'fitness for purpose' or 'conformity with requirements' are everyday concepts.

To some, quality must be based in money terms. Quality for the customer is that he gets what he thought he was going to get, and at the right time and for the price that he thought in his budget; furthermore that the product will have a reasonable service life without incurring servicing and maintenance costs greater than he expected. There is a great deal being expected, therefore.

> "You must be able to measure quality. If you can't you'll never know whether you've got it."
>
> Pateman (1986b)

Once it can be measured the type of organisation and production processes and cost that level of quality can be devised. In this school of thought, well described by Pateman for example (1986a,b,1987) and discussed in Brandon and Powell (1984) 'you get what you pay for'.

For others quality is more of an ideological issue, separate from, but involving politics and economics. Quality like beauty, is 'in the eye of the beholder' and cannot be uniquely defined; the search for descriptions and attainment of 'Quality' is akin to the search for the Holy Grail. Ferry (1984) and others in Brandon and Powell (*op cit*) discuss quality in relation to buildings and architecture.

<u>Concern for Quality</u>

In recent years there appears to have been wider concern about quality. Tait (1988) believes that

> "concern for quality is a mark of an advanced society."

Why should there be such concern and why are customers dissatisfied with the product that they get? Is it that their expectations are greater than before or is quality deteriorating? One could point to countries like Japan and Germany who have established reputations for high quality goods such as motor cars, cameras, audio equipment and so on. This reputation is for reliability with price quite often a secondary marketing feature. Expectations are raised and in order to compete United Kingdom firms are urged, by media, commentators and practitioners to adopt similar procedures and commitment to quality. In the case of the Construction Industry, its reputation has suffered over recent years, for example:- timber-framed housing, high alumina cement, motorway reconstruction and so on. These faults arise for many reasons; from poor design and construction, unexpected effects during a long service life and unexpected loading or changes of use. These reasons can often be explained by the structure of the industry and its product's unique uncertain characteristics. Some claim that the problems are caused by the contracting system used in the Construction Industry.

Certainly the construction industry and its customers believe that there is a problem of quality. Bragg and subsequent studies indicate a problem in falsework and the study by National Economic Development Office (N.E.D.O.) (1987) reflects the concern with quality of building construction. This study echoed those of the Bragg committee, blaming the problem of fragmentation, and recommended more formal and legal procedures as a basis of the solution.

Quality procedures and Quality Assurance

How then is this nebulous concept of quality achieved? In the case of the manufacturing industries, for example, product characteristics can be relatively easily specified and prescribed. The large scale batch production means that techniques such as Quality Control (Q.C.) can be applied to ensure quality. Some firms have extended these Q.C. techniques to control the production process by Statistical Process Control (S.P.C.) or, even further, by implementing Quality Assurance (Q.A.) schemes to control, the whole procedure of production including suppliers and the design function.

It is difficult to describe the principles of Q.A. in a sentence where some require a whole textbook. Put simply:-

> "It is a rule book which documents the systems that a company requires to control the quality of a product or service. All those procedures which are the basis of the controlling process must be written down."
>
> (pg. Pateman *op cit*)

Without formality employers and employees interpret unwritten rules differently. Quality Assurance schemes call for formality of procedures, and independent checking; this philosophy compares with Bragg. It can also be seen as a traditional response of the advocates and practitioners in the classical school of formal organisation theory (Part 3). Quality Assurance is seen as a natural extension of the 'Kitemark' applied by B.S.I. to products having a British Standard, in particular by high spending purchasers with suppliers whose very livelihood or reason for existence is dependent upon them. Suppliers may be forced therefore to adopt Q.A. procedures and be registered (see below) or accredited. Some suppliers see intangible opportunities of gaining marketing advantages over their competitors by having Q.A. Moreover:

> "because of the threat of foreign imports some Trade Associations have used Q.A. as a market survival kit." (Pateman *op cit*)

With the experience of Japan in mind, many industries and firms are now looking further than Q.A. Their organisations, they believe, should not be product-led but client-led, where focus is upon satisfying customers' expectations and where the whole philosophy of the enterprise should be one of continually improving quality. To these ends the 'buzz-words' of today are the 'Total Quality Concept', the 'Taguchi Method' and 'Quality Function Deployment'. Manton (1988) gives an excellent brief synopsis of the current state in the car industry. The notion is one of commitment to quality by the firms and the suppliers and is an extension of the idea of Quality Circles as a method of organisation. An introduction to Quality Circles is given in Robson (1982) for example. British Telecommunications and Austin-Rover are just two firms embracing the Total Quality Concept in a big way.

In the car industry the message seems to be one of learning from Japan, with its commitment to raising expectations for reliability in the market place. The Japanese do not fear the initiatives now being made in the United Kingdom, for a leading Japanese economist is quoted in a Department of Trade and Industry (D.T.I.) mission as saying:-.......

> It would take you ten years to get where we are now and by that time we shall be even further ahead. And besides.....we know you won't do it."
>
> (quoted in Manton *op cit*).

In their search for straightforward solutions, production engineers and some organisation theorists tend to overlook the socio-economic structure and culture and dismiss the resulting 'informal' structures (see Part 3) and tend to advocate trivialised prescriptions for organising production and the industry. Many industries, therefore, assume quality assurance to operate as part of more embracing organisational solutions for obtaining quality and reliability in the market. Many clients are used to having Q.A. schemes applied to them and their suppliers and therefore see no reason why such schemes should not apply to the Construction Industry. Government, in the form of the Department of Trade and Industry (D.T.I.), and their White Paper at the beginning of 1988, has expressed concern and instructed the (construction) industry to look into Q.A. Government is naturally looking towards 1992 when trade barriers with Europe are lifted and British industry could face severe competition on quality and other factors. Government is also signalling that it will demand Q.A. in its future contracts, in addition to those Ministry of Defence (M.O.D.) and Nuclear works it commissions now. The Central Electricity Generating Board (C.E.G.B.) and the M.O.D. have been using Q.A. for about 10 years for the obvious reasons of safety and national security. The Channel Tunnel is subject to Q.A. and third party independent checking. Traditional methods of accrediting products with a 'Kitemark' cannot be applied to products which do not have British Standards, nor to a Code of Practice which covers design. The B.S.I. introduced a scheme for "firms of assessed capability" and introduced BS 5750 *Quality Systems*. Any firm seeking to be registered or accredited will normally comply with the Quality Systems described in BS 5750; any firm wishing to check upon the Quality System of a potential supplier can also use BS 5750. The National Accreditation Council for Certification Bodies (N.A.C.C.) accredits those bodies who can then approve the Quality Systems and register firms as Quality Assured. British Standards Institution Quality Assurance Services (B.S.I.Q.A.S) is one of four third party Certification Bodies accredited by the N.A.C.C.

Subsequent to the Bragg committee's findings and the introduction of the Health and Safety at Work Act, which signalled Government's concern for safety, the industry had to be seen to be acting on temporary works and safety or risk measures being imposed externally by the H.S.E. In a similar way, but on a far greater scale covering quality in the whole industry and not just quality or safety in falsework (temporary works), the industry is looking to put its house in order before being forced to do so by large private clients and the public sector; and at the same time some firms are seeking a market lead. Bodies such as C.I.R.I.A., Institution of Structural Engineers, Institution of Civil Engineers, Chartered Institute of Building, Building Employers' Federation, Federation of Civil Engineering Contractors, Royal Institution of British Architects, British Property Federation and many others are giving great emphasis to Q.A. The professions appear cautious and fear erosion of their professional status. (Beal 1988a,1988b). Their role may be further undermined when their practices and Quality Assurance schemes are adjudicated by non-engineering B.S.I., or Lloyds' register personnel. Recent discussions and colloquia on the subject by the Institution of Structural Engineers (1987a 1987b,1988) and C.I.R.I.A. reports (1985a,1985b,1987) give an explanation of how Q.A. can be applied to the Civil Engineering (Construction) Industry.

Those who advocate Q.A. being applied in the construction industry point to the better reputation and relationship gained with a more satisfied client, and argue that it helps to organise a design or site office in that new personnel can be given a quality manual and find out quickly how things are done. It can also be used as a means of training, in the absence of other forms of training of management and supervising personnel, which are frequently neglected in the present economic, political climate. The advocates say that by implementing a full Q.A. system, the subcontractors will be forced to employ certified, trained operatives and so training levels will be enhanced by these formalised contractual procedures. On another more cynical note, the proliferation of more formalised checks can often be used to justify claims. One project manager in a recent personal communication expressed that claims were now watertight due to Q.A. on his site and much of the argument obviated.

Quality Assurance in the Construction Industry involves procedures, whereby the client's requirements can be identified, clarified and finalised with him; where procedural checks are performed, independently, throughout the design and construction stages. The procedures and the quality system also ensure that contractors, suppliers and sub-contractors will all be quality assured. The Q.A. system therefore shows a marked similarity to the procedures recommended by Bragg and the Code of Practice for Falsework, of formalised procedures, and independent checks by a coordinator. Quinion makes reference to this (Quinion 1988) and in personal communication suggests that the Code of Practice for Falsework is an ideal example of Q.A. being applied in practice, and bringing tangible results. The N.E.D.O. study also advocates similar types of formal or contractual control as a solution. This study, in attempting to evaluate the relationship between organisation and quality and the effects formal procedures have upon the attainment of quality of falsework, is particularly relevant to the implementation of formal procedures in general to the whole construction project as is intended in Q.A. schemes.

Earlier reference to other industries suggested that they are now looking to be client-led rather than product-led. To a certain extent the construction industry has always had to be client-led, offering as it does a service, to build to the client's requirements.

Manufacturing and other industries have a great advantage in that client's requirements and expectations are reasonably easy to ascertain (or cynically, via marketing and selling, influenced and prescribed) and that the many standard products sold can be evaluated quickly during their short life span. Furthermore, unlike the Construction Industry, the client does not expect a bespoke product to suit his unique needs (Part 3) It is soon clear when a particular model of car does not meet the customers' requirements. On the other hand service industries (and even nursing and the Health Service are looking into Quality Assurance, for example see Kitson and Kendall (1986) and Kitson (1986)) have great difficulties in assessing requirements and conformity to requirements. In the construction industry the client usually does not know how to satisfy his requirements and rarely knows the detailed requirements except for example in the case of a building for the basic requirements of: the structure, the skin and the internal environment. The client usually engages consultants to advise him on how to fulfil his requirements, and relies on the market to get economies of construction and quality via the reputations of consultants and the contractors. The whole relationship is based on trust. The client's requirements may change; for example the building owner may sell to another who changes its use, the structure may then not be suitable for his needs or may fail. Thus, arguably, the designer can never satisfy all of the client's requirements who does not know them at the time himself. There are also problems of service life and maintenance costs. The client may not be interested in 'life-cycle' costs but may blame the designer subsequently when maintenance costs exceed his expectations. The quality of design therefore is extremely problematical. The concepts of 'buildability' and 'life-cycle costs' are discussed in Brandon and Powell (1984) and by Tietz (1987,1988). The first requirement of a Q.A. system is to establish client's requirements and a design brief in practice is extremely difficult to determine. The next feature of Q.A. applied to design is that of checking other designers. Here one is always exercising engineering judgement and discretion. Quality cannot be defined in absolute terms since discretion is always exercised; some ability in the designer is always assumed by the checker. Similarly in construction some product characteristics can be defined and checked (although arguably some discretion is still exercised) but largely specifications relate to workmanship standards. These standards of workmanship cannot be defined in absolute terms and again discretion must be exercised when checking workmanship. On site it is impractical or economically irrational to check upon every activity and trust is placed in the selection procedures of the personnel or the functioning of the occupational order (Part 3).

This study involves the assessment of quality of falsework and stresses that absolute standards of quality cannot be defined and the definition of the quality of workmanship is difficult since it depends on who prescribes those standards (see below). If such assessments are difficult in a comparatively simple, self-contained product, it is surely difficult to judge the standards of the design and/or construction of the whole project as is implicit in any Q.A. scheme. In judging design, Quality Assurance schemes attempt as do expert systems, the distilling of engineering knowledge and judgement. It is suggested here that absolute criteria or definitive procedures cannot be devised since some judgement or discretion is always required by the researcher and the practitioner.

In the studies reported in this thesis an attempt was made to measure quality with respect to comparing levels of quality. To be fair in reality this is all Quality Assurance can do, offer various procedures which will have various probabilities of achieving a level of quality, the level of quality never, in fact being defined in absolute terms. The procedural aspects of Q.A. have clear similarities with those of the Code of Practice for falsework, and, strictly, discussions and explanations belong in Part 3 of this thesis. Quality Assurance has been included here in relation to the difficulties of assessing quality of design and of the resulting product. The wide concern shown by designers illustrates this point.

Bragg and the N.E.D.O. study indicated that there are problems of quality. The objective of this study was to derive a method of measuring quality which could be used to rank sites in terms of their levels of quality and compare organisational factors that led to their levels of quality (see Part 3). To this end a method was devised to measure quality which is not an absolute one but is suitable for the purposes of this study. Bearing in mind all of these difficulties some method of assessing and measuring relative quality standards of falsework was pivotal to the study. The problems of defining and measuring quality of falsework construction are now addressed.

<u>Measurement of Quality in Falsework</u>

It is now necessary to discuss methodological problems in the measurement of quality on site. To a certain extent the problems envisaged were not as serious as first thought and in the event a satisfactory method of measuring quality was determined, after a great deal of concern and discussion. It should be noted that judgement based upon the author's expertise and knowledge of falsework had to be called upon in the final assessment. Interpreting respondents' comments required subjective, engineering judgement and discretion even by so-called impartial, objective academic researchers. It has also to be noted that whether a perfect system was devised or not, some form of measurement and ranking had to be devised in order that the study could proceed with its prime objectives. Although the researchers had some reservations, they were assured by practitioners at the outset that it was possible and that they could judge relative standards. All that remained was, of course, to distil the expert knowledge of the investigators and these practitioners. Some of the problems of scoring are reported in Chapter 9.

When looking at most products or services the appropriate level of quality is usually defined, in albeit a very imprecise abstract manner at times, for the reasons argued above, by the market (customer). Design, engineering and other criteria are then assessed in order to perform the production function to that (specified) quality level. Immediately when faced with falsework structures there is the difficulty of defining the appropriate quality which just fits the purpose in terms of concrete finish and safety, within the cost and time constraints. Moreover falsework is temporary and open to abuse and regarded as just one of the risks borne by the contractor. The quality of the falsework product *per se* does not matter in so far as the finished concrete is acceptable as regards dimensional tolerances, strength and so on.

Typically products can be defined in terms of, for example, dimensional, strength and density tolerances and these engineering criteria are easily measured. Variability in material properties can be catered for statistically as in limit state design, for example. In any measurement there is always some element of judgement. For example, there were differences in eyesight and sensitivity of touch in inspectors in the case told by Buffa (1987). Some elements of judgement can be 'designed out', for example by electronic digital micrometers, in the above case, but not all of them. Falsework equipment may be designed as 'idiot-proof' to minimise certain errors due to skill, or to facilitate quick checking.

Even though discretion is always exercised in testing or checking, certain product types are amenable to measurement and their production processes related statistically by the use of Q.C. or S.P.C. Structural Steel and Concrete Codes of Practice (BS 5950 and BS 8110) use current research and engineering theory to produce limit state designs based upon statistical evidence of material properties and loadings. Workmanship does not have to be presented in much detail since product characteristics can be measured in the final structure. In the cases of the transient, diverse types of falsework structures, using wide varieties of types of equipment such engineering sophistication with limit state design is deemed unwarranted by the Code of Practice and most practitioners. As discussed in Chapter 4 design methods are related very closely to assumed, and later prescribed, workmanship standards. The final test of the product is that it just remains in place long enough to produce the required concrete structure.

Standards of workmanship outlined in the Code of Practice are explained and embellished with knowledge of equipment types, in Chapter 4. Reliance is placed upon workmanship standards in erection and catering for horizontal forces and there is little doubt that a substantial amount of discretion is exercised in design, checking and erection of falsework. The questions of inherent rigidity, different equipment types and capacities, degree of knowledge and competence have been mentioned earlier, and discussed more fully in later chapters, and these all affect the degrees to which standards are known and adhered to. If these standards are not attained then there two options for the industry and code drafters:-

1) Incorporate higher factors of safety in the design - resulting in more equipment which may compound the suspicion of over design etc. in the eyes of the non-engineers.

2) Design-out potential errors - this may lead to further deskilling and further assumptions as to the competence needed which may lead to a further erosion of quality (Part 3).

It must be stressed that these studies are concerned with quality of workmanship on site and not structural quality. It is beyond the scope of the enquiry to judge the design and the competence of the designers. These studies are related to the control on site of quality; factors which affect quality which are out of the direct control of site must be ignored.

It is quality of workmanship which is at issue, and the relationship between organisation of the erection process and the quality of workmanship as evidenced on site. The basic references used in the assessment of workmanship are the Code of Practice, the summarised standards of Chapter 4, suppliers' literature and design drawings. Where the drawings have been produced and made available they are used as a convenient aid in the assessment of bracing and lacing and jack extensions (although guidance on jack extensions and their bracing is seldom included on drawings).

Correspondence to the layout in terms of the grid size and spacing of vertical members was never envisaged, or evidenced, as being a source of error. Where a grid size is modified the erectors or supervisors always make conservative judgements by reducing the spacings. It is recognised that it could be argued that such decisions on grid sizes would be regarded as 'design' decisions rather than fundamental workmanship considerations. The author maintains that it is sufficiently widely understood by all but the most incompetent personnel, for such decisions to be features of basic workmanship.

Design drawings are of assistance in the checking process. Departures from the drawing may not always be due to poor workmanship but a failure in the design and design brief to meet the site's requirements (Such considerations are beyond the scope of enquiry).

Where drawings are not available, either because there are none, or they have been lost (or claimed to be lost) or are simply not made available, on an uncooperative, sensitive site, then this does not present a problem to the research. The efficacy of the design is not considered so a design is not needed in the research. Furthermore, where no designs are formally performed, then this is part of an organisation decision made on some simple straightforward building structures where requirements for lacing and bracing are straightforward and not requiring calculation. The stability of a structure is regarded in this study as a fundamental requirement of workmanship, sufficient bracing and/or tying-in is determined based upon known standards of workmanship, noted in the Code of Practice. The assessment of the required amount of bracing therefore presents no problem to the research in the case of sites where no drawing exists (or where it is no longer relevant) since it is based upon trades practice standards. The requirements for lacing are also considered in the same light as bracing in that basic good workmanship demands orthogonal lacing on props, tubes and proprietary systems; the Code of Practice standard solutions and manufacturers' brochures reflect the basic criteria for good workmanship standards.

The study of the relationship between organisation on site and quality of workmanship demands that quality standards can be assessed, compared and ranked across the whole range of sites, structures, and equipment types.

The choice of support type is based on a number of technical, organisational and commercial factors addressed in later chapters. A response could be to restrict the study to a narrow range of structures (height, loading, physical layout etc.), one support system and one brand of equipment. One could then relate the range of quality standards on this particular structural arrangement to the type of organisation and control exercised. Such an investigation of fifty particular types of sites at convenient times and locations was clearly impractical if not impossible during the period of the study. The uses of this type of investigation would, it was thought, be very limited for practitioners or for any meaningful conclusions on organisation. The purpose of the studies was to provide an overall picture of the levels of quality on a range of sites and relate these levels to the type of site control exercised.

The differing types of system and equipment used require different levels of skill; these may be reflected in the tolerances listed in Chapter 4. Some types have the potential for a particular error eradicated by design. For example the connections of proprietary decking beams to the heads ensure concentric loading, the use of 'trigger braces' automatically ensures tight fixity at the node position and so on. By contrast, adjustable steel props not only require skill, but additional connectors to enable bracing and bottom lacing to be fixed. The scoring system must take account of situations where potential errors are eliminated and reflect this in the overall score of quality. The choice of systems or equipment type is largely an organisational (not technical) one based upon costs, speed of erection and skill levels needed and these choices should be reflected in the quality attained. Such decision processes imply that choices are consciously made based upon interest, knowledge and concern for quality and not pure cost.

Conclusions

The phenomenon of quality is impossible to describe and measure absolutely. Other industries are adopting various strategies and commitment to quality by Quality Assurance, Total Quality Concept and so on; these imply that quality can be and is measured. This study of falsework construction which has its own version of a Quality Assurance scheme (Code of Practice) is clearly relevant to the implementation of Quality Assurance as a whole. However, the definition and measurement of quality of falsework presents problems to the researcher. For the purposes of this study, quality in falsework is restricted to quality of workmanship on site. The method of measurement and scoring of this workmanship must be rigorous enough to take into account the whole range of equipment types, structures and sites and to enable comparisons to be made, across the board, of relative quality levels. These levels of quality, irrespective of equipment type and so on, have to be determined in such a way that they can be compared to a range of organisational factors. The findings on workmanship standards, derivation of the scoring system and comparisons of quality levels appear later in Part 2.

CHAPTER 6

Study of Quality of Falsework -The Sample

Introduction

Studies by the Bragg Committee, Health and Safety Executive and Building Research Establishment, for example indicated problems of quality standards in falsework construction and these were attributed to the difficulties in communication and coordination exacerbated by the fragmentation of the production process. This thesis draws upon interviews performed since 1982 on the response of the industry towards policies and procedures advocated first by Bragg and subsequently in the Code of Practice. Views were abstracted from suppliers and temporary works (falsework) coordinators. Twelve studies were also performed in 1983 into the structure of individual formwork/falsework sub-contractors; much had been, and is, said of sub-contractors by contractors, unions, suppliers and so on but very little was known of their views; the results of this research are incorporated in Part 3. Eight in-depth case studies were performed during 1984 to ascertain how falsework was organised from tender time through to erection. These interviews with suppliers, contractors, sub-contractors and client representatives and measurements from site formed the basis of the S.E.R.C. proposal in Management of Falsework Construction in 1984. The proposal had good support from the range of interested practitioners. On receipt of the award from S.E.R.C., the two year study began in February 1985.

Sample Description

A sample of 54 sites in England and Wales was obtained. The organisation of site data took place during the period of May 1985 to August 1986.

NO.	LOCATION	CONTRACT SIZE	SIZE OF CONTRACTOR	DESCRIPTION OF WORK
1	West and Wales	M	M	Multi Storey Office Block
2	Midlands	M	L	Multi Storey Office Block
3	Midlands	S	M	Shopping Centre
4	Midlands	M	M	Multi Storey Offices
5	Midlands	L	L	Multi Storey Offices
6	North	M	M	Hospital
7	Midlands	M	L	Multi Storey Offices
8	Midlands	L	VL	Multi Storey Hospital
9	West and Wales	M	L	Large Public Building Extension
10	West and Wales	M	L	Shopping Centre/Car Park
11	West and Wales	M	VL	Shopping Centre/Car Park
12	Midlands	M	L	Showroom
13	Midlands	M	L	Factory
14	Midlands	L	L	Multi Storey Public Building
15	North	M	VL	Office Block
16	North	VL	L	Public Building
17	London	M	VL	Supermarket
18	London	M	VL	Industrial Units/Offices
19	West and Wales	S	S	Private House
20	London	M	L	Ramp to Building
21	London	VL	L	Multi Storey Shopping Centre
22	Midlands	M	VL	Bridge Structure
23	East Anglia	M	S	Multi Storey Flats
24	East Anglia	S	S	Hospital Laboratory Extension
25	East Anglia	L	VL	Water Treatment Building
26	East Anglia	M	M	River Bridge
27	East Anglia	M	VL	Multi Storey Office Block
28	East Anglia	S	M	Two Storey Building
29	East Anglia	L	M	River Culvert
30	Midlands	M	L	Shopping Centre
31	North East	M	L	Offices/Car Park
32	North East	VL	L	Shopping Centre
33	North East	S	S	2 Storey Teaching Block
34	North East	S	VL	Retain Wall/Footbridge
35	North East	S	S	Flats
36	North East	L	VL	Shopping Complex
37	North East	M	M	Service Reservoir
38	Midlands	M	L	Car Park
39	Midlands	M	L	Culvert
40	West and Wales	L	L	Office Block
41	London	VL	VL	Viaduct
42	North	S	S	Multi Storey Building
43	West and Wales	M	L	Office Block
44	Midlands	S	S	Library
45	West and Wales	L	VL	M/W Road Bridge
46	West and Wales	L	M	Multi Storey Office Block
47	Midlands	S	S	Shopping Centre
48	North	VL	VL	Bridge
49	West and Wales	M	L	Multi Storey Office Block
50	Manchester	S	S	Shopping Arcade
51	Midlands	S	M	Hospital
52	Midlands	L	VL	Town Centre Development
53	Midlands	S	L	Pumping Station
54	London	L	L	Multi Storey Office Block

Table 1

Table 1 shows that the sample comprises a fairly representative range of sites and regions including building, and civil engineering, variation in size of contractor, size of contract and, within the limit of the general title of "falsework to soffit for beam and slab construction", a range of structure types. The information in Table 1 is abstracted from the master matrix of variables appearing in the Appendix. The definition of variables appears in the Appendix but it is necessary here to explain these definitions:

Building or Civil Engineering is classified on the strength of the type of contract used; Joint Contract Tribunal(J.C.T.1986) or variant, or Institution of Civil Engineers (I.C.E.1979) or variant. G.C. Works was not encountered in the study but it would be evident whether the conditions applied to building or civil engineering.

Size of contract: Small (S), Medium (M), Large (L), Very Large (VL).

The total value of contract is taken as an index of size.

Small	: less than £1 million.
Medium	: £1.1 million - £5 million.
Large	: £5.1 million - £10 million.
Very Large	: above £10.1 million.

Size of main contractor: Small (S), Medium (M), Large (L), Very Large (VL).

The four bands used are:

Small	: up to £5 million turnover per annum.
Medium	: from £10 million - £50 million turnover p.a.
Large	: from £85 million - £400 million turnover p.a.
Very large	: above £800 million turnover p.a.

This categorisation is used since it conveniently clustered firms within the bands selected and moreover approximately corresponds with what is commonly understood by the terms small, large etc. No firms in the sample fell outside these bands. Turnover figures relate to firms which are legally identifiable in their own right or which form part of a larger parent company.

Methodology

The guiding criteria for selection, in addition to size, location and so on were;

1) to include both cases where equipment was owned and hired;

2) that the various proprietary systems should be adequately represented in the sample;

3) that different kinds of support system should be included;

4) that a range of different contractual arrangements should be represented.

Initially the principal method of contacting sites was via the three main proprietary systems suppliers and other suppliers. Having obtained the names of the clients who were currently using or about to use their equipment, such clients were contacted and permission to conduct the research was sought. Assistance was also sought from the firms represented by the supporters to the S.E.R.C. proposal. A standard letter was also prepared and sent to contractors. A subsequent telephone call revealed the availability of appropriate falsework structures and willingness to collaborate.

As the research progressed less formal methods were used to identify sites. Individuals amongst both main contractors and sub-contractor personnel reported sites that might be suitable and amenable.

It cannot be claimed that the sample is statistically representative in terms of, for example, type of falsework structure, organisations, value of contracts and so on. Since this kind of study is dependent on the goodwill and cooperation of practitioners and subject to time and cost constraints, such rigour is impossible. Moreover it is extremely difficult to determine the kind of statistical sampling required. For example should it be based upon size of workload based upon: value of contract, value of falsework component (almost impossible to determine in practice), number of employees, geographical dispersion catering for differing labour markets, skill distribution, types of work, types of equipment and so on. Bearing in mind the logistical constraints therefore an adequate sampling technique is difficult to describe and impossible to implement.

It will be suggested in Part 3 that such concern for size (however that is defined), choice of system etc. as determinants of organisational strategies is unwarranted, and that the effective functioning of the Occupational Order is of more importance. Insofar as the Occupational Order relies upon competence it would be of interest in a later study to describe distribution of competence or the incidence of supply and fix arrangements demographically. Here location may affect the understandings or work cultures, for example it is postulated that sub-contracting, in particular supply and fix, is resisted by companies in the North-East. Is this a question of culture, ideology, labour markets or a simple 'time-lag' between the practices in the South being applied in the North ?

One possible defect in the sample was that small sites were under-represented. The reason for this is that small sites were difficult to locate and even when they were, on many occasions permission for access was not given. It is also possible that since the research on site depended on goodwill, occasions when sites were contacted and willingness to participate in the study was not forthcoming, were also the occasions when practitioners were less than proud of the standards being achieved. On the whole this is thought not to be so; in most cases the site would have no concern for falsework quality *per se* or believe that it was poor. The reason for rejecting a request to collaborate in the study was, it is suggested, the simple suspicion that time would be wasted in talking to 'sightseers', or that the researcher was a tax or safety inspector in disguise. Those that did collaborate, both in allowing initial access and subsequently in talking, and being recorded on tape, (and that was the majority contacted), were to a man courteous, patient, and, in the author's opinion, frank. The verbatim statements included in this thesis seem to bear this out. On initial contact having been made, the purposes of the research were explained and the confidentiality of findings with respect to individuals, sites and firms was stressed.

A site visit, on average, took two to three days and was arranged to coincide with a concrete pour to the formwork supported by the falsework to be checked. Checking took place immediately prior to, or immediately after the pour. The research activities on site comprised the following:

1) Select a representative sample of falsework comprising approximately 50 vertical standards and carry out a detailed check with respect to the tolerances listed in Chapter 4 and using the checklist of Chapter 7. Make sketches with plans and elevations sufficient to prepare drawings of the falsework structure. Obtain copies of the design drawings if available.

2) Take photographs of the falsework sample area, the area surrounding and of the whole site where possible.

3) Observe and record any activities, for example erecting, and checking related to falsework.

4) Interview as many individuals as possible concerned with the falsework in question, beginning with the site agent/project manager and finally on to the erectors. A list of the job holders interviewed on site is shown below. The usual constraint of time meant that not everyone listed was actually interviewed. On average six to seven people were interviewed in each case. In the great majority of cases the interviews were tape-recorded and subsequently transcribed. On the few occasions when this was not possible detailed notes were taken.

Interviews were open ended, conducted using standard schedules of questions for the different categories of personnel. These lists were intended for guidance only, and were developed from the experience of earlier studies and experience of the falsework industry. In addition to the interviews on site, these were supplementary background interviews with suppliers, training board, health and safety personnel, for example, plus those concerned with the preparation of the checklist and scoring mechanism (see Chapter 7 onwards). Approximately 500 interviews were conducted.

Interviewees on site were drawn from:

Main contractors

Project manager/Site Agent.

Senior Engineer

Works Manager/General Foreman

Engineer in charge of falsework (F.W.C.)

Safety Officer

Erectors

Sub-contractors' organisation:

Managing Director or most senior person on site

General Foreman

Erectors

plus representatives of the Client's representatives on site, and suppliers or contractors' designers where possible.

It has been emphasised earlier that the judgement and definition of quality is an almost impossible undertaking, although evidence on which judgements were arrived at is presented later when discussing the means of scoring. (Chapter 9). The main intention is to be able to compare quality rather than to suggest absolute standards.

The findings shown in Chapter 8 reveal a wide range of quality standards, which it is suggested represent the kind of standards being achieved nationwide, bearing in mind the problems of statistical sampling earlier. If the sample possibly under-represents the smaller sites, which, it is concluded later, tend to be of poorer quality for organisational reasons and not size *per se*, then the national picture could be worse than that indicated by the research. Whether the quality standards are or are not acceptable can only be judged by the industry although the author's views are given. The possible under-representation of the smaller sites would add support to the claims made in Part 3 that the effective functioning of the occupational order leads to good quality; it is more likely on these smaller sites that the assumptions of competence tend to become invalidated. The inclusion of more smaller sites would, it is suggested, support the opinions on quality standards and the hypotheses of Part 3.

Collapses are fortunately rare, and the probability of meeting one in a sample of 54 cases studied over a period of more than a year was extremely low. Not meeting one therefore is no grounds for assuming that objectively many potentially dangerous cases were not to be and still cannot be found. Thus, though the study does not report any failures or even near failures, it is worth noting that one of the cases in the study sample was one of a series of twenty three similar pours on that site. While the one actually researched was found to be of 'fair' quality, it was reported that one previously, had in fact failed under loading. Despite attempts to find out, no reasons for failure were available.

Types of Falsework Structure

From Table 1, there were 11 civil engineering sites in the sample: 7 bridges, 2 culverts and 2 pumping stations. The 43 building jobs ranged from a novel private house of £70,000 to a very large £60 million multi-storey shopping complex.

Of the wide variety of possible types of falsework support and decking described in Chapter 2, essentially only 4 types were encountered in the study:

1) Proprietary systems with traditional decking using timber or aluminium beams.

2) Proprietary systems with proprietary decking beams, with traditional or system decking.

3) Adjustable steel props with traditional decking using timber or aluminium beams.

4) Tubes and fittings with traditional decking using timber or aluminium beams.

Type	Building	Civ.Eng	Total
Proprietary system/ traditional.(1)	14	11	25
Proprietary system/ proprietary.(2)	17	0	17
Adjustable props/ traditional.(3)	11	0	11
Tubes & fittings/ traditional.(4)	1	0	1
Total	43	11	54

Table 2: Types of falsework system used on sites.

From Table 2 it can be seen that tubes and fittings are rarely used to support formwork to concrete, as was suggested in Chapter 2. Tubes and fittings are frequently used for specialised work involving dead shores and flying shores, for technical reasons and economics of being needed for long durations. Tubes and fittings are today predominately used for long term access and in the installation and maintenance of large-scale construction works where their extreme flexibility and very long term use makes them the technical and economically rational solution.

It should be noted that the one site using tubes and fittings was in the locality of a major scaffolding contractor (specialising in industrial scaffolding) who undertook the sub-contract on the job for all access and support work. Any conclusions regarding workmanship and quality on the one single case study (No.32) using tube and fittings for the sole falsework support are, it is suggested, unwarranted.

Only one case (Case No.8) used a proprietary system based upon a tower system. As was suggested in Chapter 2, tower systems are no longer favoured by falsework designers for the reason of stability. The supplier (S.G.B.) of this particular type of system no longer hires it or specifies its use and sold most of the equipment some years ago. The supply and fix sub-contractor of Case No.8 owns a plentiful supply, bought at good discounts from the supplier (S.G.B.).

For the purposes of any findings on workmanship there are generally therefore 3 types of falsework system based on pocket scaffolding or adjustable steel props.

Table 2 indicates that Civil Engineering sites in the sample do not use proprietary systems with proprietary decking. In the case of bridges for example, the facility for quick-stripping and re-use of falsework on another pour is not in much demand. Proprietary decking is frequently unsuitable as regards structural capacity, concrete finish or amenable to the types of shape and cambers required in the soffit. In the cases of the culverts proprietary decking would have been suitable for use in for example, the travelling formwork used in Case No.39. Composite steel and concrete structures not addressed in this sample, frequently use permanent formwork.

Types of Equipment

Type		Brand Type			
		R.M.D.	S.G.B.	G.K.N./ Kwikform	Aluma
Proprietary system/Trad. Decking	Bui.	5	3	6	0
	Civ.	1	2	7	1
Proprietary system/ Proprietary Decking	Bui.	5	2	10	0
Total		11	7	23	1

Table 3: Proprietary brand of equipment used in each type.

Table 3 shows the use of particular brands. The term 'brand' is used rather than supplier or manufacturers since Kwikform equipment can be supplied by G.K.N./Kwikform Limited or by Acrow/Leada Limited and other smaller falsework specialists. Manufacturing of the different types of equipment is performed by many small firms around the country for the main brand firms.

This study is not intended to assess the merits or demerits of particular brands of equipment, indeed the sample sizes are too small in any case. Also it is not possible to draw conclusions on market share, suitability and so on, taking into account the way in which the sample was obtained.

Bearing in mind these caveats some tentative conclusions may be drawn which the author believes, reflect opinions in the industry.

G.K.N./Kwikform still dominate the industry in terms of systems scaffolding for access and falsework. The most common form of bridge support is by G.K.N./Kwikform; in fact 6 of the 7 bridge sites in the sample used this brand of equipment. The other 4 sites in the 'Civils' category were more akin to building structures being culvert or pumping station roofs. No one brand dominates the market in terms of proprietary decking. This is because each of the wide variety of proprietary decking systems satisfies different demands; for example a quick-stripping facility by R.M.D.; or the trough and waffle decking of G.K.N. with support of 'Kwikstage' by G.K.N./Kwikform.

Secondary Cases

On a number of cases (9), the main falsework support was supplemented by tubes and fittings (2 cases) or by adjustable steel props (7 cases). These secondary cases or 'B' sites occur in cases where the modular rectangular systems cannot support irregular shapes, in plan or elevation. Certain infill panels have to be supported; these are left totally to the contractor on site to 'design', and are omitted, for commercial and legal reasons, by any supplier on his drawing of the scheme. Although these areas of support are often quite simple and inherently stable if between two halves of a designed rigid structure, they are frequently subject to abuse and lack of attention. Areas such as eccentricity and fixity may therefore be a problem, verticality may be easier to obtain unless there are other obstructions. An assessment of workmanship was thought necessary at the time on these cases since in some cases, there were a large number of props used (eg. Case No.3 where the secondary area used 37 props). To a certain extent these secondary 'B' sites formed a sample on their own, requiring a different checklist of tolerances from the main sample. Support work to these secondary sites, or infill panels generally occurs once the formwork is erected, and is performed by the formwork carpenters. The support work therefore is erected at different times, frequently by a different workgroup, and to different (*ad hoc*) designs to that of the main sample structure.

Conclusions

The methodology of obtaining the sample has been addressed. The sample of the sites in the study have been described with respect to size, location, type of construction and type of falsework system used. The following chapters in this Part 2 address the measurement of quality of workmanship and the findings on these sites.

CHAPTER 7

The Measurement of Quality of Falsework

Introduction

This chapter briefly repeats the methodology discussed in Chapter 6. The main purpose of the chapter is to discuss the derivation of the checklist which incorporates the comprehensive list of tolerances and workmanship standards discussed in detail in Chapter 4. It was important that the development of the checklist paid attention to the views of practitioners who were encouraged to make an active contribution.

Methodology

A falsework structure consisting of about 50 verticals (proprietary standards/individually erected adjustable props/tubes and fittings standards) or a representative sample selection of about 50 verticals where a larger structure was involved, was selected on each study site. A drawing was prepared, with photographs in most instances, together with transcripts of taped interviews conducted with designers and site personnel. The main instrument for reporting, measuring and (subsequently) scoring quality, was a checklist.

Preparation of the Checklist

The checklist was based upon previous research leading up to the S.E.R.C. proposal which followed the same lines as the B.R.E. study of 1975. The checklist was developed further with the aid of five prominent people in the falsework industry and with reference to the Code of Practice and brochures. The exhaustive list is explained in Chapter 4. The checklist was designed mainly as a research tool to collect data on quality (of workmanship) in the falsework supporting the soffits to beam and slab structures.

The format of the checklist would then be used as a means of scoring and comparing overall quality standards on various sites.

Entering data on the checklist was a reasonably straightforward task, requiring few subjective judgements. Measurements were taken of the range of error in the case of verticality with an inclinometer, or by simply reporting the number of instances where tolerances were exceeded. Information, and comments were included on any gross errors, malpractice or extenuating circumstances.

Throughout the period of study efforts were made to keep the industry apprised of progress and comments were sought on the interim report prepared for the S.E.R.C. and in particular on the contents of the checklist. The five original supporters were expanded into an 18 strong 'panel of experts'; the purpose of having such sources of cooperation were:

1) To ensure that the checklist was satisfactory and comprehensively reflected the knowledge available.

2) To establish the credibility of the investigators in terms of research ability and knowledge of falsework and the construction industry. It was important to develop a mechanism of incorporating industry's comments and a sense of involvement. If findings or conclusions were to be of any use or value to practitioners, then they must be involved.

3) Most importantly, the panel members were enlisted to provide assistance and guidance from a practical point of view on scoring of quality. This involved assessing the severity of particular incidences of error and their relative severity in terms of how they affect the overall quality of the structure. This is dealt with in Chapter 9.

The comprehensive checklist including the factors listed at the end of Chapter 4 was modified from time to time during the research (taking care that relevant data were never missed) to simplify the acquisition of data, for example categories were changed or combined. Once the research commenced and details of the sample sites emerged, a typology of falsework systems was developed. The checklists reflected this typology and separate checklists were prepared for each type. This facilitated data collection and subsequent scoring. The checklists were also revised to facilitate the scoring method devised (see Chapter 9). As in all types of research many activities took place concurrently. The collection and analysis of data, formulation of checklists, and derivation of scoring mechanisms all took place at the same time requiring several alterations. What had to be ensured was that the data collected from sites prior to any reappraisal were sufficient to ensure that the ultimate scoring system adopted would be applied consistently to all cases in the sample.

Assumptions

It is necessary to restate the assumptions made in preparing and using the checklist. The assessment of quality is one based upon standards of workmanship and not design. Formwork design and formwork materials are not considered; neither are the detailed ground conditions or foundation design; in these respects the research study made the same restrictions as the proprietary systems designers. The tolerances for tubes and fittings are assumed to apply to proprietary systems.

It is reasonable and pragmatic to exclude design activities from the consideration of quality. The main purpose of the study is to relate site control mechanisms or organisations to quality. The design function is frequently performed by separate organisations beyond the control of site. On the grounds of pragmatism it is clearly beyond the scope of the study to analyse designs and assess the efficiency of the design, structural capacity and so on.

One perhaps debatable area is bracing and stability. It could be argued that provision and design of bracing for lateral or local stability is a design function. The provision of bracing is regarded in this thesis, as a fundamental element of workmanship well established for example in scaffolding trades practices, in their training courses, and described in the Code of Practice Standard Solutions in Section 7.

At the same time that workmanship checks were made on the structure, information was gathered on: condition of materials, access and safety and information relating to falsework drawings. The checklist is the ideal document for reporting the above types of information as will be seen from the example checklists in the Appendix.

The condition of the various materials or equipment used in the structure is clearly stated in the Code of Practice as a function of workmanship. It is part of good workmanship to discard defective equipment. This is clearly an area related to competence and more importantly the right to exercise that competence. In the vast majority of instances the workforce will have to work with the equipment provided. This information included in the checklist is part of the organisational variables and not treated as pure workmanship in subsequent analyses of quality.

Tidiness and safety are also a function of workmanship and competence but are affected by many more personnel moving around site. Access to the underneath of the structure and to the sides is clearly a design factor. Access and safety is assessed in the checklist but do not form part of the analysis of workmanship.

Condition of materials and provision of access and safety are not considered in the analysis of workmanship or scoring of overall quality on site but are included for the interest of practitioners.

The provision of drawings and conformity to them, and confirmation of design changes are all factors directly related to organisational control and which are part of the set of formalised procedures recommended in the Code of Practice. This information is addressed in Part 3.

Conclusions

At the end of the period of data acquisition the following documents were produced:

1) Checklists to suit four different types of falsework, for recording data. There is also the possibility of their being used by practitioners themselves in checking.

2) Shortened checklists to enable scoring of major items.

3) A scoring system for use in the research study only, and not as a site control mechanism. It is certainly not the intention for it to be used on sites to score certain structures and perhaps sanction errors.

Copies of the various checklists plus samples of completed checks are included in the Appendix.

The information included in the checklist is summarised on drawings numbers 1 and 2 in the Appendix. The findings on workmanship standards are addressed in Chapter 8.

CHAPTER 8

The Findings

Introduction

It must be stressed once again that the main purpose of this part of the study is to arrive at an overall assessment of quality of workmanship in beam and slab falsework structures on various sites to enable comparisons to be made on the type and nature of control that lead to such quality. It is of interest to report, in a sub-analysis, the nature of this quality in overall terms (see Chapters 9 and 10) and in terms of particular workmanship standards. The findings presented here simply report the workmanship standards in particular elements in the structure, and in different types of system. Any comments or conclusions are tentative, based on small sizes of sample, and are intended to describe and explain the sorts of practices which take place.

The comprehensive list of tolerances presented in Chapter 4 was incorporated into checklists as reported in Chapter 7. The checklists were modified during the study to reflect types of error and systems used and the format devised to facilitate the subsequent scoring of Chapter 9. This process of deriving the checklists is covered in Chapter 7.

Workmanship requirements

To facilitate data acquisition, subsequent scoring, and use by practitioners as a checking document, the checklists were devised to suit the range of types of falsework structure defined in Chapter 6. The results of the checking operation are summarised in drawing Nos.1 and 2. To reiterate, the data related to what the author believed were the fundamental requirements of a falsework structure:

Head Condition:

> Transfer of load concentricity (within limits) without imposing undue bending or horizontal forces on the structure; and fixity in order that the structure is rigid and not a mechanism.

Base condition:

> As above where the seating of the base or soleplate (or condition of foundation) must be adequate to resist vertical and horizontal forces.

Jack extensions:

> If these are excessive then their capacity to transmit combinations of vertical loads and horizontal loads is reduced.

Vertical members:

> These must be capable of carrying the load without buckling or excessive deflections, which would thus transfer loading onto other members precipitating collapse, or distorting the soffit. They should also be vertical (within limits) in order that the induced horizontal forces are not greater than assumed.

Bracing/Tying-in:

> To cater for lateral (overall) stability of the structure against horizontal forces (due to wind forces, those due to erection etc.) and provide stability of nodes against rotation and lateral displacement.

The workmanship standards achieved within these conditions are discussed below for the sample of 54 sites.

Sample findings

The sample described in Table 2 in Chapter 6 comprised 54 sites. Of these 25 cases used Type 1 (Proprietary systems with traditional timber or aluminium beams), 17 Type 2 (Proprietary systems with proprietary decking beams), 11 Type 3 (Adjustable steel props with traditional timber or aluminium beams), and 1 Type 4 (Tubes and fittings with traditional timber or aluminium beams). Type 1 systems were used on 14 building sites and 11 civil engineering sites.

In addition to these 54 cases where they represented the dominant type of falsework support on site, there were 9 cases where a secondary type of structure was encountered. These cases arise where proprietary systems, due to the their relatively inflexible, modular nature, cannot fulfil the total requirements of the falsework support structure. Infill panels are required in the awkward areas around the perimeter for example or under a dropbeam. In these secondary cases or B sites, adjustable steel props (7 cases) or tubes and fittings (2 cases) are used. The peculiar nature of these rather *ad hoc* structures has been discussed and will be again in Chapter 9. For completeness a discussion of the workmanship standards in these 'B' sites is included in this chapter.

The findings of workmanship standards with respect to individual types of error, types of system and so on are now reported.

Tubes and fittings

Only one case used tubes and fittings in the dominant falsework structure. Comparisons and conclusions on workmanship are therefore unwarranted. For completeness the errors are reported below:

Site No.32 had 45% of the heads with eccentricities greater than 25mm, and 16% with inadequate fixity; 50% of the bases offered insufficient vertical and horizontal restraint; 16% of the standards were beyond the tolerance limit for verticality; there was sufficient bracing and tying in present to satisfy requirements, however all of the bracing connections were greater than 150mm from the node positions.

Tables 1-10 at the end of the chapter represent the incidence level of errors. That is to say the percentage number of members with errors greater than the specified tolerance, or the percentage of members omitted or incorrectly positioned. The number of cases within a range of incidence level and falsework type is shown in tables compiled for each level or condition in the structure. Each condition is now discussed with reference to these tables and drawing numbers 1 and 2 in the main appendix.

Head condition

Note that case No.37 is not applicable. Type 2 systems are excluded from the analysis since errors in eccentricity and fixity are obviated by design (but see below). There are therefore 35 applicable cases.

Eccentricity

Table 1 shows that 54% (19 No.) of the total 35 cases achieved standards within the tolerance. Of these 48% (17 No.) were Type 1 and 6% (2 No.) were Type 3. One case in Type 1 had an incidence rate of 80%, and one in Type 3 a total incidence of error of 100%.

Of those 17 Type 1 cases incurring acceptable errors, 10 were civil engineering sites. The remaining one civil engineering site (Case 34) had 50% of the heads outside the tolerance.

Fixity

Table 2 shows that 46% (16 No.) of the total 35 cases achieved fixity and adequate bearing of the primary members at the head. Of these 34% (12 No.) were Type 1 and 12% (4 No.) were Type 3. Four cases in Type 1 and 2 cases in Type 3 had all connections beyond requirements.

Of those 12 Type 1 cases achieving adequate fixity, 9 were civil engineering sites. The remaining civil engineering sites, case numbers 39 and 26, had 50% and 16% respectively of connections unsatisfactory.

Comments

It is clearly possible to achieve tolerances and standards prescribed, but with approximately half of the cases incurring errors in the head condition there are clearly problems. There may be a case for more use of Type 2 systems, but as evidenced by case number 13, errors are still possible if pins in jacks are inserted incorrectly.

Adequate bearing and fixity tends to be more of a problem than eccentricity in both Type 1 and Type 3. Civil engineering sites tend to produce better standards than building.

Type 1 systems tend to be better than Type 3, although when civil cases are removed from the comparison the distinction is not so marked, indeed fixity is possibly worse in Type 1 systems.
Such comparisons are of course based on small samples.

Base condition

Table 3 shows that 62% (33 No.) of 53 cases achieved adequate horizonal and vertical restraint. Type 1 represented 26% (14 No.) of these, Type 2 25% (13 No.) and Type 3 11% (6 No.). All types had instances where all of the bases were unsatisfactory.

Six (of 11) civil engineering sites had problems with base condition.

Comments

Base conditions generally should not be a problem. The majority of building sites have good concrete finishes on which to found soleplates or bed baseplates. However 14 out of 42 building sites still managed to produce unacceptable construction methods, using inadequate offcuts of plywood as packers or supporting baseplates at the edges of concrete or on bricks. Standards are still found wanting therefore. Civil engineering sites, particularly bridges, even with their greater control (see Part 3), tend to be more inherently problematic. Foundations have to be prepared, timber sleepers bedded and haunched in concrete and baseplates properly seated and set out and so on. Even discounting civil engineering sites, Type 2 tend to produce better results than Type 1, although no reason for this suggests itself; adjustable steel props of Type 3 may be marginally worse than the other types used on building sites.

Adjustable Jacks

Head level

Table 4 shows that 83% (33 No.) of 40 applicable cases had no problems in this area. Type 1 represented 45% (18 No.) of these and Type 2, 38% (15 No.).

Three cases in Type 1 and 2 cases in Type 2 had all of the head jacks extended excessively and unbraced. One civil engineering site, case number 39 was among these.

Within Type 1, civil engineering sites had the same level of performance as building.

Base level

At the base level the degree of error is marginally better, 86% (30 No.) of the 35 applicable cases were acceptable. Type 1 represented 51% (18 No.) of these and Type 2, 35% (12 No.).

One case in Type1 and 2 cases in Type 2 had all of the base jacks extended excessively and unbraced. No civil engineering site incurred an error.

Again since the prevalence of error is low, civil engineering sites were similar to building sites and little comparison can be made.

Comments

Errors of this type appear relatively infrequently. However when they do they are significant, typically one half or all of the jacks being extended, unbraced beyond tolerances.

These errors would be reduced if more information was given on drawings on the restrictions upon jack extensions and bracing provisions, particularly on proprietary equipment which sometimes has different standards for different brands.

Vertical members

Lacing, position and distribution

Referring to table 5 it can be seen that 62% (33 No.) of 53 cases had the required amounts of lacing, fixed at the right levels in the structure. Of these, 36% (19 No.) were Type 1, 19% (10 No.) were Type 2, 7% (4 No.) were Type 3 systems.

Four cases in Type 1 had at least 50% of the standards with strut lengths greater than shown on the drawing, one case in Type 2 had a similar level of error, 5 cases in Type 3 however, had between 50% and 85% of the adjustable props unlaced.

Just one civil engineering site incurred any error (of 50%!); again this was case number 39.

Verticality

Table 6 shows that 17% (9 No.) of 53 cases were within the tolerances of the Code of Practice. Type 1 accounted for 9% (5 No.), Type 2, 4% (2 No.) and Type 3, 4% (2 No.). Three Type 1 cases had over 50% of the standards beyond requirements, and one Type 2 had 50% of standards beyond tolerance.

No civil engineering site had more than 30% of standards beyond tolerance.

Within Type 1 systems, civil engineering sites performed similarly to building. Type 1 performed marginally better than Type 2.

Comments

The position and distribution of lacing members affects the assumptions regarding strut lengths.

Problems frequently occur where a level of lacing is lowered to facilitate access to level formwork, or is removed to facilitate access to walk through the structure. The former represents problems for effective length particularly if the top level is lowered. The latter is not usually a problem where access is through the middle of a properly braced structure. Access through the structure in the case of bridges is normally designed for, using bridging beams for example, since vehicular access may be needed. Access through birdcage structures in building tends to be more *ad hoc* and therefore problematical. Again sufficient information should be available on drawings or information on the maximum strut lengths, when supported or unsupported; and provision for access designed for originally.

Type 2 systems are more prone to abuse by lowering the level of lacing to facilitate a rapid striking of decking, although a level of lacing still remains near the top and the cantilever effect is minimised.

Although the requirements for lacing of adjustable steel props are well known, and indeed very often essential to enable erection to commence, the majority of these sites omit lacing. There are perhaps understandable reasons for omitting lacing at the base of the prop since special fittings are required.

Verticality appears to be a widespread problem across the range of types and within building and civil engineering. Whilst the incidence of error may be widespread the magnitude is not particularly severe, indeed non-verticality tends to be in random directions in the sample and may be self-compensating or encourage stability rather than cause instability. (see for example the C.I.R.I.A. study). It has already been stressed in Chapter 4 that tolerances for proprietary systems will be assumed to be the same as for tubes and fittings. Equipment suppliers claim the systems to be self-levelling and 'plumbing', however plumbing to a half of a degree based on levelling lacers with a 1 metre spirit level is difficult as evidenced by the results. Suppliers may claim that test results show that tolerances outside those in the Code of Practice may be allowed. Until such tolerances are made known and freely available to operatives and supervisors alike then one can only assume workmanship standards of tubes and fittings. In the event it may prove unreasonable to expect knowledge in the workforce of different tolerances applying to different equipment brands.

Type 2 may tend to be worse than Type 1 since frequently bracing, if fitted, (see below) is left until the structure is decked out, where errors in verticality are built in and not remedied by bracing.

Even with the relaxed standards precipitated by the C.I.R.I.A. studies, adjustable steel props are still being erected beyond the workmanship tolerances. The perennial problem of incorrect pins being used in the case of adjustable steel props is still in evidence. Drawing No. 2 shows that four props had errors in this respect, one case having 80% of the props using unsuitable materials for pins.

Bracing

Proportion and distribution

Table 7 indicates the percentages of bracing missing in both directions. Table 8 the maximum percentage missing in any one direction. Failure due to overall instability can occur in any one direction, depending on the degree of restraint and disturbing horizontal forces and so on. Findings are based upon the more severe occurrences represented in Table 8. The need for bracing (and to a marginally lesser extent, lacing) is a fundamental requirement of workmanship; it is at least essential in order to begin erection of some types of structure.

Referring to Table 8 it can be seen that 31% (15 No.) of 49 cases had sufficient bracing. Of these 20% (10 No.) were Type 1, and 11% (5 No.) were Type 2, all of the applicable adjustable prop systems had bracing missing in one or two directions. Four Type 1, five Type 2 and seven Type 3 systems had all of the bracing missing in one or more directions.

Referring to Table 8, in fact one Type 1, three Type 2, and six Type 3 had all of the required bracing missing in both directions.

Of those 10 Type 1 systems where sufficient bracing was fixed, seven were civil engineering sites, of the remaining four civil engineering sites, one, Case No.45 had 50% of the bracing missing in one direction.

Connections

Table 9 shows that in the 38 instances where bracing was fixed, 61% (23 No.) were fixed within 150mm from the node points. Of these 45% (17 No.) were Type 1 and 16% (6 No.) were Type 2.

Four Type 1 and one Type 2 systems had all of the connections beyond tolerance.

Eight of the 17 Type 1 systems where connections were acceptable were civil engineering sites, one of the remaining three civil engineering sites incurring errors was case 39 where all of the connections were outside the tolerance limit.

Comments

It is good workmanship practice to connect any members of scaffolding as close to a node point as possible. Many of the systems scaffolding facilitate fixing coincident with the node. G.K.N./Kwikform on their heavy duty shoring system incorporate trigger braces which can only fit at the level of lacing. Most of the errors in connections of bracing arise from changes in layout. Changes made to grid or to levels of lacing (to facilitate access for example) usually mean that equipment delivered on site cannot be used. Poor workmanship therefore is usually combined with poor organisation in that 'design' changes are made *ad hoc*.

A possible anomaly occurs when reporting connections of bracing members, in that errors cannot occur if no bracing is fixed. This raises potential problems in assessing overall workmanship as a condition and for the site itself; however inspection shows that errors in bracing connection correlate with general problems in the provision of bracing.

The position and distribution of bracing is a fundamentally important workmanship condition, recognised by the Code of Practice, training courses and by trades practices. From a structural quality viewpoint there is a marked difference in 100% of standards being outside the eccentricity tolerance and 100% of the bracing omitted. The absence of bracing means no local stability at node points and only an unknown amount of rigidity or fixity at the top and hence an overall stability problem. It would appear that what trades practice believes is necessary on any one site and what the Code of Practice recommends widely differ. Sites may make contingent judgements based on assumptions of rigidity at deck level, but this rigidity is unlikely to assist the Code requirements for node stability.

The civil engineering sites, typically perform better than building sites (see later Part 3), but bracing is still a major problem on these sites.

Even when omitting the civil engineering sites, Type 2 systems tend to omit more bracing than corresponding Type 1 systems. A possible explanation for this is that Type 2 systems incorporate decking beams which are fixed as the structure is erected, the bracing being the last to be inserted, the received wisdom is that the system is more rigid than others. Type 1 systems on the other hand, frequently have the bracing inserted before formwork. Generally speaking, bracing is deliberately omitted from all structures until they are adjusted and then fitted, or not, as the case may be.

It is in Type 3 adjustable steel props where conventional wisdom departs most drastically from workmanship standards prescribed in the Code of Practice. All of those eight cases requiring bracing omitted it almost totally. Only one site incorporated adequate bracing and that in one direction only. The Code of Practice recommends lacing and bracing to facilitate erection of props, and from practical experience this would seem a reasonable suggestion. The trades practice therefore, exercised in the erection of adjustable steel props, does not see the need for much degree of bracing or lacing, and relies on rigidity and fixity at the deck level (which may be unfounded bearing in mind the comments made on the Head Condition!). On the non-applicable Type 3 cases, lacing was fixed and adequately butted against the walls of the building.

It is not necessarily ignorance that accounts for the omission of bracing to props; on two occasions drawings showed bracing but the workforce chose (or were allowed) to omit all of it.

Although, strictly speaking, verticality has a higher incidence of error with respect to tolerances, the degree of incidence tends, generally, to be low. Omission of bracing, on the other hand, is widespread and where it occurs it does so in high degrees. Lack of provision of stability by lacing and bracing is far more important as regards structural quality since it is this stability which tolerates the errors elsewhere in the structure.

It is not suggested that the site personnel knowingly erect structures which are unstable, but that their assumptions of rigidity and fixity may not be valid, and in any case will not cater for stability of the node positions. As reported in Chapter 5, there were no instances of failure on any of these cases; however the incidence of errors in all conditions and particularly lack of bracing must point to an increased probability of failure.

<u>Stability</u>

Bracing or tying-in (at all levels) is required to resist known horizontal forces and those arising from errors in erection. When all other conditions are within the limits specified therefore, bracing is required. Since bracing is omitted on quite a large scale there is thus cause for some concern, as the factor of safety due to rigidity and so on is eroded.

A thorough structural analysis would require a vast number of cases and a detailed analysis of each case with each combination of errors, and is clearly beyond the scope of this study. A statistical calculation of the various combination of errors is also unjustified since it would be distorted by the many cases incurring no errors beyond tolerance; also the severity of incidence level would have to be specified and perhaps weighted in order to provide an indication of an overall structural problem.

The statistical calculations in Chapter 9 are performed in order to check the scoring system and to provide overall correlations between categories of site.

It is for industry to determine whether the workmanship standards reported here are 1) representative; (the author would maintain that they are or that the true picture may be worse when including smaller sites); or 2) a cause for concern, particularly with regard to stability. It is interesting to perform a crude combination of errors due to lack of bracing and others which increase the need for it. A level of 50% is chosen as a serious incidence of error; that is 50% of bracing is omitted in any one direction, - this could, for example, mean one complete lift of bracing or one complete bay which would represent a serious stability problem; or 50% of the standards in a sample have an error beyond the tolerance limits.

By inspection of drawing number 2, there are 25 cases where 50% or more bracing is omitted. Of these, 9 coincide with a head condition error in excess of 50%, 3 with base condition and 11 with verticality. Moreover six of these 25 cases have 50% level of errors between bracing and two of the conditions, Head, Base and Verticality.

These are instances, therefore where factors of safety are being further eroded and probabilities of failure increased. It will be seen from later in Chapter 9 that it is the poorer category of sites that demonstrate errors in workmanship in all conditions.

Comparison of System Types

A comparison of the types of system based on workmanship standards at each condition is hindered by the small sample sizes and the method of sampling. As pointed out at the beginning of the Chapter such comparisons are secondary to the main purpose of the study. More useful comparisons in terms of overall quality standards may be made once the sites are ranked and categorised. (see Chapter 9 and subsequent Chapters in this Part 2).

Apart from the comments made earlier with respect to each condition or level in the structure, there is very little to choose between Type 1 and Type 2 systems, particularly when the civil engineering sites are excluded. Bracing tends to be more of a problem in Type 2 systems for the reasons given earlier. Type 2 systems do not represent a problem at the Head Condition due to the design of the equipment.

As regards comparisons between proprietary systems and adjustable steel props, the workmanship standards at every applicable element of the structure are worse for adjustable steel props; particularly marked with respect to lacing and bracing.

It is postulated, based on this study and personal experience, that occasions where adjustable steel props are all fully braced and laced as per the Code requirements are very rare. The cost and time involved in such schemes far outweigh any equipment costs of other systems, and only where systems are totally unsuitable will adjustable steel props be used, and perhaps properly laced and braced.

Secondary Cases

As reported in Chapter 6, in a number of instances additional structures are sometimes required where the modular basis of proprietary systems cannot cope with awkward shapes, obstructions and so on. These secondary cases or 'B' sites are often *ad hoc* structures and conceived of as different to the main dominant falsework structure.

The errors on these cases were reported on separate checklists and incorporated in drawings numbers 1 and 2.

Seven of these cases used Type 3 adjustable steel props and two, Type 4 tubes and fittings.

Any comparison or conclusions on tubes and fittings are clearly superfluous. For completeness, one tube and fittings 'B' case incurred any degree of error: 50% of standards being greater than the eccentricity tolerance, and 75% of the standards being greater than the verticality tolerance.

Table 10 indicates the number of cases in these adjustable steel props 'B' sites, where levels of incidence of error are reported in each of the conditions or levels in the structure.

The size of each sample is too small to justify rigorous analysis with respect to individual conditions, and is sufficiently different organisationally from the main structures on the same site; and structurally from other adjustable steel props sites, to draw any demonstrable conclusions. There then follows a general form of discussion of these sites and approximate comparisons in order to describe their nature and characteristic differences.

These 'B' sites are often *ad hoc* structures and frequently open for abuse. Design frequently excludes them for commercial and legal reasons and it is left to the operative on site, generally, to provide a solution. An inspection of the types of error indicates that where errors occur in the main structure they are frequently worse in the secondary structure.

Typically the props are erected once the main structure is decked out; and the main problem is one of fixity, the prop heads are simply inserted under the timber primaries and not nailed or wedged; it is assumed that the main structure is rigid enough. This assumption is also made with respect to bracing and lacing, and indeed if the structure is fully braced or tied there is little need for bracing providing that lacing is restrained. The table shows, however, that where bracing is needed it is still omitted as for other adjustable prop cases. Verticality should be easier to achieve on 'B' sites since the structure to be supported is already erected and props have simply to be inserted; where problems do occur it is where obstructions prevent proper location of the baseplate. Similarly, eccentricity should also be less of a problem than on main prop sites.

Generally the standards of workmanship on the secondary cases are the same or worse (particularly fixity) than on the corresponding main sites or adjustable steel prop sites in general. In terms of an overall quality score (see Chapter 9) these 'B' sites may be raised owing to the fact that frequently bracing is not needed and hence penalties are not applicable.

Conclusions and Recommendations

With the exception perhaps of verticality, the standards advocated in the Code of Practice are easily achievable. This study shows, however, that in many cases they are not being achieved.

One particular instance where trades practice departs from that advocated in the Code is provision of bracing (and lacing). This is more pronounced in the case of adjustable steel prop structures.

Clearly there is a need for training and dissemination of Code recommendations or redrafting of these.

This study found that the typical type of errors reported in previous studies, for example that funded by B.R.E. (see Chapter 3); poor base seating, eccentricity and so on are still occurring but on a frequency far greater than that reported in that study. Those sites included in the B.R.E. study were frequently the best examples and frequently the checklist reported on previously checked and subsequently rectified structures. The purposes of the B.R.E. study were somewhat different to this one.
The main purpose of this Chapter has been to identify the types of error and describe how falsework is erected. This is only a minor sub-analysis making tentative conclusions based on small samples and some subjectivity. Further analysis is performed in Chapter 9 where overall quality of workmanship is addressed.

Incidence of error-%	Type1	Type3	Total
0	17	2	19
1 - 10	1	1	2
11 - 30	2	6	8
31 - 50	3	-	3
51 - 70	-	1	1
71 - 90	1	-	1
91 -100	-	1	1
Total	24	11	35

Table 1: Incidence of error with respect to eccentricity in Head Condition.

Incidence of error-%	Type1	Type3	Total
0	12	4	16
1 - 10	1	2	3
11 - 30	3	2	5
31 - 50	3	1	4
51 - 70	-	-	-
71 - 90	1	-	1
91 -100	4	2	6
Total	24	11	35

Table 2: Incidence of error with respect to fixity in Head Condition.

Incidence of error-%	Type1	Type2	Type3	Total
0	14	13	6	33
1 - 10	2	-	-	2
11 - 30	5	3	2	10
31 - 50	2	-	2	4
51 - 70	-	-	-	-
71 - 90	1	-	-	1
91 -100	1	1	1	3
Total	25	17	11	53

Table 3: Incidence of error with respect to Base Condition

Incidence of error-%	Type1	Type2	Total	
0	18	15	33	
10 - 20	1	-	1	
50	1	-	1	**Head**
100	3	2	5	
Total	23	17	40	
0	18	12	30	
10 - 20	-	1	1	
50	1	-	1	**Base**
100	1	2	3	
Total	20	15	35	

Table 4: Incidence of error with respect to Jacks at Head and Base levels.

Incidence of error-%	Type1	Type2	Type3	Total
0	19	10	4	33
1 - 10	1	4	1	6
11 - 30	-	1	1	2
31 - 50	3	2	2	7
51 - 70	2	-	1	3
71 - 90	-	-	2	2
Total	25	17	11	53

Table 5: Incidence of error with respect to Lacing.

Incidence of error-%	Type1	Type2	Type3	Total
0	5	2	2	9
1 - 10	3	4	2	9
11 - 30	14	6	4	24
31 - 50	-	5	3	8
51 - 70	2	-	-	2
71 - 90	1	-	-	1
Total	25	17	11	53

Table 6: Incidence of error with respect to Verticality

Incidence of error-%	Type1	Type2	Type3	Total
0	10	5	-	15
1 - 10	3	1	-	4
11 - 30	5	-	-	5
31 - 50	2	4	1	7
51 - 70	2	1	-	3
71 - 90	1	3	1	5
91 -100	1	3	6	10
Total	24	17	8	49

Table 7: Incidence of error with respect to Bracing (percentage missing in both directions)

Incidence of error-%	Type1	Type2	Type3	Total
0	10	5	-	15
1 - 10	2	1	-	3
11 - 30	3	-	-	3
31 - 50	1	3	-	4
51 - 70	4	1	-	5
71 - 90	-	2	1	3
91 -100	4	5	7	16
Total	24	17	8	49

Table 8: Incidence of error with respect to Bracing (maximum percentage missing in any one direction).

Incidence of error-%	Type1	Type2	Total
0	17	6	23
1 - 10	1	2	3
30 - 40	1	4	5
50 - 60	1	1	2
100	4	1	5
Total	24	14	38

Table 9: Incidence of error with respect to Bracing Connections.

% Incidence	Ecc.	Fix.	Base	Lace	Verty.	Brace
0	4	1	4	2	1	-
1 - 10	-	-	-	-	1	-
11 - 30	3	-	1	-	4	-
31 - 50	-	1	1	3	-	-
51 - 70	-	-	-	1	1	-
71 - 90	-	-	1	-	-	-
91 -100	-	5	-	-	-	2
Total Applicable	7	7	7	6	7	2

Table 10: Summary of incidence of error for Secondary Cases using adjustable steel props.

CHAPTER 9

Scoring and ranking of quality

Introduction

A means of scoring the overall quality of workmanship on various sites had to be devised which enabled comparison between different types of structure, equipment type and so on. The sites could then be ranked and categorized in order to relate organisation variables and types of control to the level of quality attained.

Derivation of scoring

The derivation of a means of scoring quality took place at the same time as the development of the checklist and data collection. It was recognised from the outset of the study that such a task would be difficult for the reasons explored in Chapter 5 and later here. One supporter of the S.E.R.C. proposal thought the exercise was ambitious in attempting to measure and score quality, however, when presented with the checklist and findings in the S.E.R.C. interim report, he still asked "Where are the numbers?"; as an engineer he was still asking for means of quantifying quality. Despite the difficulties of scoring some method, however crude, had to be devised since the assessment of quality was pivotal to the main objective of the study. There was a need for a pragmatic approach, where members of the industry could be involved and with a direct end in mind of some means of measuring quality across a wide range of structures and equipment types. The main purpose of measuring quality was to enable relative standards of quality to be compared between each site and with the organisational factors on site. Members of industry gave assurances that some form of measurement could be devised. Members of the 'panel of experts' for example, were judging quality all of the time checking structures on site. Of course their assessments of sites were not concerned with relative quality standards but quality standards on a particular site based upon particular contingent factors (loading conditions and so on). The Code of Practice lays down minimum standards but the research initially attempted to assess the relative importance of particular degrees of error in workmanship. All the research had to do was to provide a rigorous objective basis to their engineering judgements, a form of 'expert system'.

The 18 members of the 'panel of experts' referred to in Chapter 7 were all experienced practitioners in falsework. Eleven participants were designers from the three main equipment suppliers, three of these designers also performed tube and fittings designs; another four members represented main contractors' designers, the remaining three were falsework coordinators.

It was essential that any scoring system would:

1) enable comparison of workmanship standards in each element of the structure, between all equipment types.

2) incorporate the relative severity of the type of error at each element of the structure and weightings applied if necessary.

3) enable, based on 1 and 2, an assessment of overall quality of workmanship on a site which could be directly compared with other sites.

The participants were presented with a checklist which included frequency of errors in every condition and were asked to comment on whether a particular error was 'good', 'fair' or 'inadequate'. They were also invited to change any frequency range. The format of this checklist was similar to that used in the B.R.E. study and the checklists used by many companies at that time. Checkers could, and indeed, did remark upon various conditions as 'good', 'fair' or 'inadequate' when checking a structure (but for different purposes to this study). This research aimed at reflecting the consensus of opinion as to what types or incidences of error were regarded as 'good' and so on. The checklists were systematically followed through during interviews with the participants. A sample of completed checklists with comments appears in the appendix.

The original intention was to attribute marks or scores to the categories of 'good', 'fair' or 'inadequate' and assess the relative severity of a particular error. However there were problems in achieving the first part of the exercise which is understandable and expected, bearing in mind the discussions in Chapter 5 of determining absolute standards and the problems of separating design from workmanship.

The main purpose of approaching the experienced group of practitioners was to enable the investigator on a particular site to use similar criteria as the professional checkers in the judgements and discretion exercised. In the interviews it soon became apparent that the practitioners' view of quality differed from that outlined in the study, in that design was addressed; and that it was affected by the contingencies (such as time, cost and level of expertise and experience) which had to be avoided in an objective study.

It was stressed from the outset, in the interviews with the participants, that the purpose of the study was to compare quality of workmanship standards and not arrive at absolute standards of workmanship or standards of quality. Their marking was more relaxed at the beginning of the interview. As the interview progressed the marking became stricter. This may be interpreted as a result of the way in which the respondents undertook the task presented them. In isolation a given fault need not be serious. As more and more faults were considered their cumulative consequences for any actual structure with which they might be confronted became apparent to them. They experienced great difficulty in providing categories. Soon their judgements became prefaced by "it depends on individual circumstances". Here the participants were reflecting their role as checkers and practical men. Each case is judged on the circumstances prevailing at the time; whether an error was in a lightly loaded standard, whether there was tying-in locally around a column. In other words, their view of quality involved an assessment of design; relaxation of workmanship standards, could be and was made depending loading conditions and design factors. These type of qualifications which were made to their comments on severity or weighting of an incidence of error could not be entertained in this study. The assessment and scoring of workmanship standards must apply universally irrespective of particular contingencies. In terms of training and supervision of quality it is undesirable to impose different standards depending upon the individual circumstances; the workforce and supervision will never know the basic minimum standards or will become disillusioned or suspicious of falsework checkers or designers. The views of the participants are understandable, they are simply reflecting their experience and expectations. Their comments depend naturally on personal opinions, ability, experience and their role in the organisation.

Temporary works designers were generally stricter than suppliers. This, it is inferred, is due to the fact that the temporary works designers can make and control engineering judgements because contractually they have ultimate responsibility for all the falsework on their firm's sites, whether or not they are the designers. They are also aware that their position and integrity would be undermined if they were seen to be adopting diverse standards. As in the case of the temporary works coordinator, they are still under some pressures from production.

Suppliers were generally more relaxed or more realistic in their expectations, taking a jaundiced view of quality standards. Their interest is a commercial one; ensuring a good relationship with their clients is more important than having to ensure perfect quality of falsework on site. Although in the long term this undermines the status of falsework knowledge and the credibility of designers, they have to adopt expediency. Their contractual position also renders them unable to demand good quality of falsework even if they should wish to. Although in most cases they supply the drawings, they do not take any responsibility for the way they are used. They are responsible for the quality and capability of the materials they supply.

The falsework coordinators' attitude also appeared to affect the nature of their involvement. They are not only responsible for making engineering judgements on site, but also are under pressure from production with a site programme to be adhered to.

In the event the panel did not disagree with the content of the comprehensive checklist. They could offer no suggestions or modifications to the range of incidences provided in this checklist. Typically any incidence of up to 5 per cent in any error was regarded as 'good'. In respect of bracing, although this is regarded as the most important area, it is also recognised as the most problematic one, where trades practice does not accept the requirements of the Code of Practice. The workforce and supervision on site might overestimate the rigidity of the structure and be ignorant of the requirements for node stability. In the event, omissions of up to 20 percent of the bracing may be regarded by the practitioners as 'good' or the best to be expected. More jaundiced views expressed the opinion that if any bracing was included, it was a bonus. Initial intentions were to 'score' the individual conditions and in determining the overall quality to apply weightings if necessary to these individual scores. No assistance could be offered by the practitioners in determining, for example, whether 20 percent of members with eccentricity of 25mm was more serious (and by how much) than 10 percent of members with eccentricity of 37mm; or whether any of these were more serious than 10 percent of the bracing being omitted. This is understandable since such an assessment depends upon the design and expectations for overall structural quality beyond the scope of this study. The objectives of the study could not be achieved by giving positive performance scores in each condition. The main conclusion drawn from the series of communications with the practitioners is that it was evident that a mutual understanding had been reached with the practitioners and a rapport established, and the author was confident that any assumptions made in the subsequent exercise would be acceptable.

The scoring method eventually adopted records the incidence and severity of errors which attract penalty (negative) scores. This avoids having to classify or make subjective judgements on an individual condition or site being 'good' or 'fair' or 'inadequate' until all sites and conditions are scored and ranked.

From a consideration of the basic requirements, as listed in Chapter 7, and an assessment of what can go wrong in each condition and the severity, a scoring system was devised.

Scoring system

The scoring system below was used in conjunction with the abbreviated checklist to analyse each case. The contents of each completed checklist are presented on drawings numbers 1 and 2. A typical completed checklist and drawings appear in the appendix.

Head Condition

Eccentricity > 25mm - maximum penalty (-100). The penalty is based upon the percentage number of vertical members with eccentricity of loading at the head level greater than 25mm.

Fixing - maximum penalty (-100).The penalty is based upon the percentage number of members with inadequate fixity, in the head level.

With proprietary systems and proprietary decking, the penalty for this condition will automatically be zero (0). In such cases where a potential error is obviated by the design of the equipment a zero score signifies a higher standard of quality. It is a matter for argument whether it should be included as a feature of workmanship. Since choice of system is an organisational one, then if this results in better overall workmanship then it should be reflected in the score. (For completeness the effect of disregarding head condition in proprietary decking systems is explained later in Ranking No.4).

Base Condition

Adequacy of seating - maximum penalty (-100). The penalty is based upon the percentage number of the members with inadequate base restraint. A whole range of factors could contribute to inadequate horizontal or vertical restraint and be classed as inadequate workmanship in a member; such as bent base plates, substandard soleplates, poor seating and bedding etc. One or more individual errors render the whole base condition of a member inadequate. Ground conditions and foundations are reported but not assessed in quality of falsework since the operation is performed by a different work group.

Jack extension

Head condition - maximum penalty (-100)

Base condition - maximum penalty (-100)

The penalty is based upon the percentage number of jacks which are extended and unbraced beyond the requirements. Whenever jacks are not provided by design then it is considered not applicable (N/A)in scoring. In the cases where there is no drawing or sufficient information on the drawing then both these head and base conditions are assessed on the basis of Code requirement, which is if the extension is > 300mm and not braced, then it is inadequate.

For props this condition will automatically be considered as Not Applicable N/A.

Vertical Members

Effective height - maximum penalty (-50).

Lacing missing - maximum penalty (-50).

Maximum negative points (-50) selected because one condition can be equally applied to the other. The penalty is based upon the number of vertical members with excessive lift heights.

Props with extended length less than 2.75m. will not be considered for lacing (N/A).

Verticality - maximum penalty (-100). The penalty is based upon the percentage number of vertical members with inclinations greater than 30 minutes of arc in the case of tube and proprietary systems, and 90 minutes of arc in the case of adjustable steel props.

Inadequate pins on props - maximum penalty (-50). The penalty is based upon the number of props using incorrect pins.

High tensile pins are recommended in the Code. Anything else is unacceptable.

Proprietary systems and tubes and fittings will not be considered for this error (N/A).

Bracing

This is viewed as a most critical item as far as lateral and node stability is considered. It was, therefore, decided to divide it into three separate categories, each with maximum (i.e.negative) penalties of its own. This may be construed as a weighting. As it was, however, this did not materially affect the overall ranking and the scoring system proved to be extremely robust with respect to individual weightings (see below).

Longitudinal direction - maximum penalty (-100).

Transverse direction - maximum penalty (-100).

Both these conditions will be considered with respect to the percentage number of bracing missing in each direction.

Nodes > 150mm - maximum penalty (-100). The penalties are based upon the percentage number of connections (usually bracing members) which are in excess of 150mm distance from the node point.

Trigger bracing will be considered as zero (0) because it signifies a case where potential error is designed out, and its effect should reflect on the total score.

For props only, two more items will be considered where bracing is installed:

Bottom Lace (-50) - the Code recommends bottom lacing if bracing is provided.

Angle (-50) - if the angle of bracing exceeds Code requirements this penalty applies.

On Triframes, bracing will count as (N/A) and nodes as zero (0).

Tying-in

If bracing was omitted, but the structure was adequately tied-in, in terms of lateral and node stability, this would attract a positive compensating score (max.100) in any particular direction.

Condition of Materials

Good (0), Old/Fair (-30).

Poor (-60), and Very Old/Poor (-100).

These penalties are based on the fact that good erectors will discard bad equipment if they are allowed to! This has been explored in Chapter 7. Scores are for comparison only, and not applicable to main study.

Access and Safety

Total maximum negative penalty (-100). This is divided into three parts:
Adequacy to check (-33).

Adequacy to concrete (-33).

Site tidiness (-33).

See Chapter 7 and comments above.

Availability of drawings

Non-availability of drawings presents no problem in the scoring of quality of workmanship. The availability of a drawing and design is a function of the type of control exercised on site (see Chapter 7) and information in this section of the checklist is used in Part 3.

The scoring system assesses workmanship in each condition and ignores effects of design or particular site conditions, loadings and so on. The scoring is based upon incidence of errors in each condition and it can be used directly to report the types of finding in Chapter 8, report workmanship in each condition and make comparisons between types.

The overall total of penalties for each case is a measure of the overall standards of workmanship, a measure of care, skill and attention that has gone into the erection of the structure in that case. It is not a measure of structural quality, since, as the practitioners say, satisfactory structural quality depends upon design, and the loading and a variety of practical factors. Nevertheless a structure with a higher incidence of errors will have a higher probability of increased structural instability. The overall score on a given case will reflect the various weightings given to each condition. It might be the case that a weighting should be given to the omission of bracing. Such a weighting might be viewed as desirable since the provision of bracing is fundamental to the requirements of stability against collapse.

It is necessary to check the scoring system for the effects of any weighting that is applied, highlight them and decide whether they are warranted. The purpose of determining overall scores provides the means to compare, rank and subsequently categorise cases or sites. The scoring system is not intended for use by a site as a control mechanism by awarding points since even the best site in this study might not be acceptable, in absolute terms. This study is essentially concerned with establishing relative quality standards between sites and organisations.

<u>Ranking and Testing</u>

The maximum penalties that could be incurred in any condition were eventually determined from consideration and experience of the magnitude and incidence occurring on site. The categories of conditions naturally evolved to those presented above. Quality of workmanship is measured on each case divorced from design or contingency factors.

All the penalty points in all of the conditions in each case study are totalled and then divided by the total of the maximum possible points each case could have incurred. These percentages are shown on drawing number 2. It is thus possible to produce a variety of rankings and comparisons based on overall or individual scores in each condition. (see Tables 1-7).

TABLE No 1: OVERALL PENALTY SCORES AND PENALTY SCORES IN INDIVIDUAL CONDITIONS.

MAIN AND SECONDARY SITES.

SITES RANKED WITH RESPECT TO FALSEWORK TYPE.

SITE NO.	TYPE NO.	RANKING 1 %	RANKING 2 %	RANKING 3 %	HEAD CONDITN	BASE CONDITN	JACK EXTENSN	VERTICAL MEMBER	BRACING
20	1	0	0	2	0	0	0	0	0
22	1	0	0	0	0	0	0	0	1
36A	1	0	7	6	0	0	0	0	0
8	1	2	1	2	0	0	0	6	0
41	1	3	3	6	0	14	0	6	3
48	1	4	4	3	0	30	0	5	0
29	1	5	5	8	0	0	0	14	7
34	1	5	5	7	25	0	0	2	0
15	1	6	5	5	0	0	0	3	18
26	1	6	5	8	8	19	N/A	7	0
6	1	7	12	15	30	0	0	0	0
37	1	9	8	11	N/A	2	7	7	13
45	1	9	8	12	0	24	0	8	17
17	1	9	8	7	15	50	0	0	0
53	1	12	11	10	0	25	0	15	17
25A	1	18	19	19	25	6	0	35	19
31	1	23	21	21	11	0	52	6	32
49	1	26	23	21	14	0	0	39	50
12A	1	26	24	23	25	75	0	38	20
47A	1	27	24	28	50	0	50	7	19
39A	1	32	32	30	25	0	50	35	33
24	1	39	35	34	60	34	0	63	36
9	1	40	37	34	90	0	0	7	69
2	1	42	38	35	65	0	0	30	77
16	1	74	67	70	50	100	100	35	67
4	2	1	3	8	0	0	0	3	0
10A	2	2	4	4	0	0	0	8	0
40	2	4	3	3	0	0	0	4	10
38	2	5	5	4	0	14	0	17	1
52	2	10	9	8	0	0	0	5	29
3	2	11	10	14	0	0	0	20	20
42	2	16	15	16	0	0	0	48	18
14A	2	17	15	14	0	0	0	7	51
46	2	19	17	24	0	100	0	20	17
11	2	20	18	17	0	0	0	7	62
5	2	24	24	25	0	0	50	10	38
30	2	25	23	23	0	20	50	14	35
33	2	26	25	26	0	0	50	3	50
13A	2	27	27	26	22	0	0	0	67
51	2	27	28	31	0	0	0	20	67
1A	2	28	25	29	0	0	0	34	67
43	2	38	35	32	0	14	57	9	67
28	3	0	3	9	0	0	N/A	0	N/A
54	3	32	29	26	20	0	N/A	0	100
19	3	32	27	28	40	44	N/A	21	N/A
27	3	33	33	36	8	0	N/A	14	100
50	3	33	30	28	66	0	N/A	9	50
44	3	40	43	43	59	100	N/A	1	N/A
18	3	41	40	36	15	0	N/A	24	87
23	3	43	43	40	8	13	N/A	36	100
21	3	45	41	44	12	0	N/A	47	100
7	3	55	55	57	35	15	N/A	50	100
35	3	67	67	60	50	40	N/A	64	100
36B	4	2	10	9	0	0	0	6	N/A
25B	4	21	22	22	25	0	0	38	N/A
32	4	24	22	20	32	50	7	8	48
10B	5	11	14	12	0	0	N/A	24	N/A
39B	5	21	22	21	58	0	N/A	0	N/A
1B	5	23	24	20	50	0	N/A	10	N/A
12B	5	27	23	21	25	75	N/A	7	N/A
13B	5	34	38	34	50	0	N/A	36	N/A
47B	5	58	58	59	58	11	N/A	43	100
14B	5	59	58	51	64	50	N/A	24	100

NOTES:-

RANKINGS 1,2 & 3 ARE RELATED TO THE PERCENTAGE PENALTIES SHOWN ON DRG No 2.

ALL OTHER COLUMNS ARE THE PERCENTAGE PENALTIES FOR EACH CONDITION

RANKING 1: HEAD CONDITION + BASE CONDITION + JACK EXTENSION + VERT. MEMBERS + BRACING

RANKING 2: RANKING 1 + MAT'L CONDITION

RANKING 3: RANKING 2 + ACCESS & SAFETY

TYPE 1 :- PROP SYSTEM/TRAD DECKING

TYPE 2 :- PROP SYSTEM/PROP DECKING

TYPE 3 :- ADJUST. PROPS/TRAD DECKING (A)

TYPE 4 :- TUBES/FITTINGS & TRAD DECKING

TYPE 5 :- ADJUST. PROPS/TRAD DECKING (B)

TABLE No 2: OVERALL PENALTY SCORES AND PENALTY SCORES IN INDIVIDUAL CONDITIONS.

MAIN AND SECONDARY SITES.

SITES RANKED WITH RESPECT TO OVERALL RANKING No.1 SCORE.

SITE NO.	TYPE NO.	RANKING 1 %	RANKING 2 %	RANKING 3 %	HEAD CONDITN	BASE CONDITN	JACK EXTENSN	VERTICAL MEMBER	BRACING
20	1	0	0	2	0	0	0	0	0
22	1	0	0	0	0	0	0	0	1
36A	1	0	7	6	0	0	0	0	0
28	3	0	3	9	0	0	N/A	0	N/A
4	2	1	3	8	0	0	0	3	0
8	1	2	1	2	0	0	0	6	0
10A	2	2	4	4	0	0	0	8	0
36B	4	2	10	9	0	0	0	6	N/A
41	1	3	3	6	0	14	0	6	3
48	1	4	4	3	0	30	0	5	0
40	2	4	3	3	0	0	0	4	10
29	1	5	5	8	0	0	0	14	7
34	1	5	5	7	25	0	0	2	0
38	2	5	5	4	0	14	0	17	1
15	1	6	5	5	0	0	0	3	18
26	1	6	5	8	8	19	N/A	7	0
6	1	7	12	15	30	0	0	0	0
37	1	9	8	11	N/A	2	7	7	13
45	1	9	8	12	0	24	0	8	17
17	1	9	8	7	15	50	0	0	0
52	2	10	9	8	0	0	0	5	29
3	2	11	10	14	0	0	0	20	20
10B	5	11	14	12	0	0	N/A	24	N/A
53	1	12	11	10	0	25	0	15	17
42	2	16	15	16	0	0	0	48	18
14A	2	17	15	14	0	0	0	7	51
25A	1	18	19	19	25	6	0	35	19
46	2	19	17	24	0	100	0	20	17
11	2	20	18	17	0	0	0	7	62
25B	4	21	22	22	25	0	0	38	N/A
39B	5	21	22	21	58	0	N/A	0	N/A
31	1	23	21	21	11	0	52	6	32
1B	5	23	24	20	50	0	N/A	10	N/A
5	2	24	24	25	0	0	50	10	38
32	4	24	22	20	32	50	7	8	48
30	2	25	23	23	0	20	50	14	35
49	1	26	23	21	14	0	0	39	50
12A	1	26	24	23	25	75	0	38	20
33	2	26	25	26	0	0	50	3	50
47A	1	27	24	28	50	0	50	7	19
13A	2	27	27	26	22	0	0	0	67
51	2	27	28	31	0	0	0	20	67
12B	5	27	23	21	25	75	N/A	7	N/A
1A	2	28	25	29	0	0	0	34	67
39A	1	32	32	30	25	0	50	35	33
54	3	32	29	26	20	0	N/A	0	100
19	3	32	27	28	40	44	N/A	21	N/A
27	3	33	33	36	8	0	N/A	14	100
50	3	33	30	28	66	0	N/A	9	50
13B	5	34	38	34	50	0	N/A	36	N/A
43	2	38	35	32	0	14	57	9	67
24	1	39	35	34	60	34	0	63	36
9	1	40	37	34	90	0	0	7	69
44	3	40	43	43	59	100	N/A	1	N/A
18	3	41	40	36	15	0	N/A	24	87
2	1	42	38	35	65	0	0	30	77
23	3	43	43	40	8	13	N/A	36	100
21	3	45	41	44	12	0	N/A	47	100
7	3	55	55	57	35	15	N/A	50	100
47B	5	58	58	59	58	11	N/A	43	100
14B	5	59	58	51	64	50	N/A	24	100
35	3	67	67	60	50	40	N/A	64	100
16	1	74	67	70	50	100	100	35	67

NOTES:-

RANKINGS 1,2 & 3 ARE RELATED TO THE PERCENTAGE PENALTIES SHOWN ON DRG No 2.

ALL OTHER COLUMNS ARE THE PERCENTAGE PENALTIES FOR EACH CONDITION

RANKING 1: HEAD CONDITION + BASE CONDITION + JACK EXTENSION + VERT. MEMBERS + BRACING

RANKING 2: RANKING 1 + MAT'L CONDITION

RANKING 3: RANKING 2 + ACCESS & SAFETY

TYPE 1 :- PROP SYSTEM/TRAD DECKING

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TYPE 4 :- TUBES/FITTINGS & TRAD DECKING

TYPE 5 :- ADJUST. PROPS/TRAD DECKING (B)

TABLE No 3: OVERALL PENALTY SCORES AND PENALTY SCORES IN INDIVIDUAL CONDITIONS.

MAIN AND SECONDARY SITES.

SITES RANKED WITH RESPECT TO HEAD CONDITION PENALTY SCORES.

SITE NO.	TYPE NO.	RANKING 1 %	RANKING 2 %	RANKING 3 %	HEAD CONDITN	BASE CONDITN	JACK EXTENSN	VERTICAL MEMBER	BRACING
20	1	0	0	2	0	0	0	0	0
22	1	0	0	0	0	0	0	0	1
36A	1	0	7	6	0	0	0	0	0
28	3	0	3	9	0	0	N/A	0	N/A
4	2	1	3	8	0	0	0	3	0
8	1	2	1	2	0	0	0	6	0
10A	2	2	4	4	0	0	0	8	0
36B	4	2	10	9	0	0	0	6	N/A
41	1	3	3	6	0	14	0	6	3
48	1	4	4	3	0	30	0	5	0
40	2	4	3	3	0	0	0	4	10
29	1	5	5	8	0	0	0	14	7
38	2	5	5	4	0	14	0	17	1
15	1	6	5	5	0	0	0	3	18
45	1	9	8	12	0	24	0	8	17
52	2	10	9	8	0	0	0	5	29
3	2	11	10	14	0	0	0	20	20
10B	5	11	14	12	0	0	N/A	24	N/A
53	1	12	11	10	0	25	0	15	17
42	2	16	15	16	0	0	0	48	18
14A	2	17	15	14	0	0	0	7	51
46	2	19	17	24	0	100	0	20	17
11	2	20	18	17	0	0	0	7	62
5	2	24	24	25	0	0	50	10	38
30	2	25	23	23	0	20	50	14	35
33	2	26	25	26	0	0	50	3	50
51	2	27	28	31	0	0	0	20	67
1A	2	28	25	29	0	0	0	34	67
43	2	38	35	32	0	14	57	9	67
26	1	6	5	8	8	19	N/A	7	0
27	3	33	33	36	8	0	N/A	14	100
23	3	43	43	40	8	13	N/A	36	100
31	1	23	21	21	11	0	52	6	32
21	3	45	41	44	12	0	N/A	47	100
49	1	26	23	21	14	0	0	39	50
17	1	9	8	7	15	50	0	0	0
18	3	41	40	36	15	0	N/A	24	87
54	3	32	29	26	20	0	N/A	0	100
13A	2	27	27	26	22	0	0	0	67
34	1	5	5	7	25	0	0	2	0
25A	1	18	19	19	25	6	0	35	19
25B	4	21	22	22	25	0	0	38	N/A
12A	1	26	24	23	25	75	0	38	20
12B	5	27	23	21	25	75	N/A	7	N/A
39A	1	32	32	30	25	0	50	35	33
6	1	7	12	15	30	0	0	0	0
32	4	24	22	20	32	50	7	8	48
7	3	55	55	57	35	15	N/A	50	100
19	3	32	27	28	40	44	N/A	21	N/A
1B	5	23	24	20	50	0	N/A	10	N/A
47A	1	27	24	28	50	0	50	7	19
13B	5	34	38	34	50	0	N/A	36	N/A
35	3	67	67	60	50	40	N/A	64	100
16	1	74	67	70	50	100	100	35	67
39B	5	21	22	21	58	0	N/A	0	N/A
47B	5	58	58	59	58	11	N/A	43	100
44	3	40	43	43	59	100	N/A	1	N/A
24	1	39	35	34	60	34	0	63	36
14B	5	59	58	51	64	50	N/A	24	100
2	1	42	38	35	65	0	0	30	77
50	3	33	30	28	66	0	N/A	9	50
9	1	40	37	34	90	0	0	7	69
37	1	9	8	11	N/A	2	7	7	13

NOTES:-

RANKINGS 1,2 & 3 ARE RELATED TO THE PERCENTAGE PENALTIES SHOWN ON DRG No 2.

ALL OTHER COLUMNS ARE THE PERCENTAGE PENALTIES FOR EACH CONDITION

RANKING 1: HEAD CONDITION + BASE CONDITION + JACK EXTENSION + VERT. MEMBERS + BRACING

RANKING 2: RANKING 1 + MAT'L CONDITION

RANKING 3: RANKING 2 + ACCESS & SAFETY

TYPE 1 :- PROP SYSTEM/TRAD DECKING

TYPE 2 :- PROP SYSTEM/PROP DECKING

TYPE 3 :- ADJUST. PROPS/TRAD DECKING (A)

TYPE 4 :- TUBES/FITTINGS & TRAD DECKING

TYPE 5 :- ADJUST. PROPS/TRAD DECKING (B)

TABLE No4: OVERALL PENALTY SCORES AND PENALTY SCORES IN INDIVIDUAL CONDITIONS.

MAIN AND SECONDARY SITES.

SITES RANKED WITH RESPECT TO BASE CONDITION PENALTY SCORES.

SITE NO.	TYPE NO.	RANKING 1 %	RANKING 2 %	RANKING 3 %	HEAD CONDITN	BASE CONDITN	JACK EXTENSN	VERTICAL MEMBER	BRACING
20	1	0	0	2	0	0	0	0	0
22	1	0	0	0	0	0	0	0	1
36A	1	0	7	6	0	0	0	0	0
28	3	0	3	9	0	0	N/A	0	N/A
4	2	1	3	8	0	0	0	3	0
8	1	2	1	2	0	0	0	6	0
10A	2	2	4	4	0	0	0	8	0
36B	4	2	10	9	0	0	0	6	N/A
40	2	4	3	3	0	0	0	4	10
29	1	5	5	8	0	0	0	14	7
15	1	6	5	5	0	0	0	3	18
52	2	10	9	8	0	0	0	5	29
3	2	11	10	14	0	0	0	20	20
10B	5	11	14	12	0	0	N/A	24	N/A
42	2	16	15	16	0	0	0	48	18
14A	2	17	15	14	0	0	0	7	51
11	2	20	18	17	0	0	0	7	62
5	2	24	24	25	0	0	50	10	38
33	2	26	25	26	0	0	50	3	50
51	2	27	28	31	0	0	0	20	67
1A	2	28	25	29	0	0	0	34	67
27	3	33	33	36	8	0	N/A	14	100
31	1	23	21	21	11	0	52	6	32
21	3	45	41	44	12	0	N/A	47	100
49	1	26	23	21	14	0	0	39	50
18	3	41	40	36	15	0	N/A	24	87
54	3	32	29	26	20	0	N/A	0	100
13A	2	27	27	26	22	0	0	0	67
34	1	5	5	7	25	0	0	2	0
25B	4	21	22	22	25	0	0	38	N/A
39A	1	32	32	30	25	0	50	35	33
6	1	7	12	15	30	0	0	0	0
1B	5	23	24	20	50	0	N/A	10	N/A
47A	1	27	24	28	50	0	50	7	19
13B	5	34	38	34	50	0	N/A	36	N/A
39B	5	21	22	21	58	0	N/A	0	N/A
2	1	42	38	35	65	0	0	30	77
50	3	33	30	28	66	0	N/A	9	50
9	1	40	37	34	90	0	0	7	69
37	1	9	8	11	N/A	2	7	7	13
25A	1	18	19	19	25	6	0	35	19
47B	5	58	58	59	58	11	N/A	43	100
23	3	43	43	40	8	13	N/A	36	100
41	1	3	3	6	0	14	0	6	3
38	2	5	5	4	0	14	0	17	1
43	2	38	35	32	0	14	57	9	67
7	3	55	55	57	35	15	N/A	50	100
26	1	6	5	8	8	19	N/A	7	0
30	2	25	23	23	0	20	50	14	35
45	1	9	8	12	0	24	0	8	17
53	1	12	11	10	0	25	0	15	17
48	1	4	4	3	0	30	0	5	0
24	1	39	35	34	60	34	0	63	36
35	3	67	67	60	50	40	N/A	64	100
19	3	32	27	28	40	44	N/A	21	N/A
17	1	9	8	7	15	50	0	0	0
32	4	24	22	20	32	50	7	8	48
14B	5	59	58	51	64	50	N/A	24	100
12A	1	26	24	23	25	75	0	38	20
12B	5	27	23	21	25	75	N/A	7	N/A
46	2	19	17	24	0	100	0	20	17
16	1	74	67	70	50	100	100	35	67
44	3	40	43	43	59	100	N/A	1	N/A

NOTES:-

RANKINGS 1,2 & 3 ARE RELATED TO THE PERCENTAGE PENALTIES SHOWN ON DRG No 2.

ALL OTHER COLUMNS ARE THE PERCENTAGE PENALTIES FOR EACH CONDITION

RANKING 1: HEAD CONDITION + BASE CONDITION + JACK EXTENSION + VERT. MEMBERS + BRACING

RANKING 2: RANKING 1 + MAT'L CONDITION

RANKING 3: RANKING 2 + ACCESS & SAFETY

TYPE 1 :- PROP SYSTEM/TRAD DECKING

TYPE 2 :- PROP SYSTEM/PROP DECKING

TYPE 3 :- ADJUST. PROPS/TRAD DECKING (A)

TYPE 4 :- TUBES/FITTINGS & TRAD DECKING

TYPE 5 :- ADJUST. PROPS/TRAD DECKING (B)

TABLE No 5: OVERALL PENALTY SCORES AND PENALTY SCORES IN INDIVIDUAL CONDITIONS.

MAIN AND SECONDARY SITES.

SITES RANKED WITH RESPECT TO JACK EXTENSION PENALTY SCORES.

SITE NO.	TYPE NO.	RANKING 1 %	RANKING 2 %	RANKING 3 %	HEAD CONDITN	BASE CONDITN	JACK EXTENSN	VERTICAL MEMBER	BRACING
1A	2	28	25	29	0	0	0	34	67
10A	2	2	4	4	0	0	0	8	0
12A	1	26	24	23	25	75	0	38	20
13A	2	27	27	26	22	0	0	0	67
14A	2	17	15	14	0	0	0	7	51
25A	1	18	19	19	25	6	0	35	19
25B	4	21	22	22	25	0	0	38	N/A
36A	1	0	7	6	0	0	0	0	0
36B	4	2	10	9	0	0	0	6	N/A
2	1	42	38	35	65	0	0	30	77
3	2	11	10	14	0	0	0	20	20
4	2	1	3	8	0	0	0	3	0
6	1	7	12	15	30	0	0	0	0
8	1	2	1	2	0	0	0	6	0
9	1	40	37	34	90	0	0	7	69
11	2	20	18	17	0	0	0	7	62
15	1	6	5	5	0	0	0	3	18
17	1	9	8	7	15	50	0	0	0
20	1	0	0	2	0	0	0	0	0
22	1	0	0	0	0	0	0	0	1
24	1	39	35	34	60	34	0	63	36
29	1	5	5	8	0	0	0	14	7
34	1	5	5	7	25	0	0	2	0
38	2	5	5	4	0	14	0	17	1
40	2	4	3	3	0	0	0	4	10
41	1	3	3	6	0	14	0	6	3
42	2	16	15	16	0	0	0	48	18
45	1	9	8	12	0	24	0	8	17
46	2	19	17	24	0	100	0	20	17
48	1	4	4	3	0	30	0	5	0
49	1	26	23	21	14	0	0	39	50
51	2	27	28	31	0	0	0	20	67
52	2	10	9	8	0	0	0	5	29
53	1	12	11	10	0	25	0	15	17
32	4	24	22	20	32	50	7	8	48
37	1	9	8	11	N/A	2	7	7	13
39A	1	32	32	30	25	0	50	35	33
47A	1	27	24	28	50	0	50	7	19
5	2	24	24	25	0	0	50	10	38
30	2	25	23	23	0	20	50	14	35
33	2	26	25	26	0	0	50	3	50
31	1	23	21	21	11	0	52	6	32
43	2	38	35	32	0	14	57	9	67
16	1	74	67	70	50	100	100	35	67
1B	5	23	24	20	50	0	N/A	10	N/A
10B	5	11	14	12	0	0	N/A	24	N/A
12B	5	27	23	21	25	75	N/A	7	N/A
13B	5	34	38	34	50	0	N/A	36	N/A
14B	5	59	58	51	64	50	N/A	24	100
39B	5	21	22	21	58	0	N/A	0	N/A
47B	5	58	58	59	58	11	N/A	43	100
7	3	55	55	57	35	15	N/A	50	100
18	3	41	40	36	15	0	N/A	24	87
19	3	32	27	28	40	44	N/A	21	N/A
21	3	45	41	44	12	0	N/A	47	100
23	3	43	43	40	8	13	N/A	36	100
26	1	6	5	8	8	19	N/A	7	0
27	3	33	33	36	8	0	N/A	14	100
28	3	0	3	9	0	0	N/A	0	N/A
35	3	67	67	60	50	40	N/A	64	100
44	3	40	43	43	59	100	N/A	1	N/A
50	3	33	30	28	66	0	N/A	9	50
54	3	32	29	26	20	0	N/A	0	100

NOTES:-

RANKINGS 1,2 & 3 ARE RELATED TO THE PERCENTAGE PENALTIES SHOWN ON DRG No 2.

ALL OTHER COLUMNS ARE THE PERCENTAGE PENALTIES FOR EACH CONDITION

RANKING 1: HEAD CONDITION + BASE CONDITION + JACK EXTENSION + VERT. MEMBERS + BRACING

RANKING 2: RANKING 1 + MAT'L CONDITION

RANKING 3: RANKING 2 + ACCESS & SAFETY

TYPE 1 :- PROP SYSTEM/TRAD DECKING

TYPE 2 :- PROP SYSTEM/PROP DECKING

TYPE 3 :- ADJUST. PROPS/TRAD DECKING (A)

TYPE 4 :- TUBES/FITTINGS & TRAD DECKING

TYPE 5 :- ADJUST. PROPS/TRAD DECKING (B)

TABLE No 6: OVERALL PENALTY SCORES AND PENALTY SCORES IN INDIVIDUAL CONDITIONS.

MAIN AND SECONDARY SITES.

SITES RANKED WITH RESPECT TO VERTICAL MEMBERS PENALTY SCORES.

SITE NO.	TYPE NO.	RANKING 1 %	RANKING 2 %	RANKING 3 %	HEAD CONDITN	BASE CONDITN	JACK EXTENSN	VERTICAL MEMBER	BRACING
13A	2	27	27	26	22	0	0	0	67
36A	1	0	7	6	0	0	0	0	0
6	1	7	12	15	30	0	0	0	0
17	1	9	8	7	15	50	0	0	0
20	1	0	0	2	0	0	0	0	0
22	1	0	0	0	0	0	0	0	1
39B	5	21	22	21	58	0	N/A	0	N/A
28	3	0	3	9	0	0	N/A	0	N/A
54	3	32	29	26	20	0	N/A	0	100
44	3	40	43	43	59	100	N/A	1	N/A
34	1	5	5	7	25	0	0	2	0
4	2	1	3	8	0	0	0	3	0
15	1	6	5	5	0	0	0	3	18
33	2	26	25	26	0	0	50	3	50
40	2	4	3	3	0	0	0	4	10
48	1	4	4	3	0	30	0	5	0
52	2	10	9	8	0	0	0	5	29
36B	4	2	10	9	0	0	0	6	N/A
8	1	2	1	2	0	0	0	6	0
41	1	3	3	6	0	14	0	6	3
31	1	23	21	21	11	0	52	6	32
14A	2	17	15	14	0	0	0	7	51
9	1	40	37	34	90	0	0	7	69
11	2	20	18	17	0	0	0	7	62
37	1	9	8	11	N/A	2	7	7	13
47A	1	27	24	28	50	0	50	7	19
12B	5	27	23	21	25	75	N/A	7	N/A
26	1	6	5	8	8	19	N/A	7	0
10A	2	2	4	4	0	0	0	8	0
45	1	9	8	12	0	24	0	8	17
32	4	24	22	20	32	50	7	8	48
43	2	38	35	32	0	14	57	9	67
50	3	33	30	28	66	0	N/A	9	50
5	2	24	24	25	0	0	50	10	38
1B	5	23	24	20	50	0	N/A	10	N/A
29	1	5	5	8	0	0	0	14	7
30	2	25	23	23	0	20	50	14	35
27	3	33	33	36	8	0	N/A	14	100
53	1	12	11	10	0	25	0	15	17
38	2	5	5	4	0	14	0	17	1
3	2	11	10	14	0	0	0	20	20
46	2	19	17	24	0	100	0	20	17
51	2	27	28	31	0	0	0	20	67
19	3	32	27	28	40	44	N/A	21	N/A
10B	5	11	14	12	0	0	N/A	24	N/A
14B	5	59	58	51	64	50	N/A	24	100
18	3	41	40	36	15	0	N/A	24	87
2	1	42	38	35	65	0	0	30	77
1A	2	28	25	29	0	0	0	34	67
25A	1	18	19	19	25	6	0	35	19
39A	1	32	32	30	25	0	50	35	33
16	1	74	67	70	50	100	100	35	67
13B	5	34	38	34	50	0	N/A	36	N/A
23	3	43	43	40	8	13	N/A	36	100
12A	1	26	24	23	25	75	0	38	20
25B	4	21	22	22	25	0	0	38	N/A
49	1	26	23	21	14	0	0	39	50
47B	5	58	58	59	58	11	N/A	43	100
21	3	45	41	44	12	0	N/A	47	100
42	2	16	15	16	0	0	0	48	18
7	3	55	55	57	35	15	N/A	50	100
24	1	39	35	34	60	34	0	63	36
35	3	67	67	60	50	40	N/A	64	100

NOTES:-

RANKINGS 1,2 & 3 ARE RELATED TO THE PERCENTAGE PENALTIES SHOWN ON DRG No 2.

ALL OTHER COLUMNS ARE THE PERCENTAGE PENALTIES FOR EACH CONDITION

RANKING 1: HEAD CONDITION + BASE CONDITION + JACK EXTENSION + VERT. MEMBERS + BRACING

RANKING 2: RANKING 1 + MAT'L CONDITION

RANKING 3: RANKING 2 + ACCESS & SAFETY

TYPE 1 :- PROP SYSTEM/TRAD DECKING

TYPE 2 :- PROP SYSTEM/PROP DECKING

TYPE 3 :- ADJUST. PROPS/TRAD DECKING (A)

TYPE 4 :- TUBES/FITTINGS & TRAD DECKING

TYPE 5 :- ADJUST. PROPS/TRAD DECKING (B)

TABLE No 7: OVERALL PENALTY SCORES AND PENALTY SCORES IN INDIVIDUAL CONDITIONS.

MAIN AND SECONDARY SITES.

SITES RANKED WITH RESPECT TO BRACING PENALTY SCORES.

SITE NO.	TYPE NO.	RANKING 1 %	RANKING 2 %	RANKING 3 %	HEAD CONDITN	BASE CONDITN	JACK EXTENSN	VERTICAL MEMBER	BRACING
36A	1	0	7	6	0	0	0	0	0
6	1	7	12	15	30	0	0	0	0
17	1	9	8	7	15	50	0	0	0
20	1	0	0	2	0	0	0	0	0
34	1	5	5	7	25	0	0	2	0
4	2	1	3	8	0	0	0	3	0
48	1	4	4	3	0	30	0	5	0
8	1	2	1	2	0	0	0	6	0
26	1	6	5	8	8	19	N/A	7	0
10A	2	2	4	4	0	0	0	8	0
22	1	0	0	0	0	0	0	0	1
38	2	5	5	4	0	14	0	17	1
41	1	3	3	6	0	14	0	6	3
29	1	5	5	8	0	0	0	14	7
40	2	4	3	3	0	0	0	4	10
37	1	9	8	11	N/A	2	7	7	13
45	1	9	8	12	0	24	0	8	17
53	1	12	11	10	0	25	0	15	17
46	2	19	17	24	0	100	0	20	17
15	1	6	5	5	0	0	0	3	18
42	2	16	15	16	0	0	0	48	18
47A	1	27	24	28	50	0	50	7	19
25A	1	18	19	19	25	6	0	35	19
3	2	11	10	14	0	0	0	20	20
12A	1	26	24	23	25	75	0	38	20
52	2	10	9	8	0	0	0	5	29
31	1	23	21	21	11	0	52	6	32
39A	1	32	32	30	25	0	50	35	33
30	2	25	23	23	0	20	50	14	35
24	1	39	35	34	60	34	0	63	36
5	2	24	24	25	0	0	50	10	38
32	4	24	22	20	32	50	7	8	48
33	2	26	25	26	0	0	50	3	50
50	3	33	30	28	66	0	N/A	9	50
49	1	26	23	21	14	0	0	39	50
14A	2	17	15	14	0	0	0	7	51
11	2	20	18	17	0	0	0	7	62
13A	2	27	27	26	22	0	0	0	67
43	2	38	35	32	0	14	57	9	67
51	2	27	28	31	0	0	0	20	67
1A	2	28	25	29	0	0	0	34	67
16	1	74	67	70	50	100	100	35	67
9	1	40	37	34	90	0	0	7	69
2	1	42	38	35	65	0	0	30	77
18	3	41	40	36	15	0	N/A	24	87
54	3	32	29	26	20	0	N/A	0	100
27	3	33	33	36	8	0	N/A	14	100
14B	5	59	58	51	64	50	N/A	24	100
23	3	43	43	40	8	13	N/A	36	100
47B	5	58	58	59	58	11	N/A	43	100
21	3	45	41	44	12	0	N/A	47	100
7	3	55	55	57	35	15	N/A	50	100
35	3	67	67	60	50	40	N/A	64	100
39B	5	21	22	21	58	0	N/A	0	N/A
28	3	0	3	9	0	0	N/A	0	N/A
44	3	40	43	43	59	100	N/A	1	N/A
36B	4	2	10	9	0	0	0	6	N/A
12B	5	27	23	21	25	75	N/A	7	N/A
1B	5	23	24	20	50	0	N/A	10	N/A
19	3	32	27	28	40	44	N/A	21	N/A
10B	5	11	14	12	0	0	N/A	24	N/A
13B	5	34	38	34	50	0	N/A	36	N/A
25B	4	21	22	22	25	0	0	38	N/A

NOTES:-

RANKINGS 1,2 & 3 ARE RELATED TO THE PERCENTAGE PENALTIES SHOWN ON DRG No 2.

ALL OTHER COLUMNS ARE THE PERCENTAGE PENALTIES FOR EACH CONDITION

RANKING 1: HEAD CONDITION + BASE CONDITION + JACK EXTENSION + VERT. MEMBERS + BRACING

RANKING 2: RANKING 1 + MAT'L CONDITION

RANKING 3: RANKING 2 + ACCESS & SAFETY

TYPE 1 :- PROP SYSTEM/TRAD DECKING

TYPE 2 :- PROP SYSTEM/PROP DECKING

TYPE 3 :- ADJUST. PROPS/TRAD DECKING (A)

TYPE 4 :- TUBES/FITTINGS & TRAD DECKING

TYPE 5 :- ADJUST. PROPS/TRAD DECKING (B)

In testing the effects of the method of scoring, the number of cases include the secondary 'B' sites; these are regarded for the purpose of these exercises as separate cases and thus as adding to the size of the sample for statistical purposes. They are not included in the categorisation and subsequent comparisons with organisation for the reasons given in previous chapters and later in this chapter.

Upon inspection of the scoring mechanism and the apparent dominance of bracing errors in the cases (see also Chapter 8), it was necessary to identify the effects, if any, that the overall penalties for bracing had upon the overall score and ranking of a site. In other words, the 'robustness' of the scoring system with respect to bracing had to be determined.

The overall score and ranking method applicable to this study of quality and its relationship to organisation, is one based on the five main conditions: Head, base, jacks, verticals and bracing/tying-in. This method is referred to as Ranking No.1.

Ranking No.2 which combines the effects of material conditions and Ranking No.3 which adds further the conditions of access and safety are not relevant to comparisons of pure workmanship with organisation for the reasons expressed in Chapter 7. They are included for interest to practitioners and are addressed briefly later on.

Ranking No.1 had to be tested for robustness. The tests were based upon the Spearman formula for rank correlation:

$$R_{(rank)} = 1 - \frac{6 \Sigma D^2}{N (N^2-1)}$$

where D = difference between ranks of corresponding values of X and Y.

N = number of pairs of values (X,Y) in the data (typically 63 No.).

A value of R close to +1 indicates a high positive correlation and a high explained variation between two ranking methods.

Method 1: Here each condition is expected to contribute the same maximum negative penalty points of -100, eg. for case No.2, the Head condition has two sub-divisions of eccentricity with a score of -50 and fixity with a score of -80.

These two scores are combined to obtain a percentage of -65 and so on with the other conditions.

Finally the scores in the five conditions are summed and percentages calculated from a maximum negative score of 500. This gives a new percentage figure for all 63 cases and these are ranked in ascending order.

The new ranking compared with the original ranking No.1 gives a rank correlation coefficient of:

$$R_{(rank)} = 0.96.$$

This would indicate a very high correlation,ie. that the scoring system is robust.

Method 2: In this method the total penalty points of the Bracing condition only is reduced from -300 to -100, and a new set of 63 percentages is obtained and ranked in ascending order, and tested with the original Ranking No.1 method. The new ranking therefore reduces the weighting of bracing further than Method 1.

The rank correlation coefficient given by this method is:

$$R_{(rank)} = 0.97.$$

Again this would indicate a very high correlation and that the scoring system is robust and there is no undue weighting by bracing.

In view of the importance of bracing, the above may be disturbing in that some weighting is desirable. However this system of scoring already presents a number of sites with very high penalty scores without imposing more onerous requirements on bracing. It will be pointed out below that the system and method of ranking and categorisation of sites provides groups of sites with top sites with good standards of workmanship across the board and bottom sites with consistently bad standards of workmanship in every condition.

Ranking No.1 is adopted for the subsequent categorisation of cases later in this chapter.

The practice of ranking cases with respect to overall scores or individual scores or combinations of individual scores enables a number of comparisons to be made in addition to the findings presented in Chapter 8; and those related later to the categories of site.

Tables 1-7, may be used to make comparisons by inspection, graphically or statistically of correlations between types of error in individual conditions or combinations of conditions. Such comparisons are of limited use however and are far more valid if made between groups and categories of site.

Comparison and predictions of quality

Based upon the data in Tables 1-7,the effects of which show several methods of ranking, a number of comparisons may be made and are reported in Table 8.

Test No.	Description	$R_{(rank)}$
1	Ranking No.1 vs. Ranking with Bracing marked/100	0.97
2	Ranking No.1 vs. Ranking with all conditions/100	0.96
3	Ranking No.1 vs. Ranking excluding Bracing	0.86
4	Ranking No.1 vs. Ranking excluding Bracing and Jacks	0.76
5	Ranking exc. Bracing vs. Ranking excluding Bracing and Jacks	0.90
6	Ranking on Bracing only vs. Ranking excluding Bracing and Jacks	0.49
7	Ranking No.1 vs. Ranking on Bracing only	0.92

Table 8: Comparison of Ranking Methods

Tests numbers 1 and 2 have been discussed above, indicating that the scoring of bracing had no undue or unwarranted influence upon the main method of ranking sites.

Subsequent tests indicated that the inclusion of bracing as an error of workmanship had little correlation with other conditions.

Test number 7 in association with Test number 1 indicates that even with a reduced maximum penalty with respect to bracing, then bracing dominates the method of ranking. This is neither surprising nor undesirable since the findings reported in Chapter 8 confirmed the view that bracing is the most frequently occurring error in terms of incidence and magnitude. The scoring system should rank those sites with particular errors in bracing which coincide with other errors which cause instability. If one error is to be weighted it should be bracing since stability is crucial. Further weighting is not necessary since the scoring and ranking system depicts those sites where 'good' workmanship occurs in all conditions and where 'bad' workmanship occurs in all conditions which is a fundamental objective of the exercise to establish overall, relative standards of workmanship on a site. For the purposes of this study or further replication studies, it would have been possible to measure errors in bracing only, in order to predict the same quality categories.

A crucial point is that when comparing ranking based simply on the combined errors of workmanship due to head, base and vertical members with that of bracing, a very low correlation coefficient of 0.49 is obtained. Only 24% (the square of the rank correlation coefficient) of the relationship between scores of bracing and the main condition is explained. Bracing, therefore, could not be used by practitioners on site as a predictor of workmanship in other main conditions and vice-versa. Similar tests on individual conditions show little overall statistical correlation between the individual conditions.

Comparisons of ranking of the whole sample overlook the effect of the distribution of errors within a condition, for example the clusters of zero scores affect the calculation of the rank coefficient. The statistical calculation is a precise one as applied to imprecise relative scoring where a change in score of one percent can have a great effect on the ranking. It is more helpful to use graphs and inspection and address only the groups of sites in a particular category. The categories explained later were the top third, middle third and bottom third, approximately.
By inspection, slight changes in ranking methods or scoring have little effect upon the category of site. When categories are superimposed on the graphs, (see Figs.1 to 4), better correlations appear at the top and bottom end of the sample. For example, when looking at the apparent extreme diversity between ranking due to bracing versus that due to combined scores of head, base and verticals, the rank coefficient was only 0.49. If only the bottom third of the cases are compared the coefficient rises to 0.81; whilst an explained variation of 64% is not large it certainly indicates that on the poorest sites

workmanship is generally poor in all conditions. In the top third also there is a correlation between workmanship conditions. It is in the middle third where by inspection of ranking tables 1-8 and graphs, that there is the widest and almost random variation, which in a sense is to be expected. More importantly, inspection and analysis confirms that the scoring and ranking method number 1 achieves the main objectives of obtaining categories of site where the top sites exhibit general high standards of workmanship and the bottom sites exhibit consistently low standards of workmanship in all conditions. The categories are now discussed in more detail.

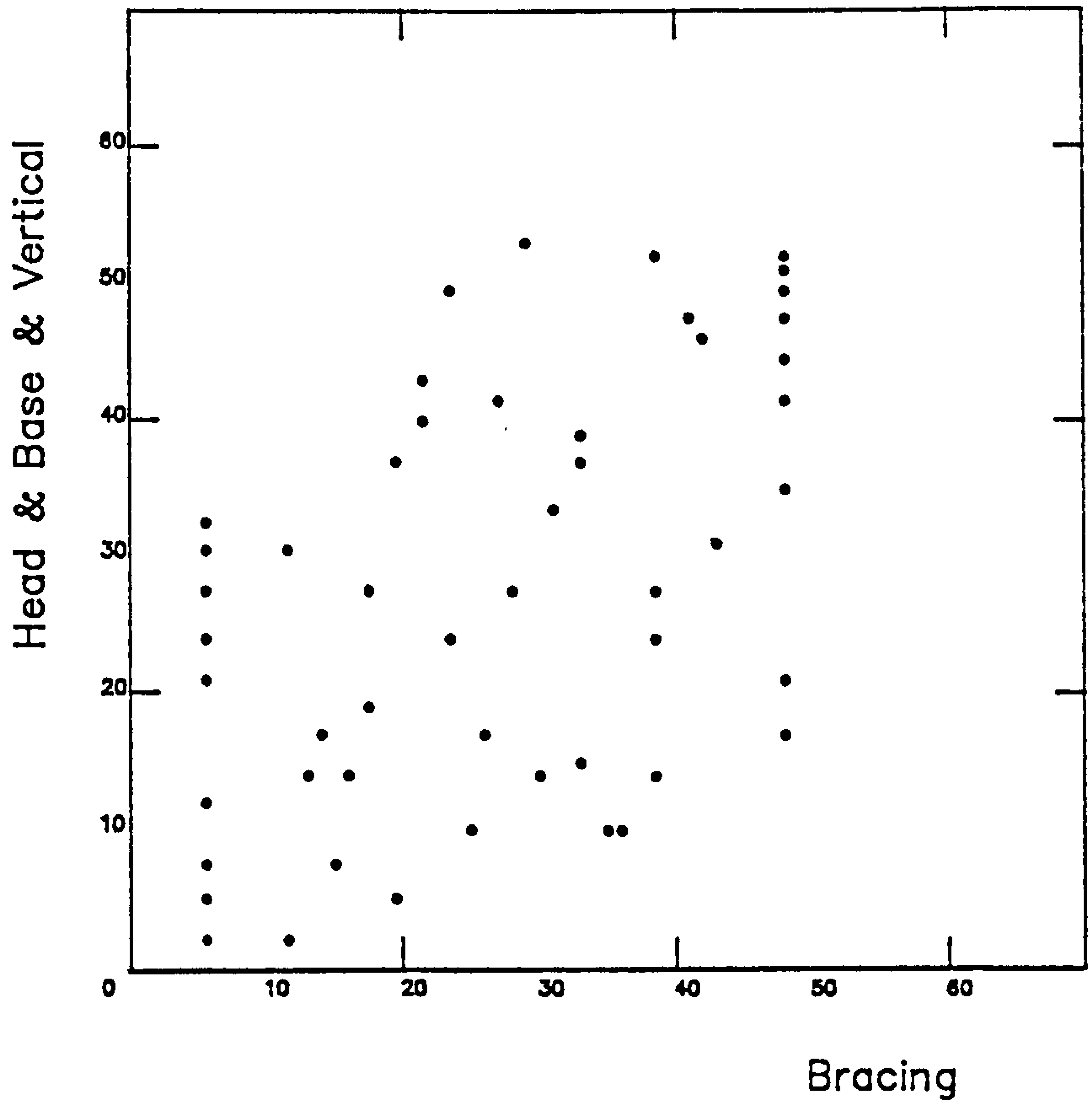

Fig.1 : Adjusted Ranking Bracing Only vs. Combined Head, Base and Vertical

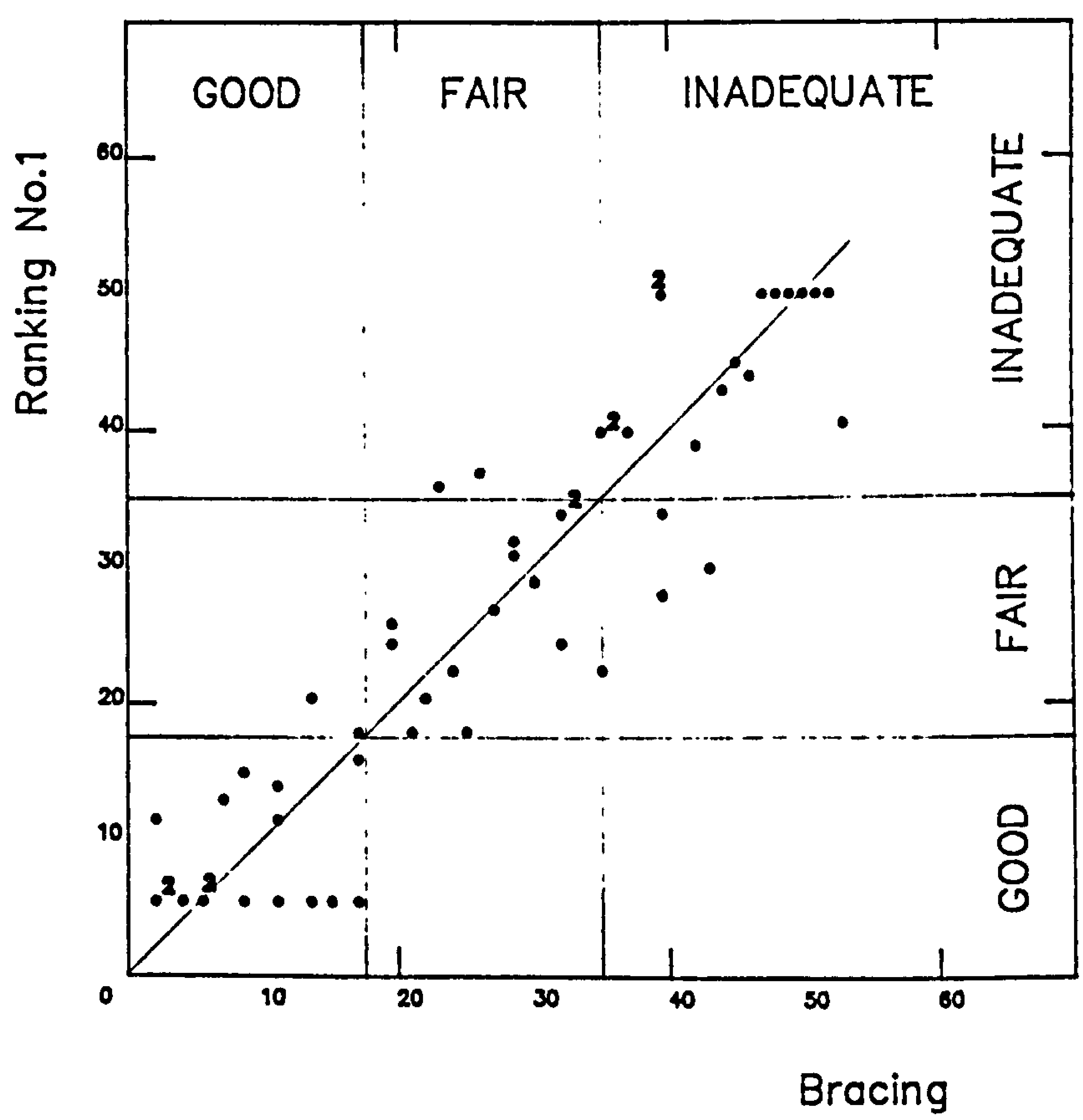

Fig.2 : Adjusted Ranking Bracing Only vs. Overall Total Ranking No.1

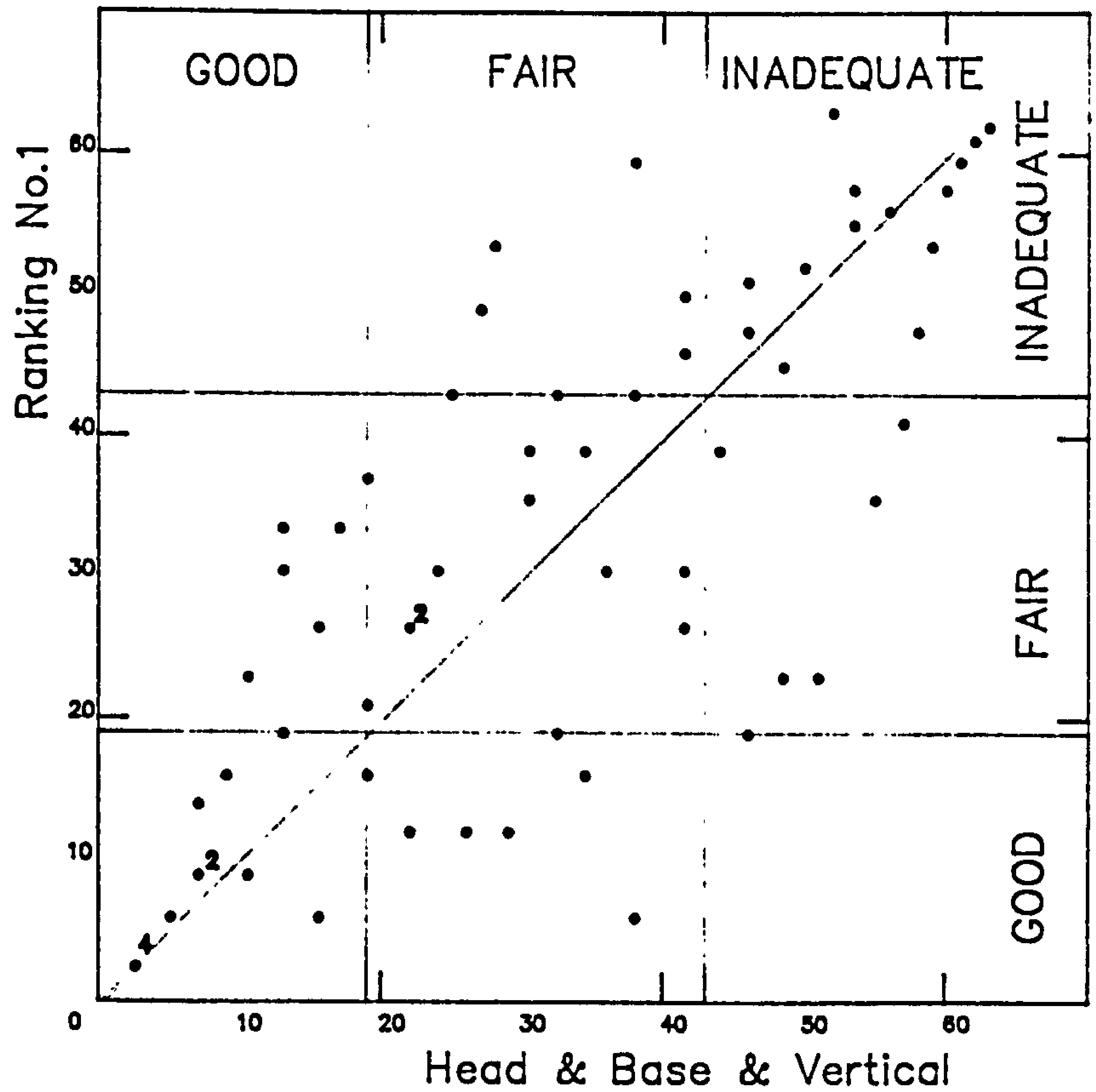

Fig.3 : Adjusted Ranking : Head, Base & Vertical Combined vs. Overall Total Ranking No.1

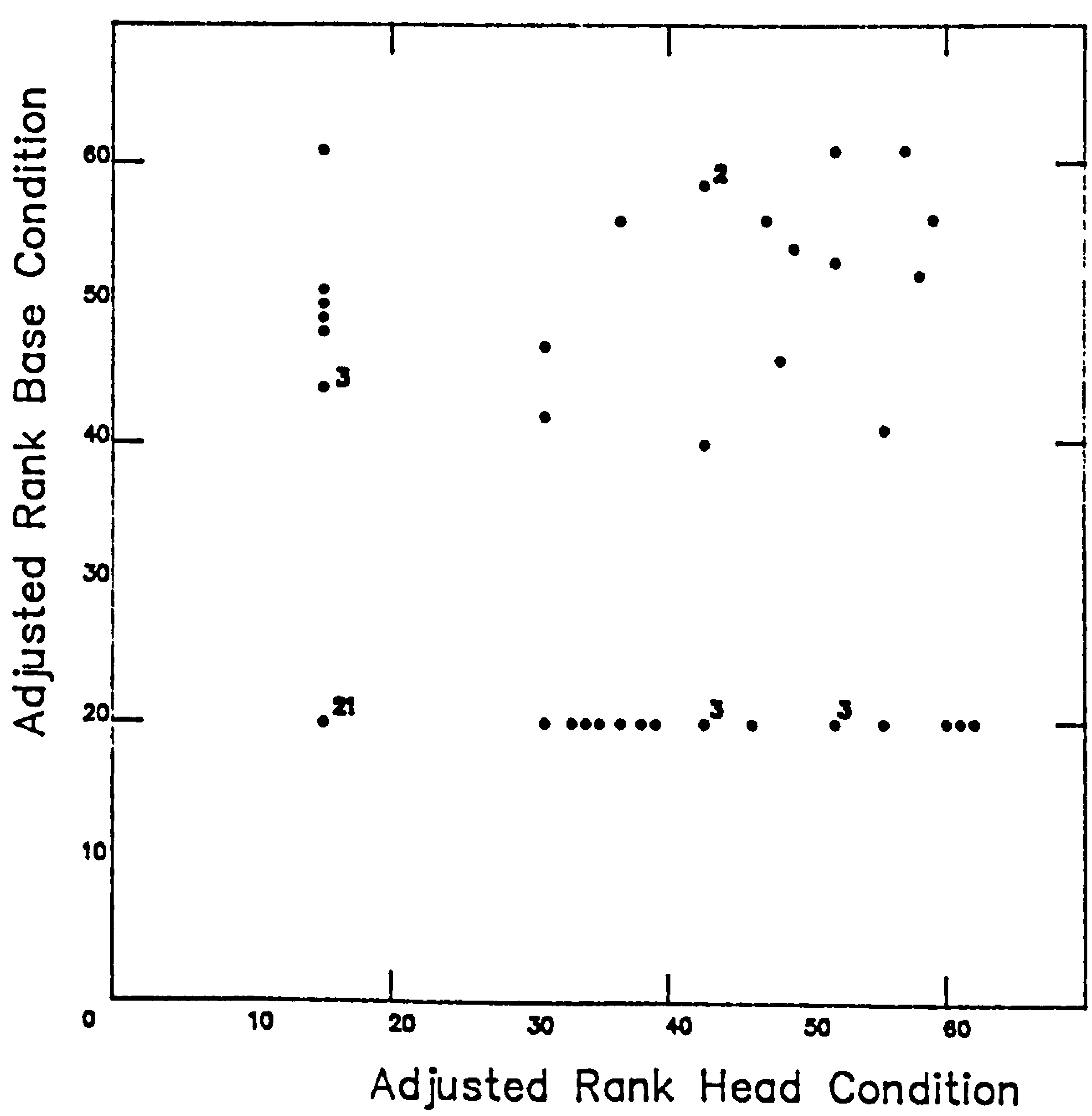

Fig.4 : Adjusted Ranking Head Condition vs. Adjusted Ranking Base Condition

Quality Categories

Having determined a satisfactory method of measuring quality of workmanship and comparing standards across the range of sample using Ranking No.1, it is now necessary to complete the main purpose of the exercise: to categorise sites to enable comparisons to be made with organisational variables and control strategies explored in part 3.

For the purposes of categorisation and subsequent organisational analysis, the secondary cases or 'B' sites are specifically excluded from the sample. These cases have already been described in Chapter 7 and the limited technical findings discussed in Chapter 8. These cases have been included in the analysis and testing of ranking and scoring since they represented an extra source of cases, and were treated as separate sites. They have always been regarded, however, as different types of structure from the main structure where comparisons are invalid.

It could be argued that these 'B' sites are part of the main sites and the overall quality score of workmanship on these mixed sites should be pooled. However such a pooling of results (though possible because the scoring system allows different systems and structures to be directly compared) is invalid or undesirable for the following reasons:

1) In a later chapter comparisons are made between systems and adjustable steel props. If categories were based on pooling the quality of the seven hybrid sites, then comparison of systems and props would then be impossible unless the analysis:

    a) ignores the hybrid sites in the comparison, severely reducing an already small sample, or

    b) re-scores and re-categorises based upon ignoring effects of 'B' cases, purely for this exercise, or

    c) ignores the contributions of the 'B' sites and categorises based upon main sites only.

2) The main reason for excluding them from the categorisation arises from the main purpose of the study; to relate organisational variables under site control to the attainment of quality. These 'B' sites have already been described as *ad hoc* structures, and being regarded organisationally and contractually as different types of structure. Design and construction can be performed by different organisations and at different times to the main falsework structure. In organisational terms these sites form somewhat of a 'rogue' element and it is not possible to compare organisational variables, which are uncertain in any case, between main and secondary cases.In organisational terms the secondary case is partly the same as the main case and partly quite distinct from it, and cannot form a separate unit or case study for the purposes of the main analysis.

Using the method of Ranking No.1 to rank 54 cases, they were then divided into quality categories with approximately an equal number in each. The two cut-off points were selected as those points where a 'natural break' occurred in the overall scorings, corresponding with the three more or less equal groups that were required. The fact that the lowest quality category comprises only 16 cases as opposed to 19 in the other two is unfortunate, but unavoidable given the distribution of scores. These quality categories, then, represent the dependent variable 'quality of falsework erection' with respect to which subsequent analysis in Part 3 is presented.

The top 19 or 'good' sites, incurred an overall penalty score less than 9%. The middle 19 or 'fair' sites, incurred an overall penalty score between 10% and 28%. The bottom 16 or 'inadequate' sites, incurred a (perhaps) disturbing overall score of up to 74%. It is important to stress that the use of the term 'inadequate' to designate the worst scoring category is not necessarily to suggest any absolute engineering criterion implying a high probability of structural failure (but certainly a higher probability than the 'good' category bearing in mind the findings of Chapter 7). The term 'poor' or 'low' for example, might equally have been used. The purpose was to establish comparative categories; and the labels are irrelevant. On pure academic grounds the labels are undesirable since they imply subjectivity; the labels do conform however, to the practice used by checkers in checking and recording errors on sites as 'good', 'fair' or 'inadequate'. Some of the practitioners would agree that the term 'good' is a reasonable one when bearing in mind an overall error score of less than 9%; others may point justifiably to individual errors in sites in the 'good' category being severe, for example see 'Bracing' below.

On balance the author prefers the convenient labelling of good, fair and inadequate and argues that many, if not all, of the cases in the 'inadequate' category are absolutely inadequate, as regards combination of errors and increased probability of failure. Again trades practice and practitioners may point to the fact that failures did not occur on these sites; but the probabilities of some failure must have been far higher than on the top sites. The categories enable certain comparisons to be made with respect to types of system, errors in various conditions, and an inspection of the effects of adjustments to scoring upon the categorisation and effects upon subsequent analyses. The categories are sufficiently broad and robust to cater for most adjustments. Tables 9-16 list the main sites and various rankings. The main categories are depicted and also shown on the master organisational matrix used in Part 3.

TABLE No 9: OVERALL PENALTY SCORES AND PENALTY SCORES IN INDIVIDUAL CONDITIONS.

MAIN SITES ONLY.

SITES RANKED WITH RESPECT TO FALSEWORK TYPE.

SITE NO.	TYPE NO.	RANKING 1 %	RANKING 2 %	RANKING 3 %	HEAD CONDITN	BASE CONDITN	JACK EXTENSN	VERTICAL MEMBER	BRACING
2	1	42	38	35	65	0	0	30	77
6	1	7	12	15	30	0	0	0	0
8	1	2	1	2	0	0	0	6	0
9	1	40	37	34	90	0	0	7	69
15	1	6	5	5	0	0	0	3	18
20	1	0	0	2	0	0	0	0	0
22	1	0	0	0	0	0	0	0	1
29	1	5	5	8	0	0	0	14	7
31	1	23	21	21	11	0	52	6	32
34	1	5	5	7	25	0	0	2	0
36	1	0	7	6	0	0	0	0	0
39	1	32	32	30	25	0	50	35	33
47	1	27	24	28	50	0	50	7	19
49	1	26	23	21	14	0	0	39	50
37	1	9	8	11	N/A	2	7	7	13
25	1	18	19	19	25	6	0	35	19
41	1	3	3	6	0	14	0	6	3
26	1	6	5	8	8	19	N/A	7	0
45	1	9	8	12	0	24	0	8	17
53	1	12	11	10	0	25	0	15	17
48	1	4	4	3	0	30	0	5	0
24	1	39	35	34	60	34	0	63	36
17	1	9	8	7	15	50	0	0	0
12	1	26	24	23	25	75	0	38	20
16	1	74	67	70	50	100	100	35	67
1	2	28	25	29	0	0	0	34	67
3	2	11	10	14	0	0	0	20	20
4	2	1	3	8	0	0	0	3	0
5	2	24	24	25	0	0	50	10	38
10	2	2	4	4	0	0	0	8	0
11	2	20	18	17	0	0	0	7	62
13	2	27	27	26	22	0	0	0	67
14	2	17	15	14	0	0	0	7	51
33	2	26	25	26	0	0	50	3	50
40	2	4	3	3	0	0	0	4	10
42	2	16	15	16	0	0	0	48	18
51	2	27	28	31	0	0	0	20	67
52	2	10	9	8	0	0	0	5	29
38	2	5	5	4	0	14	0	17	1
43	2	38	35	32	0	14	57	9	67
30	2	25	23	23	0	20	50	14	35
46	2	19	17	24	0	100	0	20	17
27	3	33	33	36	8	0	N/A	14	100
18	3	41	40	36	15	0	N/A	24	87
21	3	45	41	44	12	0	N/A	47	100
28	3	0	3	9	0	0	N/A	0	N/A
50	3	33	30	28	66	0	N/A	9	50
54	3	32	29	26	20	0	N/A	0	100
23	3	43	43	40	8	13	N/A	36	100
7	3	55	55	57	35	15	N/A	50	100
35	3	67	67	60	50	40	N/A	64	100
19	3	32	27	28	40	44	N/A	21	N/A
44	3	40	43	43	59	100	N/A	1	N/A
32	4	24	22	20	32	50	7	8	48

NOTES:-

RANKINGS 1,2 & 3 ARE RELATED TO THE PERCENTAGE PENALTIES SHOWN ON DRG No 2.

ALL OTHER COLUMNS ARE THE PERCENTAGE PENALTIES FOR EACH CONDITION

RANKING 1: HEAD CONDITION + BASE CONDITION + JACK EXTENSION + VERT. MEMBERS + BRACING

RANKING 2: RANKING 1 + MAT'L CONDITION

RANKING 3: RANKING 2 + ACCESS & SAFETY

TYPE 1 :- PROP SYSTEM/TRAD DECKING

TYPE 2 :- PROP SYSTEM/PROP DECKING

TYPE 3 :- ADJUST. PROPS/TRAD DECKING (A)

TYPE 4 :- TUBES/FITTINGS & TRAD DECKING

TYPE 5 :- ADJUST. PROPS/TRAD DECKING (B)

TABLE No 10: OVERALL PENALTY SCORES AND PENALTY SCORES IN INDIVIDUAL CONDITIONS.

MAIN SITES ONLY.

SITES RANKED WITH RESPECT TO OVERALL RANKING No 1 SCORE. - AND CATEGORISED.

SITE NO.	TYPE NO.	RANKING 1 %	RANKING 2 %	RANKING 3 %	HEAD CONDITN	BASE CONDITN	JACK EXTENSN	VERTICAL MEMBER	BRACING	
20	1	0	0	2	0	0	0	0	0	
22	1	0	0	0	0	0	0	0	1	
36	1	0	7	6	0	0	0	0	0	
28	3	0	3	9	0	0	N/A	0	N/A	
4	2	1	3	8	0	0	0	3	0	
8	1	2	1	2	0	0	0	6	0	
10	2	2	4	4	0	0	0	8	0	
41	1	3	3	6	0	14	0	6	3	G
48	1	4	4	3	0	30	0	5	0	O
40	2	4	3	3	0	0	0	4	10	O
29	1	5	5	8	0	0	0	14	7	D
34	1	5	5	7	25	0	0	2	0	
38	2	5	5	4	0	14	0	17	1	
15	1	6	5	5	0	0	0	3	18	
26	1	6	5	8	8	19	N/A	7	0	
6	1	7	12	15	30	0	0	0	0	
37	1	9	8	11	N/A	2	7	7	13	
45	1	9	8	12	0	24	0	8	17	
17	1	9	8	7	15	50	0	0	0	
52	2	10	9	8	0	0	0	5	29	
3	2	11	10	14	0	0	0	20	20	
53	1	12	11	10	0	25	0	15	17	
42	2	16	15	16	0	0	0	48	18	
14	2	17	15	14	0	0	0	7	51	
25	1	18	19	19	25	6	0	35	19	
46	2	19	17	24	0	100	0	20	17	
11	2	20	18	17	0	0	0	7	62	F
31	1	23	21	21	11	0	52	6	32	A
5	2	24	24	25	0	0	50	10	38	I
32	4	24	22	20	32	50	7	8	48	R
30	2	25	23	23	0	20	50	14	35	
49	1	26	23	21	14	0	0	39	50	
12	1	26	24	23	25	75	0	38	20	
33	2	26	25	26	0	0	50	3	50	
47	1	27	24	28	50	0	50	7	19	
13	2	27	27	26	22	0	0	0	67	
51	2	27	28	31	0	0	0	20	67	
1	2	28	25	29	0	0	0	34	67	
39	1	32	32	30	25	0	50	35	33	
54	3	32	29	26	20	0	N/A	0	100	
19	3	32	27	28	40	44	N/A	21	N/A	
27	3	33	33	36	8	0	N/A	14	100	I
50	3	33	30	28	66	0	N/A	9	50	N
43	2	38	35	32	0	14	57	9	67	A
24	1	39	35	34	60	34	0	63	36	D
9	1	40	37	34	90	0	0	7	69	E
44	3	40	43	43	59	100	N/A	1	N/A	Q
18	3	41	40	36	15	0	N/A	24	87	U
2	1	42	38	35	65	0	0	30	77	A
23	3	43	43	40	8	13	N/A	36	100	T
21	3	45	41	44	12	0	N/A	47	100	E
7	3	55	55	57	35	15	N/A	50	100	
35	3	67	67	60	50	40	N/A	64	100	
16	1	74	67	70	50	100	100	35	67	

NOTES:-

RANKINGS 1,2 & 3 ARE RELATED TO THE PERCENTAGE PENALTIES SHOWN ON DRG No 2.

ALL OTHER COLUMNS ARE THE PERCENTAGE PENALTIES FOR EACH CONDITION

RANKING 1: HEAD CONDITION + BASE CONDITION + JACK EXTENSION + VERT. MEMBERS + BRACING

RANKING 2: RANKING 1 + MAT'L CONDITION

RANKING 3: RANKING 2 + ACCESS & SAFETY

TYPE 1 :- PROP SYSTEM/TRAD DECKING

TYPE 2 :- PROP SYSTEM/PROP DECKING

TYPE 3 :- ADJUST. PROPS/TRAD DECKING (A)

TYPE 4 :- TUBES/FITTINGS & TRAD DECKING

TYPE 5 :- ADJUST. PROPS/TRAD DECKING (B)

TABLE No. 11:OVERALL PENALTY SCORES AND PENALTY SCORES ININDIVIDUAL CONDITIONS.

MAIN SITES ONLY.

SITES RANKED WITH RESPECT TO HEAD CONDITION PENALTY SCORES.

SITE NO.	TYPE NO.	RANKING 1 %	RANKING 2 %	RANKING 3 %	HEAD CONDITN	BASE CONDITN	JACK EXTENSN	VERTICAL MEMBER	BRACING
20	1	0	0	2	0	0	0	0	0
22	1	0	0	0	0	0	0	0	1
36	1	0	7	6	0	0	0	0	0
28	3	0	3	9	0	0	N/A	0	N/A
4	2	1	3	8	0	0	0	3	0
8	1	2	1	2	0	0	0	6	0
10	2	2	4	4	0	0	0	8	0
41	1	3	3	6	0	14	0	6	3
48	1	4	4	3	0	30	0	5	0
40	2	4	3	3	0	0	0	4	10
29	1	5	5	8	0	0	0	14	7
38	2	5	5	4	0	14	0	17	1
15	1	6	5	5	0	0	0	3	18
45	1	9	8	12	0	24	0	8	17
52	2	10	9	8	0	0	0	5	29
3	2	11	10	14	0	0	0	20	20
53	1	12	11	10	0	25	0	15	17
42	2	16	15	16	0	0	0	48	18
14	2	17	15	14	0	0	0	7	51
46	2	19	17	24	0	100	0	20	17
11	2	20	18	17	0	0	0	7	62
5	2	24	24	25	0	0	50	10	38
30	2	25	23	23	0	20	50	14	35
33	2	26	25	26	0	0	50	3	50
51	2	27	28	31	0	0	0	20	67
1	2	28	25	29	0	0	0	34	67
43	2	38	35	32	0	14	57	9	67
26	1	6	5	8	8	19	N/A	7	0
27	3	33	33	36	8	0	N/A	14	100
23	3	43	43	40	8	13	N/A	36	100
31	1	23	21	21	11	0	52	6	32
21	3	45	41	44	12	0	N/A	47	100
49	1	26	23	21	14	0	0	39	50
17	1	9	8	7	15	50	0	0	0
18	3	41	40	36	15	0	N/A	24	87
54	3	32	29	26	20	0	N/A	0	100
13	2	27	27	26	22	0	0	0	67
34	1	5	5	7	25	0	0	2	0
25	1	18	19	19	25	6	0	35	19
12	1	26	24	23	25	75	0	38	20
39	1	32	32	30	25	0	50	35	33
6	1	7	12	15	30	0	0	0	0
32	4	24	22	20	32	50	7	8	48
7	3	55	55	57	35	15	N/A	50	100
19	3	32	27	28	40	44	N/A	21	N/A
47	1	27	24	28	50	0	50	7	19
35	3	67	67	60	50	40	N/A	64	100
16	1	74	67	70	50	100	100	35	67
44	3	40	43	43	59	100	N/A	1	N/A
24	1	39	35	34	60	34	0	63	36
2	1	42	38	35	65	0	0	30	77
50	3	33	30	28	66	0	N/A	9	50
9	1	40	37	34	90	0	0	7	69
37	1	9	8	11	N/A	2	7	7	13

NOTES:-

RANKINGS 1,2 & 3 ARE RELATED TO THE PERCENTAGE PENALTIES SHOWN ON DRG No 2.

ALL OTHER COLUMNS ARE THE PERCENTAGE PENALTIES FOR EACH CONDITION

RANKING 1: HEAD CONDITION + BASE CONDITION + JACK EXTENSION + VERT. MEMBERS + BRACING

RANKING 2: RANKING 1 + MAT'L CONDITION

RANKING 3: RANKING 2 + ACCESS & SAFETY

TYPE 1 :- PROP SYSTEM/TRAD DECKING

TYPE 2 :- PROP SYSTEM/PROP DECKING

TYPE 3 :- ADJUST. PROPS/TRAD DECKING (A)

TYPE 4 :- TUBES/FITTINGS & TRAD DECKING

TYPE 5 :- ADJUST. PROPS/TRAD DECKING (B)

TABLE No 12: OVERALL PENALTY SCORES AND PENALTY SCORES IN INDIVIDUAL CONDITIONS.

MAIN SITES ONLY.

SITES RANKED WITH RESPECT TO BASE CONDITION PENALTY SCORES.

SITE NO.	TYPE NO.	RANKING 1 %	RANKING 2 %	RANKING 3 %	HEAD CONDITN	BASE CONDITN	JACK EXTENSN	VERTICAL MEMBER	BRACING
20	1	0	0	2	0	0	0	0	0
22	1	0	0	0	0	0	0	0	1
36	1	0	7	6	0	0	0	0	0
28	3	0	3	9	0	0	N/A	0	N/A
4	2	1	3	8	0	0	0	3	0
8	1	2	1	2	0	0	0	6	0
10	2	2	4	4	0	0	0	8	0
40	2	4	3	3	0	0	0	4	10
29	1	5	5	8	0	0	0	14	7
15	1	6	5	5	0	0	0	3	18
52	2	10	9	8	0	0	0	5	29
3	2	11	10	14	0	0	0	20	20
42	2	16	15	16	0	0	0	48	18
14	2	17	15	14	0	0	0	7	51
11	2	20	18	17	0	0	0	7	62
5	2	24	24	25	0	0	50	10	38
33	2	26	25	26	0	0	50	3	50
51	2	27	28	31	0	0	0	20	67
1	2	28	25	29	0	0	0	34	67
27	3	33	33	36	8	0	N/A	14	100
31	1	23	21	21	11	0	52	6	32
21	3	45	41	44	12	0	N/A	47	100
49	1	26	23	21	14	0	0	39	50
18	3	41	40	36	15	0	N/A	24	87
54	3	32	29	26	20	0	N/A	0	100
13	2	27	27	26	22	0	0	0	67
34	1	5	5	7	25	0	0	2	0
39	1	32	32	30	25	0	50	35	33
6	1	7	12	15	30	0	0	0	0
47	1	27	24	28	50	0	50	7	19
2	1	42	38	35	65	0	0	30	77
50	3	33	30	28	66	0	N/A	9	50
9	1	40	37	34	90	0	0	7	69
37	1	9	8	11	N/A	2	7	7	13
25	1	18	19	19	25	6	0	35	19
23	3	43	43	40	8	13	N/A	36	100
41	1	3	3	6	0	14	0	6	3
38	2	5	5	4	0	14	0	17	1
43	2	38	35	32	0	14	57	9	67
7	3	55	55	57	35	15	N/A	50	100
26	1	6	5	8	8	19	N/A	7	0
30	2	25	23	23	0	20	50	14	35
45	1	9	8	12	0	24	0	8	17
53	1	12	11	10	0	25	0	15	17
48	1	4	4	3	0	30	0	5	0
24	1	39	35	34	60	34	0	63	36
35	3	67	67	60	50	40	N/A	64	100
19	3	32	27	28	40	44	N/A	21	N/A
17	1	9	8	7	15	50	0	0	0
32	4	24	22	20	32	50	7	8	48
12	1	26	24	23	25	75	0	38	20
46	2	19	17	24	0	100	0	20	17
16	1	74	67	70	50	100	100	35	67
44	3	40	43	43	59	100	N/A	1	N/A

NOTES:-

RANKINGS 1,2 & 3 ARE RELATED TO THE PERCENTAGE PENALTIES SHOWN ON DRG No 2.

ALL OTHER COLUMNS ARE THE PERCENTAGE PENALTIES FOR EACH CONDITION

RANKING 1: HEAD CONDITION + BASE CONDITION + JACK EXTENSION + VERT. MEMBERS + BRACING

RANKING 2: RANKING 1 + MAT'L CONDITION

RANKING 3: RANKING 2 + ACCESS & SAFETY

TYPE 1 :- PROP SYSTEM/TRAD DECKING

TYPE 2 :- PROP SYSTEM/PROP DECKING

TYPE 3 :- ADJUST. PROPS/TRAD DECKING (A)

TYPE 4 :- TUBES/FITTINGS & TRAD DECKING

TYPE 5 :- ADJUST. PROPS/TRAD DECKING (B)

TABLE No 13: OVERALL PENALTY SCORES AND PENALTY SCORES IN INDIVIDUAL CONDITIONS.

MAIN SITES ONLY.

SITES RANKED WITH RESPECT TO JACK EXTENSION PENALTY SCORES.

SITE NO.	TYPE NO.	RANKING 1 %	RANKING 2 %	RANKING 3 %	HEAD CONDITN	BASE CONDITN	JACK EXTENSN	VERTICAL MEMBER	BRACING
20	1	0	0	2	0	0	0	0	0
22	1	0	0	0	0	0	0	0	1
36	1	0	7	6	0	0	0	0	0
4	2	1	3	8	0	0	0	3	0
8	1	2	1	2	0	0	0	6	0
10	2	2	4	4	0	0	0	8	0
40	2	4	3	3	0	0	0	4	10
29	1	5	5	8	0	0	0	14	7
15	1	6	5	5	0	0	0	3	18
52	2	10	9	8	0	0	0	5	29
3	2	11	10	14	0	0	0	20	20
42	2	16	15	16	0	0	0	48	18
14	2	17	15	14	0	0	0	7	51
11	2	20	18	17	0	0	0	7	62
51	2	27	28	31	0	0	0	20	67
1	2	28	25	29	0	0	0	34	67
49	1	26	23	21	14	0	0	39	50
13	2	27	27	26	22	0	0	0	67
34	1	5	5	7	25	0	0	2	0
6	1	7	12	15	30	0	0	0	0
2	1	42	38	35	65	0	0	30	77
9	1	40	37	34	90	0	0	7	69
25	1	18	19	19	25	6	0	35	19
41	1	3	3	6	0	14	0	6	3
38	2	5	5	4	0	14	0	17	1
45	1	9	8	12	0	24	0	8	17
53	1	12	11	10	0	25	0	15	17
48	1	4	4	3	0	30	0	5	0
24	1	39	35	34	60	34	0	63	36
17	1	9	8	7	15	50	0	0	0
12	1	26	24	23	25	75	0	38	20
46	2	19	17	24	0	100	0	20	17
37	1	9	8	11	N/A	2	7	7	13
32	4	24	22	20	32	50	7	8	48
5	2	24	24	25	0	0	50	10	38
33	2	26	25	26	0	0	50	3	50
39	1	32	32	30	25	0	50	35	33
47	1	27	24	28	50	0	50	7	19
30	2	25	23	23	0	20	50	14	35
31	1	23	21	21	11	0	52	6	32
43	2	38	35	32	0	14	57	9	67
16	1	74	67	70	50	100	100	35	67
28	3	0	3	9	0	0	N/A	0	N/A
27	3	33	33	36	8	0	N/A	14	100
21	3	45	41	44	12	0	N/A	47	100
18	3	41	40	36	15	0	N/A	24	87
54	3	32	29	26	20	0	N/A	0	100
50	3	33	30	28	66	0	N/A	9	50
23	3	43	43	40	8	13	N/A	36	100
7	3	55	55	57	35	15	N/A	50	100
26	1	6	5	8	8	19	N/A	7	0
35	3	67	67	60	50	40	N/A	64	100
19	3	32	27	28	40	44	N/A	21	N/A
44	3	40	43	43	59	100	N/A	1	N/A

NOTES:-

RANKINGS 1,2 & 3 ARE RELATED TO THE PERCENTAGE PENALTIES SHOWN ON DRG No 2.

ALL OTHER COLUMNS ARE THE PERCENTAGE PENALTIES FOR EACH CONDITION

RANKING 1: HEAD CONDITION + BASE CONDITION + JACK EXTENSION + VERT. MEMBERS + BRACING

RANKING 2: RANKING 1 + MAT'L CONDITION

RANKING 3: RANKING 2 + ACCESS & SAFETY

TYPE 1 :- PROP SYSTEM/TRAD DECKING

TYPE 2 :- PROP SYSTEM/PROP DECKING

TYPE 3 :- ADJUST. PROPS/TRAD DECKING (A)

TYPE 4 :- TUBES/FITTINGS & TRAD DECKING

TYPE 5 :- ADJUST. PROPS/TRAD DECKING (B)

TABLE No 14: OVERALL PENALTY SCORES AND PENALTY SCORES IN INDIVIDUAL CONDITIONS.

MAIN SITES ONLY.

SITES RANKED WITH RESPECT TO VERTICAL MEMBERS PENALTY SCORES.

SITE NO.	TYPE NO.	RANKING 1 %	RANKING 2 %	RANKING 3 %	HEAD CONDITN	BASE CONDITN	JACK EXTENSN	VERTICAL MEMBER	BRACING
20	1	0	0	2	0	0	0	0	0
22	1	0	0	0	0	0	0	0	1
36	1	0	7	6	0	0	0	0	0
13	2	27	27	26	22	0	0	0	67
6	1	7	12	15	30	0	0	0	0
17	1	9	8	7	15	50	0	0	0
28	3	0	3	9	0	0	N/A	0	N/A
54	3	32	29	26	20	0	N/A	0	100
44	3	40	43	43	59	100	N/A	1	N/A
34	1	5	5	7	25	0	0	2	0
4	2	1	3	8	0	0	0	3	0
15	1	6	5	5	0	0	0	3	18
33	2	26	25	26	0	0	50	3	50
40	2	4	3	3	0	0	0	4	10
52	2	10	9	8	0	0	0	5	29
48	1	4	4	3	0	30	0	5	0
8	1	2	1	2	0	0	0	6	0
41	1	3	3	6	0	14	0	6	3
31	1	23	21	21	11	0	52	6	32
14	2	17	15	14	0	0	0	7	51
11	2	20	18	17	0	0	0	7	62
9	1	40	37	34	90	0	0	7	69
37	1	9	8	11	N/A	2	7	7	13
47	1	27	24	28	50	0	50	7	19
26	1	6	5	8	8	19	N/A	7	0
10	2	2	4	4	0	0	0	8	0
45	1	9	8	12	0	24	0	8	17
32	4	24	22	20	32	50	7	8	48
43	2	38	35	32	0	14	57	9	67
50	3	33	30	28	66	0	N/A	9	50
5	2	24	24	25	0	0	50	10	38
29	1	5	5	8	0	0	0	14	7
30	2	25	23	23	0	20	50	14	35
27	3	33	33	36	8	0	N/A	14	100
53	1	12	11	10	0	25	0	15	17
38	2	5	5	4	0	14	0	17	1
3	2	11	10	14	0	0	0	20	20
51	2	27	28	31	0	0	0	20	67
46	2	19	17	24	0	100	0	20	17
19	3	32	27	28	40	44	N/A	21	N/A
18	3	41	40	36	15	0	N/A	24	87
2	1	42	38	35	65	0	0	30	77
1	2	28	25	29	0	0	0	34	67
25	1	18	19	19	25	6	0	35	19
39	1	32	32	30	25	0	50	35	33
16	1	74	67	70	50	100	100	35	67
23	3	43	43	40	8	13	N/A	36	100
12	1	26	24	23	25	75	0	38	20
49	1	26	23	21	14	0	0	39	50
21	3	45	41	44	12	0	N/A	47	100
42	2	16	15	16	0	0	0	48	18
7	3	55	55	57	35	15	N/A	50	100
24	1	39	35	34	60	34	0	63	36
35	3	67	67	60	50	40	N/A	64	100

NOTES:-

RANKINGS 1,2 & 3 ARE RELATED TO THE PERCENTAGE PENALTIES SHOWN ON DRG No 2.

ALL OTHER COLUMNS ARE THE PERCENTAGE PENALTIES FOR EACH CONDITION

RANKING 1: HEAD CONDITION + BASE CONDITION + JACK EXTENSION + VERT. MEMBERS + BRACING

RANKING 2: RANKING 1 + MAT'L CONDITION

RANKING 3: RANKING 2 + ACCESS & SAFETY

TYPE 1 :- PROP SYSTEM/TRAD DECKING

TYPE 2 :- PROP SYSTEM/PROP DECKING

TYPE 3 :- ADJUST. PROPS/TRAD DECKING (A)

TYPE 4 :- TUBES/FITTINGS & TRAD DECKING

TYPE 5 :- ADJUST. PROPS/TRAD DECKING (B)

TABLE No 15: OVERALL PENALTY SCORES AND PENALTY SCORES IN INDIVIDUAL CONDITIONS.

MAIN SITES ONLY.

SITES RANKED WITH RESPECT TO BRACING PENALTY SCORES.

SITE NO.	TYPE NO.	RANKING 1 %	RANKING 2 %	RANKING 3 %	HEAD CONDITN	BASE CONDITN	JACK EXTENSN	VERTICAL MEMBER	BRACING
20	1	0	0	2	0	0	0	0	0
36	1	0	7	6	0	0	0	0	0
6	1	7	12	15	30	0	0	0	0
17	1	9	8	7	15	50	0	0	0
34	1	5	5	7	25	0	0	2	0
4	2	1	3	8	0	0	0	3	0
48	1	4	4	3	0	30	0	5	0
8	1	2	1	2	0	0	0	6	0
26	1	6	5	8	8	19	N/A	7	0
10	2	2	4	4	0	0	0	8	0
22	1	0	0	0	0	0	0	0	1
38	2	5	5	4	0	14	0	17	1
41	1	3	3	6	0	14	0	6	3
29	1	5	5	8	0	0	0	14	7
40	2	4	3	3	0	0	0	4	10
37	1	9	8	11	N/A	2	7	7	13
45	1	9	8	12	0	24	0	8	17
53	1	12	11	10	0	25	0	15	17
46	2	19	17	24	0	100	0	20	17
15	1	6	5	5	0	0	0	3	18
42	2	16	15	16	0	0	0	48	18
47	1	27	24	28	50	0	50	7	19
25	1	18	19	19	25	6	0	35	19
3	2	11	10	14	0	0	0	20	20
12	1	26	24	23	25	75	0	38	20
52	2	10	9	8	0	0	0	5	29
31	1	23	21	21	11	0	52	6	32
39	1	32	32	30	25	0	50	35	33
30	2	25	23	23	0	20	50	14	35
24	1	39	35	34	60	34	0	63	36
5	2	24	24	25	0	0	50	10	38
32	4	24	22	20	32	50	7	8	48
33	2	26	25	26	0	0	50	3	50
50	3	33	30	28	66	0	N/A	9	50
49	1	26	23	21	14	0	0	39	50
14	2	17	15	14	0	0	0	7	51
11	2	20	18	17	0	0	0	7	62
13	2	27	27	26	22	0	0	0	67
43	2	38	35	32	0	14	57	9	67
51	2	27	28	31	0	0	0	20	67
1	2	28	25	29	0	0	0	34	67
16	1	74	67	70	50	100	100	35	67
9	1	40	37	34	90	0	0	7	69
2	1	42	38	35	65	0	0	30	77
18	3	41	40	36	15	0	N/A	24	87
54	3	32	29	26	20	0	N/A	0	100
27	3	33	33	36	8	0	N/A	14	100
23	3	43	43	40	8	13	N/A	36	100
21	3	45	41	44	12	0	N/A	47	100
7	3	55	55	57	35	15	N/A	50	100
35	3	67	67	60	50	40	N/A	64	100
28	3	0	3	9	0	0	N/A	0	N/A
44	3	40	43	43	59	100	N/A	1	N/A
19	3	32	27	28	40	44	N/A	21	N/A

NOTES:-

RANKINGS 1,2 & 3 ARE RELATED TO THE PERCENTAGE PENALTIES SHOWN ON DRG No 2.

ALL OTHER COLUMNS ARE THE PERCENTAGE PENALTIES FOR EACH CONDITION

RANKING 1: HEAD CONDITION + BASE CONDITION + JACK EXTENSION + VERT. MEMBERS + BRACING

RANKING 2: RANKING 1 + MAT'L CONDITION

RANKING 3: RANKING 2 + ACCESS & SAFETY

TYPE 1 :- PROP SYSTEM/TRAD DECKING

TYPE 2 :- PROP SYSTEM/PROP DECKING

TYPE 3 :- ADJUST. PROPS/TRAD DECKING (A)

TYPE 4 :- TUBES/FITTINGS & TRAD DECKING

TYPE 5 :- ADJUST. PROPS/TRAD DECKING (B)

TABLE No 16: OVERALL PENALTY SCORES AND PENALTY SCORES IN INDIVIDUAL CONDITIONS

MAIN SITES ONLY

SITES RANKED WITH RESPECT TO OVERALL RANKING No 4 SCORE.

SITE NO.	TYPE NO.	RANKING 1 %	RANKING 2 %	RANKING 3 %	RANKING 4 %	HEAD CONDITN	BASE CONDITN	JACK EXTENSN	VERTICAL MEMBER	BRACIN
20	1	0	0	2	0	0	0	0	0	
22	1	0	0	0	0	0	0	0	0	
36	1	0	7	6	0	0	0	0	0	
28	3	0	3	9	0	0	0	N/A	0	N/
4	2	1	3	8	1	0	0	0	3	
8	1	2	1	2	2	0	0	0	6	
10	2	2	4	4	2	0	0	0	8	
41	1	3	3	6	3	0	14	0	6	
48	1	4	4	3	4	0	30	0	5	
29	1	5	5	8	5	0	0	0	14	
34	1	5	5	7	5	25	0	0	2	
40	2	4	3	3	5	0	0	0	4	1
26	1	6	5	8	6	8	19	N/A	7	
6	1	7	12	15	7	30	0	0	0	
38	2	5	5	4	7	0	14	0	17	
37	1	9	8	11	9	N/A	2	7	7	1
45	1	9	8	12	9	0	24	0	8	1
17	1	9	8	7	9	15	50	0	0	
53	1	12	11	10	12	0	25	0	15	1
52	2	10	9	8	12	0	0	0	5	2
3	2	11	10	14	14	0	0	0	20	2
25	1	18	19	19	18	25	6	0	35	[illegible]
14	2	17	15	14	21	0	0	0	7	[illegible]
42	2	16	15	16	21	0	0	0	48	1
31	1	23	21	21	23	11	0	52	6	[illegible]
46	2	19	17	24	24	0	100	0	20	1
32	4	24	22	20	24	32	50	7	8	[illegible]
11	2	20	18	17	25	0	0	0	7	[illegible]
15	1	6	5	5	26	0	0	0	3	[illegible]
49	1	26	23	21	26	14	0	0	39	[illegible]
12	1	26	24	23	26	25	75	0	38	[illegible]
47	1	27	24	28	27	50	0	50	7	1
5	2	24	24	25	29	0	0	50	10	[illegible]
13	2	27	27	26	29	22	0	0	0	[illegible]
39	1	32	32	30	32	25	0	50	35	[illegible]
33	2	26	25	26	32	0	0	50	3	[illegible]
30	2	25	23	23	32	0	20	50	14	[illegible]
54	3	32	29	26	32	20	0	N/A	0	1[illegible]
19	3	32	27	28	32	40	44	N/A	21	N/
27	3	33	33	36	33	8	0	N/A	14	1[illegible]
50	3	33	30	28	33	66	0	N/A	9	[illegible]
51	2	27	28	31	34	0	0	0	20	[illegible]
1	2	28	25	29	35	0	0	0	34	[illegible]
24	1	39	35	34	39	60	34	0	63	[illegible]
9	1	40	37	34	40	90	0	0	7	[illegible]
44	3	40	43	43	40	59	100	N/A	1	N/
18	3	41	40	36	41	15	0	N/A	24	[illegible]
2	1	42	38	35	42	65	0	0	30	[illegible]
23	3	43	43	40	43	8	13	N/A	36	1[illegible]
21	3	45	41	44	45	12	0	N/A	47	1[illegible]
43	2	38	35	32	49	0	14	57	9	[illegible]
7	3	55	55	57	55	35	15	N/A	50	1[illegible]
35	3	67	67	60	67	50	40	N/A	64	1[illegible]
16	1	74	67	70	74	50	100	100	35	[illegible]

NOTES:-

RANKINGS 1,2 & 3 ARE RELATED TO THE PERCENTAGE PENALTIES SHOWN ON DRG No 2.

ALL OTHER COLUMNS ARE THE PERCENTAGE PENALTIES FOR EACH CONDITION

RANKING 1: HEAD CONDITION +

TYPE 1 :- PROP SYSTEM/TRAD DECKING

TYPE 2 :- PROP SYSTEM/PROP DECKING

TYPE 3 :- ADJUST. PROPS/TRAD DECKING (A)

TYPE 4 :- TUBES/FITTINGS & TRAD DECKING

TYPE 5 :- ADJUST. PROPS/TRAD DECKING (B)

Inspection of the tables reveals for example that the overall quality determined using ranking No.2 (including materials) and using ranking No.3 (including materials and access and safety) has negligible effects upon the categorisation of the sites. Although it was argued that these methods of scoring were not strictly appropriate to the subsequent study, their inclusion would have made no difference. The column entitled ranking No.4 is also included in Table 16; this method of scoring and ranking ignores the workmanship at the head condition in Type 2 systems. This has the effect of increasing the overall scores of Type 2 systems in ranking No.1 by 25%. However in terms of categorisation there is negligible effect, case Number 1 moving from the bottom of the 'fair' category to the 'inadequate' category. Many of the conclusions suggested earlier in this chapter are supported when categories are superimposed on the analysis.

Inspection of the columns regarding individual conditions also confirms the tentative conclusions of Chapter 8 that bad workmanship is encountered uniformly in the worst sites.

Typification of the three Quality Categories

The following descriptions highlight typical features that characterise the quality of workmanship expected on each category of site. Reference is made to drawing number 2 and Table number 10. These descriptions are included to provide a broad indication of the quality standards that are implied by the terms 'good', 'fair' and 'inadequate'. They lend support to the tentative conclusions of Chapter 8 and the correlations of bad workmanship suggested in this chapter.

'Good' quality sites

Five cases had some form of bracing problem, one case having 50% missing in one direction. The only problem occurring in vertical members was a very minor one of verticality, the worst instance on 2 cases was 30% of standards being in excess of Code requirements, typically the rest incurred penalties of 10% or less. Only one case had a serious base condition problem of inadequate seating of all standards on poor quality packers. Only 2 cases had any problem of eccentricity (with 10% and 50% penalties). One case had 50% of the clips missing to the aluminium runners.

'Fair' quality sites

All of those applicable cases had a bracing problem; ranging from 20% missing in one direction to 2 cases where 100% was missing in both directions. All cases had some problem with verticality where the worst one had 60% of standards in excess of Code requirements. Also in this category of site there were instances of missing lacing (9 cases) the worst one having 20% missing. On four cases lift heights were excessive. One third of the cases incurred penalties for excessive, unbraced jack extensions. The base condition became progressively worse, 7 cases having a problem with four of those having very poor seating on inadequate packers or substandard sleepers. Six cases had eccentricity problems, the worst incurring a 50% penalty. Four cases had fixity problems at the head, where one incurred the maximum penalty of 100%, due to a lack of fixity of the timber runners. It is in this category of site where there is an almost random association of the errors in different conditions.

'Inadequate' quality sites

All of the applicable 14 cases had a bracing problem, 12 ranging from 80% missing in one direction to 10 cases where 100% bracing was omitted in both directions. Two cases had a problem with excessive lift heights throughout. Ten of the applicable cases had lacing missing, with one case with a maximum of 85% omitted in one direction, usually lacing, where omitted, was in both directions. All cases had some problem with verticality, the worst two (proprietary system) cases had 60% of the standards in excess of Code requirements (0.5 degree), the worst props case had 45% of props outside requirements (of 1.5 degrees). Ten cases had problems with base condition, two of these with simply atrocious seating. All of the applicable 6 cases incurred maximum penalties for excessive and unbraced jack extensions at the head or base, one case incurring maximum penalties at both head and base levels. Thirteen (out of 19) cases had problems with eccentricity, with four cases in excess of 50% (including 1 with a maximum of 100%) penalties. Sixteen cases had fixity problems, nine of which incurred the maximum penalty. It should be stated that 13 of these cases in this 'inadequate' category used adjustable steel props, which almost by definition incur penalties in bracing and lacing where Code requirements, which may not be understood or accepted, were strictly applied to the applicable cases. Fixity was very poor to the flatheads used in the props cases.

Conclusions

As envisaged at the onset and discussed in Chapter 5, there were problems in deriving a scoring system of quality, even with the able assistance of practitioners. Nevertheless a satisfactory system was developed which was proved to be robust and reflected in the ranking of sites, the desired requirements.

Using a relevant method of ranking sites in terms of overall quality, a categorisation of sites was achieved. This categorisation is fundamental to the purposes of the study of organisation and its effects on quality.

It is crucial to point out the uses and misuses of ranking and any statistical tests then applied. Ranking of sites has been useful in checking the effects of the various scoring mechanisms and their robustness. Associations between different errors have been tentatively explored; there are no adequate predictions of workmanship standards for use on site to expedite the checking of falsework. The main use of ranking is to obtain categories. Rigorous or semi-rigorous statistical analysis is of no use in the comparison of quality standards between individual sites with respect to their precise rank order or score. Comparisons, statistical or otherwise, are however valid between groups of site within categories. Poor quality occurs more or less uniformly across all of the conditions in the lowest category of site. Thus quality of workmanship standards can be described with respect to each category of site and more importantly organisational factors can be related to categories of sites which have a consistent level of workmanship within a category.

CHAPTER 10

Quality Findings and Category of Site

Introduction

Here the typical descriptions of the sites in each category given at the end of Chapter 9, and the findings and comments of Chapter 8 are expanded upon. Reference should also be made to Ranking Table 1 and Table 2, in order to inspect the types of error occurring in the various quality categories of falsework.

Errors (departures from tolerance standards) in theory should not be a function of the type of system used unless the potential for error is eliminated or reduced, for example eccentricity and fixity errors in proprietary systems, or node connections in 'trigger-brace' systems are virtually eliminated. Basic workmanship standards demand that the structure is erected to tolerances and that the structure is stable. Any marked differences in standards of workmanship between systems can be explained by:-

1) Difficulty in erection;
2) Abuse or misconceptions of rigidity or capacities;
3) Different trades practices being exercised in different types of system, or by different trades groups;
4) Poor jobs could be poor jobs irrespective of system because of competence, supervision or general organisation.

In other words there are other possibilities which reside firmly in the organisational factors addressed in Part 3. This chapter will highlight the fact that there are many unexplained variations which can only be due to organisational factors.

Bearing in mind the above qualifying remarks, findings will now be reported using quality categories to support some of the suggestions made in Chapters 8 and 9.

TABLE No 1: OVERALL PENALTY SCORES AND PENALTY SCORES IN INDIVIDUAL CONDITIONS.

MAIN SITES ONLY.

SITES RANKED WITH RESPECT TO OVERALL RANKING No 1 SCORE. - AND CATEGORISED.

SITE NO.	TYPE NO.	RANKING 1 %	RANKING 2 %	RANKING 3 %	HEAD CONDITN	BASE CONDITN	JACK EXTENSN	VERTICAL MEMBER	BRACING	
20	1	0	0	2	0	0	0	0	0	
22	1	0	0	0	0	0	0	0	1	
36	1	0	7	6	0	0	0	0	0	
28	3	0	3	9	0	0	N/A	0	N/A	
4	2	1	3	8	0	0	0	3	0	
8	1	2	1	2	0	0	0	6	0	
10	2	2	4	4	0	0	0	8	0	
41	1	3	3	6	0	14	0	6	3	G
48	1	4	4	3	0	30	0	5	0	O
40	2	4	3	3	0	0	0	4	10	O
29	1	5	5	8	0	0	0	14	7	D
34	1	5	5	7	25	0	0	2	0	
38	2	5	5	4	0	14	0	17	1	
15	1	6	5	5	0	0	0	3	18	
26	1	6	5	8	8	19	N/A	7	0	
6	1	7	12	15	30	0	0	0	0	
37	1	9	8	11	N/A	2	7	7	13	
45	1	9	8	12	0	24	0	8	17	
17	1	9	8	7	15	50	0	0	0	
52	2	10	9	8	0	0	0	5	29	
3	2	11	10	14	0	0	0	20	20	
53	1	12	11	10	0	25	0	15	17	
42	2	16	15	16	0	0	0	48	18	
14	2	17	15	14	0	0	0	7	51	
25	1	18	19	19	25	6	0	35	19	
46	2	19	17	24	0	100	0	20	17	
11	2	20	18	17	0	0	0	7	62	F
31	1	23	21	21	11	0	52	6	32	A
5	2	24	24	25	0	0	50	10	38	I
32	4	24	22	20	32	50	7	8	48	R
30	2	25	23	23	0	20	50	14	35	
49	1	26	23	21	14	0	0	39	50	
12	1	26	24	23	25	75	0	38	20	
33	2	26	25	26	0	0	50	3	50	
47	1	27	24	28	50	0	50	7	19	
13	2	27	27	26	22	0	0	0	67	
51	2	27	28	31	0	0	0	20	67	
1	2	28	25	29	0	0	0	34	67	
39	1	32	32	30	25	0	50	35	33	
54	3	32	29	26	20	0	N/A	0	100	
19	3	32	27	28	40	44	N/A	21	N/A	
27	3	33	33	36	8	0	N/A	14	100	I
50	3	33	30	28	66	0	N/A	9	50	N
43	2	38	35	32	0	14	57	9	67	A
24	1	39	35	34	60	34	0	63	36	D
9	1	40	37	34	90	0	0	7	69	E
44	3	40	43	43	59	100	N/A	1	N/A	Q
18	3	41	40	36	15	0	N/A	24	87	U
2	1	42	38	35	65	0	0	30	77	A
23	3	43	43	40	8	13	N/A	36	100	T
21	3	45	41	44	12	0	N/A	47	100	E
7	3	55	55	57	35	15	N/A	50	100	
35	3	67	67	60	50	40	N/A	64	100	
16	1	74	67	70	50	100	100	35	67	

NOTES:-

RANKINGS 1,2 & 3 ARE RELATED TO THE PERCENTAGE PENALTIES SHOWN ON DRG No 2.

ALL OTHER COLUMNS ARE THE PERCENTAGE PENALTIES FOR EACH CONDITION

RANKING 1: HEAD CONDITION + BASE CONDITION + JACK EXTENSION + VERT. MEMBERS + BRACING

RANKING 2: RANKING 1 + MAT'L CONDITION

RANKING 3: RANKING 2 + ACCESS & SAFETY

TYPE 1 :- PROP SYSTEM/TRAD DECKING

TYPE 2 :- PROP SYSTEM/PROP DECKING

TYPE 3 :- ADJUST. PROPS/TRAD DECKING (A)

TYPE 4 :- TUBES/FITTINGS & TRAD DECKING

TYPE 5 :- ADJUST. PROPS/TRAD DECKING (B)

Types of Error \ Types of System	TOP 19 – GOOD SITES					MIDDLE 19 – FAIR SITES					BOTTOM 16 – INADEQUATE SITES				
	Type 1	Type 2	Type 3	Type 4	Total	Type 1	Type 2	Type 3	Type 4	Total	Type 1	Type 2	Type 3	Type 4	Total
HEAD CONDITION															
Eccentricity	2	–	–		2	2	–		1	3	3	–	9		12
Joints in beam > 15 mm	3	–	1		4	1	–		1	2	3	–	2		5
Clips/Wedges/Inad. Fixity	1	–	–		1	3	1		1	5	5	–	8		13
BASE CONDITION															
Inadequate seating	6	1	–		7	3	2		1	6	2	1	6		9
JACK EXTENSIONS															
Head	–	–	N/A			3	1	N/A	1	5	2	1	N/A		3
Base	–	–	N/A			1	2	N/A	–	3	1	1	N/A		2
VERTICAL MEMBERS															
Lift height excessive	–	–	–			2	2		–	4	2	–	–		2
Lacing missing one or both	–	1	–		1	2	5		–	7	1	–	6		7
Verticality > 30'	11	3	N/A		14	6	11		0	17	5	1	N/A		6
> 90'	N/A	N/A	0		0	N/A	N/A		N/A	–	N/A	N/A	7		7
BRACING															
None fixed	–	–	–		–	–	2		1	2	1	1	6		8
Missing in one) both)	2 / 3 5	–	–		5	3 / 3 5	– / 11 11		1 1	17	1 / 3 4	1 1	8 / 8 8		13
Nodes > 150 mm	1	2	N/A		3	2	6	N/A	1	9	4	N/A	N/A		4
No. samples in each system	14	4	1	0	19	6	12	0	1	19	5	1	10	0	16

Table 2: Number of sites incurring errors

The table of ranked, categorised sites indicates a progressive worsening of each condition as one moves down the categories, the odd individual error of 50%, 75% or 100% becoming more frequent and combined with similar errors in other conditions more and more. To some extent 'commonsense' is proved in the worst category of sites where bad workmanship occurs throughout all conditions and in the high category of sites good workmanship occurs generally throughout all conditions.

Errors in verticality are more evenly spread through the sample and the marks for vertical condition perhaps show less marked deterioration until the bottom few sites where lacing, totally omitted in adjustable steel props, dominates the score.

Each condition will now be discussed briefly with relation to what various categories of site achieved. Each section is prefaced with the overall distribution of error taken from Tables 1-8 in Chapter 8 to provide a background.

<u>Head Condition</u>

Eccentricity: 54% of sites had no incidence of error.
29% of sites had between 1% and 30% incidence of error.

Fixity: 46% of sites had no incidence of error.
23% of sites had between 1% and 30% incidence of error.

Fixity should not be a problem in Type 2 systems although site No.13 indicates that anything is possible. Problems occur on the best category of sites. The frequency of sites with an incidence of error and the magnitude of this incidence increases from category to category, the 'inadequate' category of sites showing a marked increase with 5 sites having inadequate fixity in all forkheads or plates.

Eccentricity, again, should be obviated in Type 2 systems. Eccentricity occurs only rarely in the 'good' and 'fair' categories. There is a marked deterioration in the 'inadequate' sites where the vast majority had problems, where the incidence level too was high at upwards of 80%.

Base Condition

62% of sites had no incidence of error.

23% of sites had between 1% and 30% incidence of error.

Base condition, like head condition above and perhaps more so, is a basic workmanship factor, and there are potential problems on any site, particularly in civil engineering. Building usually should present few problems unless there is poor concrete finish, holes in floors to bridge across, edges to support and so on.

On building sites there were few sites with high incidence rates in the 'good' and 'fair' categories where one or two had poor scores of 75% or 100%. The 'inadequate' category provided far more sites, over half, with an incidence of error, but only two sites with 75% or 100% inadequacy of seating.

The condition should not be problematic but throughout the sample, abuses and sheer bad workmanship and lack of care occur.

Jacks

22% of sites had a problem with jack extensions.

These problems did not occur in 'good' category sites. When the problem does occur it is usually a 100% incidence level at either the top or bottom; sometimes the error arises from poor setting out or changes in lift height; two sites had similar scores for both head and base condition; this is very rare and can only take place where there are obstructions at the base level and head level.

There is no suggestion that jack extensions are more problematic on 'inadequate' sites; unless for 'organisational' reasons of lack of drawings, competence, supervision for example.

<u>Vertical Condition</u>

Effective heights:

62% of sites had no incidence of error.

15% of sites had between 1% and 30% incidence of error.

Verticality:

17% of sites had no incidence of error.

62% of sites had between 1% and 30% incidence of error.

Excessive lift heights only occur in birdcage systems and in this sample only in proprietary systems. Predominantly the error is due to lowering a complete level of lacing to facilitate access, and attracts the full 50% penalty scores. In the 'good' category jobs there appears to be no such instances. The practice would very rarely be sanctioned on heavily loaded, thoroughly designed bridge structures. Practices are equally bad on 'fair' and 'inadequate' sites and these are not due to simple workmanship or technical reasons but lack of control.

In birdcage structures odd lacing members can be omitted by mistake, or sometimes complete bays of lacing may be omitted to permit access through the structure. Again practices are similar on 'fair' and 'inadequate' sites. Such practices are a rare occurrence on 'good' sites where, for example, bridge structures have any through access incorporated in the structure. Again there are complicating design and organisational factors to be considered in comparing standards.

The omission of lacing in props is another matter, and not for the reasons of facilitating access since lacing is at quite a high level. Six adjustable props sites in the 'inadequate' category had high incidences of error with respect to omitting lacing. However some lacing was always fixed and two sites had all of it fixed.

Verticality

There is some problem with verticality on the majority of jobs. The incidence level is generally small, usually less than 30%. Where errors do occur in proprietary systems they are seldom greater than one degree out of plumb, and props are never out of plumb by more than two degrees.

The problem gets progressively worse through the categories with more sites incurring incidences of error; there is also some evidence to suggest that the degree out of plumb also deteriorates. However, the only two proprietary systems cases where any vertical member was two degrees out of plumb occurred in the 'good' category of site.

Tolerances for systems may be tight, but using a higher tolerance does not reveal any changes to the general comments above.

Distribution of errors in out of plumb and their direction is random and there is no real cause for alarm.

Bracing

Node Connections: 60% of sites had no incidence of error.

21% had between 1% and 30% incidence of error.

Bracing: 31% of sites had no bracing missing.

12% of sites had between 1% and 30% missing in any direction.

Node connections are generally not a serious problem. The workmanship does deteriorate through the categories. Four Type 1 sites and one Type 2 site had all connections greater than 150mm from the node, all of these Type 1 sites were in the 'inadequate' category. Operatives can only fix the equipment they have, and fix at node positions; problems arise when grid size or lacing is changed. Generally these are features of organisation over which the operatives have little control.

The provision of bracing has always been recognised as a potential problem due to differing conceptions and judgements of the stability and rigidity of a structure. Only the most ignorant of sites would not care about stability. The worst sites in the sample made assumptions consciously or unconsciously, which no doubt they believed were justified by the fact that there was no failure; although the probability was arguably greater than on a comparative 'good' site.

Even on 'good' sites some bracing was omitted; one site had 50% omitted in one direction, although this site was the lowest in this category of site. The number of sites with bracing omitted and the amounts omitted became markedly worse from category to category. The 'fair' category had all but two sites with problems, for example: two sites did not have any bracing, two sites with 100% and 50% missing in each direction, and six sites with between 50% and 75% missing in one direction.

In the 'inadequate' category all adjustable steel prop sites had some problem, six sites without bracing at all, one without bracing in one direction and one site with 75% missing in both directions. It cannot be claimed that proprietary systems fared much better, 2 sites in this category had no bracing at all, and 2 sites without any bracing in one direction.

On the 'inadequate' category of sites, the magnitude of this error is serious in that it is almost totally omitted in one or both directions. All adjustable steel props where bracing was applicable, had serious errors and it could be postulated that the common practice is to ignore bracing or stability, however this does not necessarily apply since some bracing (however minimal) is fixed on some of the sites. Thus on these poorest jobs where the problem is indeed serious, some assumptions are arguably being made of rigidity.

Comments

Workmanship standards get progressively worse and distinctions are particularly clear in 'inadequate' category of site. Here and in previous chapters it has been demonstrated that 'inadequate' sites exhibit a high correlation of errors in each error condition. In the case of the 'good' category sites there are generally low penalty scores across the range of error conditions. 'Inadequate' sites are a cause for concern since the coincidence of errors and lack of stabilising bracing increase the risk of collapse.

The differences in workmanship may be due to technical reasons, or due to differences in trades practices as applied to different systems, or differing standards of competence exercised differentially. The discussion will now move on to the comparison of systems where there is an opportunity to raise such questions and highlight the need to analyse and discuss organisational factors which form the main focus of the thesis.

Comparison of falsework systems

Table 3 shows the number of cases and Fig. 1 the frequency of cases within each type of falsework with respect to the three categories of quality.

Quality Category	Type1		Type2	Type3	Type4	Total
	Bui	Civ				
Good	5	9	4	1	-	19
Fair	5	1	12	-	1	19
Inadequate	4	1	1	10	-	16
Total	25		17	11	1	54

Table 3: Number of cases in each type of falsework category with respect to three categories of quality.

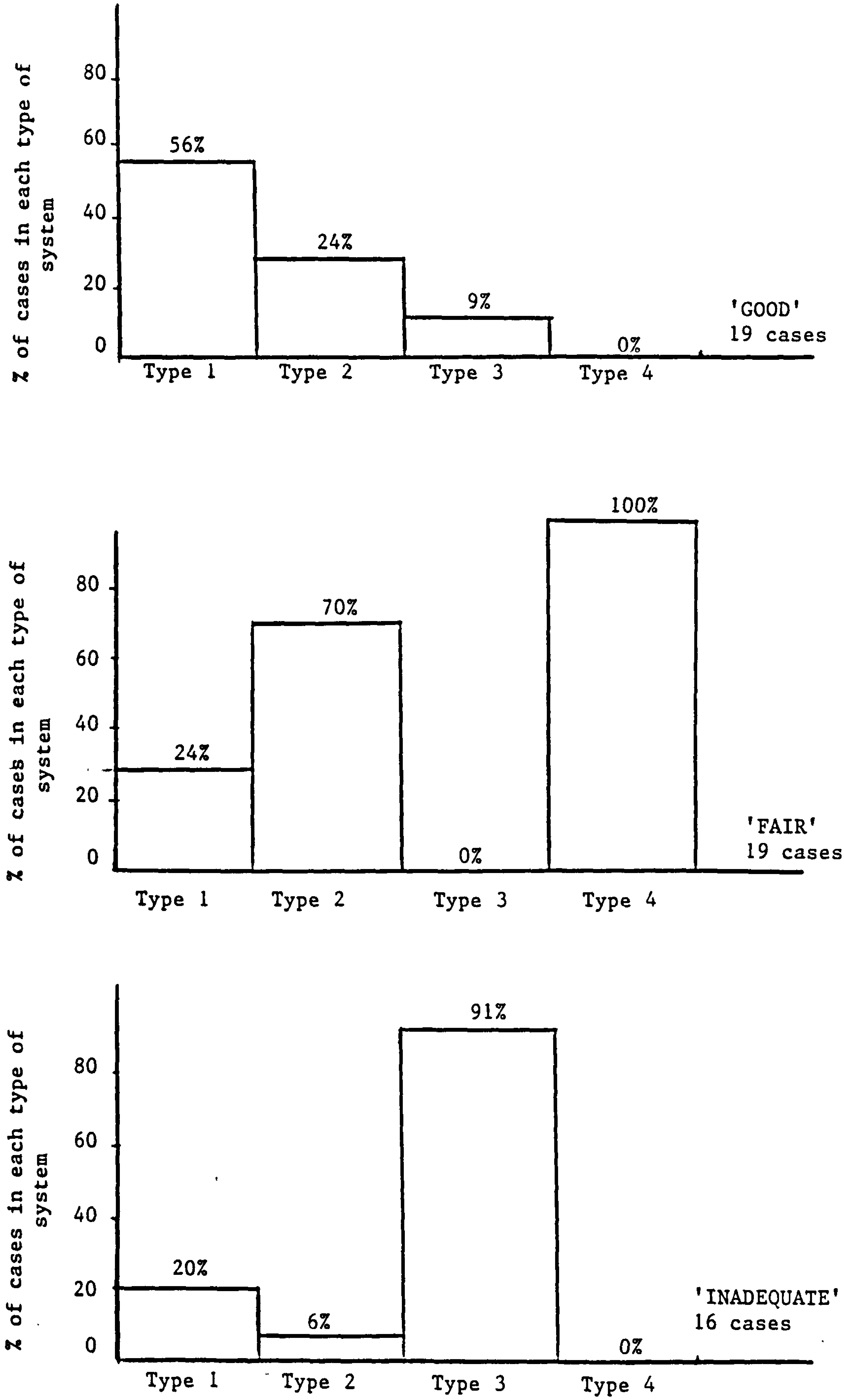

Fig. 1: Frequency of sites in each type of falsework category with respect to three categories of quality.

Within Type 1 systems civil engineering sites had better quality than building sites. Technically there can be no reason for this. Building structures are technically different in terms of loading and scale perhaps, but building may pose problems of layout, phasing of pours and so on. There is, however, no obvious reason why workmanship standards should differ. If structures are more intricate or difficult in bridges, for example, one might argue that there is more potential for errors to be made. Conclusions must lie of course, in the degree of control, competence standards and so on; that is : organisational variables.

Fig. 1 would indicate, perhaps, that Type 1 sites performed better than Type 2 in that a higher frequency of sites appear in the 'good' category. If the 'better' civil engineering sites are excluded then the differences are less marked; the designed better standards at the head condition in Type 2 are undermined by the apparently worse assumptions regarding bracing in these systems. When comparing penalty scores and incidences as in Chapter 8 there are few differences between these systems. Essentially there should be very few differences between the two types of system. They are the same type of modular pocket scaffolding system requiring the same workmanship standards and the same tolerances. (These tolerances being those for tubes and fittings). The only difference can be where equipment design obviates a potential error, or where the system is perceived to be different, requiring different stability measures. Systems scaffolding are frequently claimed to be 'idiot-proof' and quicker and easier to erect than tubes and fittings and there are also claims of the technical and economic advantage over adjustable steel props.

It would be more fruitful to compare, therefore, proprietary systems and props; there is an apparent difference in quality standards. In the scoring system devised, it is claimed that different types of system should and must be compared since the choice of system type, the erection team and so on are firmly organisational factors which are being compared from site to site with respect to the quality attained. The scoring system achieves this comparability by recognising the different tolerances of standards, set out in the Code of Practice, that may apply. These standards may then be accepted in varying degrees in different types by different workgroups, of differing levels of competence. Proprietary systems and adjustable steel props are clearly sufficiently different in technical terms to compare them in terms of quality standards attained.

Forty three percent of proprietary systems appear in the 'good' category, 43% in the 'fair' category and 14% in the 'inadequate' category. Comparing these figures with adjustable steel props where one site appears in the 'good' category and the remaining 91% in the inadequate category appears *prima facie* a severe indictment.

It could be argued that the prop sites were all building and thus civil engineering sites be excluded from comparison. Adjustable steel props are used on building jobs in preference to systems for a variety of reasons based upon design and organisational factors. There is no reason why props could not be used on civil engineering sites, (where loading permits) and no reason why quality should differ. This thesis will claim that adjustable steel props used on civil engineering sites would tend to be of high quality (Chapter 17).

Considering building sites only, 29% of proprietary systems appear in the 'good' category, 55% in the 'fair' category and 16% in the 'inadequate' category. This only marginally improves the comparison, and prop sites appear to reside in the worst category of sites.

An immediate conclusion therefore, could be to abandon the use of props and improve quality. But quality here is relative to sample; absolute scores are of more importance. There are still a significant proportion of proprietary systems in the 'inadequate' category incurring serious penalties for various workmanship standards. 38% of 'inadequate' sites used proprietary systems. Systems therefore are not 'idiot-proof', although easier to erect; serious errors of 'basic' workmanship can and do occur. Perhaps the assumptions of being 'idiot-proof' lead to less competent people erecting such systems and thereby incurring more errors.

It is also clearly possible to obtain near perfect (or within tolerances) workmanship standards using adjustable steel props as at one site, No.28. Some may speculate, cynically, that if bracing had been applicable on this site that it might not have been fixed.

The point is that errors can and do occur in some severity in proprietary systems jobs and it is not the technical features of the system *per se* that determine quality or superiority over props. Simplistic conclusions that adjustable steel props produce low quality in contrast to proprietary systems are disputed. One must also point to the small sample size and the distribution of systems within the sample which also undermines such conclusions.

The factors that determine quality are more complex and are interrelated; they are based on trades practices, competence levels, occupational specialisms, control and so on. These organisational factors have therefore to be examined as to how they affect the quality of workmanship and what is defined as workmanship on a particular site by various personnel. Joiners or labourers typically erect adjustable steel props, whilst scaffolders, joiners, labourers or combinations of them erect systems scaffolding. Trades practice may differ between groups as will competence.

There are technical, economic and therefore organisational reasons for choosing adjustable steel props. Usually the results of such organisational strategy is no formal design, as evidenced by a drawing. In the case of these sites, therefore, one is relying more on the skills of the workforce (or supervision) to 'design' a structure and on their knowledge and acceptance of the Code of Practice requirements. In the scoring of quality the Code requirements were quite rigidly applied; but trades practices may differ from that prescribed in the Code. Furthermore a formal design might make allowances which in the absence of design the researcher cannot. Props arguably require more care and skill, though the workforce might argue otherwise, to erect to the required workmanship standards. To some extent, this is recognised by greater tolerances. Special fittings or equipment might be required in order to fix lacing and bracing; this cannot be fixed if not provided, and it is unlikely that the workforce can demand them. This is another complicating organisational factor.

The fact remains that the poorest sites do, it is suggested, exhibit inadequate standards of quality and adjustable steel props are in the majority. A disturbing number of proprietary systems are in the worst category and many more incur large incidences and severity of error which with other complicating factors make conclusions of basic technical merits of systems unwarranted and simplistic.

The reader may have further doubts about prop sites, for example that their inclusion distorts the sample and categories. That is to say that they cannot be compared or included in the same sample. Their inclusion simply results in a re-categorisation into three equal categories of sites and a simple shift of the borderline between the ranked sites. More importantly the comparisons performed in Part 3 between category of site and organisational variables are not materially affected, particularly those on which hinge the main findings and hypotheses: Routine, Formalisation and Competence.

Conclusions

In this chapter the quality categories have been used to discuss further the findings, explanations and general descriptions of the process found in Chapters 8 and 9.

The discussion presented highlights that definitive statements on workmanship cannot be made, and this is not simply due to small samples. It has to be remembered that the prime purpose of measuring and categorisation of quality was to enable the comparisons of organisation to proceed. However, discussions on quality are important and interesting in their own right.

Workmanship standards in individual conditions deteriorate through the ranked sites and coincide with the individual standards on the lower category sites. The lowest category of sites demonstrate a general overall deterioration of workmanship. Although this only goes to prove 'commonsense', at least the scoring system is performing properly and demonstrates 'commonsense'.

The terms 'good', 'fair' and 'inadequate' as applied to the categories are purely labels and any notion of subjectivity is unintended; it is for industry and practitioners to decide what level of error in any individual condition is acceptable, or what levels are acceptable in the overall structure. This aside, the author confirms his opinions of previous chapters that the conditions in the 'inadequate' category are cause for concern.

Straightforward, technical, statistical comparisons are not valid, due to the range of interrelated organisational factors which impinge upon the attainment of quality of workmanship on site. In order to make more technical comparisons between props and systems or types of systems the sample would have to comprise the same types of job using similar organisations (bearing in mind the difficulty in defining and categorising organisation - Chapter 12), the same team of erectors and so on. The effects organisational factors have upon the quality of workmanship is of course recognised by practitioners and part of the reason for the study is to describe such factors and their influence.

Bracing is singled out, because of its importance to overall structural performance and safety, but mainly because with different assumptions being made and differing conformity to design and Code workmanship standards, it highlights the complex differences in trades practices, control, competence and so on.

Apparent differences in quality standards in building and civil engineering might point to difference in control, for example over supervision or recruitment.

Quality standards on proprietary systems and adjustable steel props sites indicate that there are not purely technical reasons for quality.

The tentative nature of conclusions and analyses of quality presented in this and preceding chapters highlight the need to use the categories of quality defined, and to explore 'Organisation" in Part 3.

CHAPTER 11

Conclusions on Quality

A sample was obtained which included a wide variety of types of structure, equipment, organisation and so on. Full access and considerable cooperation was given on all of the 54 sites comprising the study.

After a good deal of concern and discussion on: what quality was to be measured, the problems of dividing design from workmanship, and the problems of encapsulating practitioners' knowledge, a method of recording workmanship standards was devised. The main purpose of this section of the study was to be able to measure and compare workmanship standards between different sites, using different equipment on varying structural types. To achieve this a robust scoring system was devised. It should be stressed that the scoring system took account of the discussions with practitioners and the assumptions do not depart seriously from their opinions. In the absence of commercial pressures and design considerations, the practitioners would apply the same judgement and scores as was performed here. The 'good' category adequately reflects their expectations of the best sites. The majority of the remaining 'fair' and 'inadequate' sites would, for some practitioners (designers) represent very poor workmanship. In order to compare the range of organisational variables on sites to the quality standards attained, the sites were ranked, according to overall scores and then categorised into three approximately equal classes. The three categories entitled 'good', 'fair' and 'inadequate' are only labels and for the purposes of this study. No prescription or subjective judgement is intended, although the author's opinions are recorded. Thus the main purpose of this section has been satisfactorily achieved; to obtain a measure of relative quality standards and establish categories. These categories adequately reflect the type of workmanship, standards encountered and in the 'good' and 'inadequate' categories, standards of workmanship are generally the same in all conditions.

The rest of the findings described in the chapters are of secondary importance to the main body of the thesis; the methodology and resulting categories are of pivotal importance to the study. The main message to be derived from the secondary issues is that conclusions and findings can only be suggested, and the discussion of differences in workmanship cannot be adequately addressed from a purely technical standpoint, but has to recognise organisational factors. This points the way into the studies of Part 3.

The findings on quality of workmanship, in individual conditions and overall are presented, and clearly illustrate that quality standards are a problem on 'inadequate' sites. The standards in all conditions on these sites deviate seriously from those prescribed by the Code of Practice. Practitioners on these 'inadequate' sites might point to the fact that they have not collapsed; however there is an increased probability of failure due to disturbing forces caused by poor workmanship and a greater risk of failure if the structure is subject to accidental loading. Some practitioners would view some of the sites in the 'good' category as inadequate in that errors in some conditions depart from the Code of Practice standards.

In terms of the overall study of relating organisational variables to quality, the fact that the poorest sites are inadequate with respect to the Code of Practice is irrelevant. The purpose of the research is to relate relative quality standards to the organisations that produced the structure. That the poor sites are inadequate adds to the importance of the conclusions on the control of quality (Chapters 16 and 17).

There are wide differences in assumptions made by trades practices and those incorporated in the Code of Practice. Moreover trades practices are affected by factors such as skills, competence, trade and so on. The problem of bracing, common in many structures demonstrates this well.

The erection of adjustable steel props clearly needs skill and attention and expectations of the Code of Practice are not usually met. On the other hand there are sufficient numbers of proprietary systems in the lowest category of site and incurring serious errors in other categories to suggest that they are not as 'idiot-proof' as is sometimes believed. The commonsense belief that 'monkeys can erect this system' may result in 'monkeys' being employed, and quality standards being lowered further (see Part 3 and Appendix L). In the comparisons of props and systems it is therefore highlighted that other factors are involved apart from simple technical ones.

The practitioners in the industry already make 'commonsense' distinctions between building and civil engineering. (These are given an academic credibility by using the model of 'Occupational Order' in Part 3). In the comparisons of quality such distinctions are also suggested that are part of a set of organisational variables and not technical.

The conclusions lead to the suggestion that quality of workmanship is affected by organisation. The categories determined by this part of the study are now used to compare means of organisational control and their effect upon quality.

PART THREE

Formal and Informal Organisation and Quality

Summary

As mentioned in the introductory Chapter 1 this thesis is written for a joint audience of social scientists and engineers (practitioners). The main purpose of the text forming Part 3 is to analyse and describe the type of organisational control with regard to falsework and the resulting level of quality. This study has to be put into the context of the construction industry in general and the study of organisation and organisation theory. It is suggested that the two models adopted in this thesis: 'the economic and occupational orders', can be applied to the analysis/study of the construction industry in general and to other industries and organisations. For non-practitioners or theorists unfamiliar with the fissiparous nature of the construction industry (one-off, site-specific in contrast to batch production organisations for example), the structure of the main contractor on site and the role of the occupational order has to be described and illustrated. In particular, the socio-economic structure of the falsework production process needs to be described.

It is useful, therefore, to the reader to summarise the structure of the following chapters, in order to illustrate the theme and trend of Part 3. The structure proceeds from the general to the specific. In Chapter 12 the study of organisations and organisation theory are briefly addressed. The traditional separation of the 'informal' and 'formal' organisation is discussed. The models of the economic order and occupational order, as particular (qualified) versions of 'formal' and 'informal' organisation are introduced. These models are used to describe the organisational structure of the general construction industry.

Chapter 13 deals with the formal organisation structure of contractors on site with respect to the whole process of production. This structure is defined in terms of the distribution of economic authority. Reference is made to how the formal structure related to falsework may be identified within this general structure.

Chapter 14 moves on from the site construction process in general to the description of the falsework production process and the parties involved in what has become a falsework/formwork industry. This description highlights the many contractual, formal, institutional relationships that are involved and are continually addressed by the parties when producing the falsework product on site.

Chapter 15 concentrates on the measurement of formalised control of falsework production and its effects upon the quality of workmanship.

Chapter 16 focuses upon the 'informal' or occupational order and illustrates/contrasts the occupational control applied on building and civil engineering sites and compares and explains the standards of quality attained.

CHAPTER 12

Examining organisations

Introduction

Part 2 suggested that variations in quality of workmanship cannot be fully explained by 'technical' differences. It may be commonly accepted, (yet unproven since in the author's experience no previous research or empirical enquiry has been conducted) that quality of workmanship is a function of the organisation of individuals each with varying expertise, in various contractual and occupational roles. Certainly the relationships between any particular organisational variables, and quality has not been analysed before. The importance of the study was recognised by the S.E.R.C. in its award of the research grant and by practitioners who supported the proposal and gave assistance during the course of the research. Part 3 addresses the impact of organisation upon the quality of workmanship attained in falsework. This chapter makes brief reference to the extensive field of theory of organisations, a subject which is beyond the scope of this thesis, as are the many methodological issues which perplex researchers. It is common in the study and modelling of organisations to refer to the 'formal' and 'informal' organisation; this approach can be justly criticised, in this thesis the distinction is used purely as a heuristic device in the formulation of the models : the 'Economic and Occupational Orders'. It is explicitly recognised here that these two models co-exist. It may be possible to describe structures of organisations in terms of formal, economic and contractual authority relationships; the effective operation of these interactive structures, however, depends upon the performance of the individual actors. Whilst practitioners and researchers may regard this as a truism many still resort to formal means and structures to describe, prescribe or control the organisation.

The social arrangements broadly termed organisation include not only the formal authority structures, policies and formalised procedures initiated by management, but also those unwritten conventions and understandings shared by practitioners in the industry at large which form part of the 'informal' organisation.These conventions are part of the shared common sense of practitioners who do not have to theorise about them or explicitly address them.

The importance of practitioners' ideas and beliefs and their commonsense perceptions of their own and others' roles cannot be underestimated. They provide the basis for the original formulation of the model of the 'occupational order' and the generation of the type of interview data analysed in Part 3.To attach a sociological 'label' to this type of research would be 'ethnomethodology'; the derivation of this term is described by Garfinkel (1967). The following have been of assistance: the work of Caton (1963) on the importance of language in describing knowledge, Elliot (1974) on describing science and commonsense, the concept of organisation by Bittner (1965) and, in particular, Sharrock (1974) on the ownership of knowledge,which provides the inspiration for the construction of the occupational order model. The notion of 'occupational order' introduced by Birch and Seymour (1977) and developed by Birch (1978), Burrows and Seymour (1983), Burrows (1983) and Seymour (1986) is applied in this thesis to empirical data, and used to identify the factors affecting quality of workmanship.

Organisation and Organisation Theory

It is necessary to discuss the evolution of the study of organisations, in albeit very brief simplistic terms. A full description is naturally beyond the scope of the thesis. Of assistance has been Lupton's book (1971) which is a common text along with Pugh (1964, 1978) used in the teaching of management to engineers and scientists. However, in the author's opinion, these texts are used selectively by teachers such that the vast majority of students, and subsequent managers are only exposed to prescriptions for management given by formal organisation, scientific management and motivation theories. Fox (1971), Burns (1966), Pfeffer (1982) and Scott (1981) are recommended as sources describing organisations and discussing the current state of organisation research.

Organisation can be regarded as a microcosm of society at large and it is easy to see why sociologists in particular have been fascinated by the study of organisations. Social scientists researching organisations may be further tempted into devising managerial solutions and prescriptions which are continually being sought by managers. Parsons (1960) explains the existence of the variety of organisations encountered every day.

> "The development of organisations is the principal mechanism by which, in a highly differentiated society, it is possible to 'get things done' to achieve goals beyond the reach of the individual."
>
> (Parsons pg. 41).

Pugh (1964) also states:

> "Organisations do not exist or operate in a vacuum. They are one sort of institution in a particular society. They have to conform to the needs and standards laid down by institutions other than themselves. The pressures of a market economy, political decisions, legal restrictions all affect organisational operations. Yet the large scale organisation is one of the dominant institutions of our time, and in turn must exert a powerful influence on the rest of society."
>
> (Pugh pg. 79).

These sentiments expressed in the above statements explain why researchers have been fascinated by the study of organisations. Historically an industrial system is seen as imposing its own structure of relationships on the people who work for it; who are dependent on it to satisfy a multitude of needs; however this organisation is judged by society and is indeed affected by society. See for example Marx (1846 tr.1954), Durkheim (1893 tr.1954), Tonnies (1887 tr. 1957).

The newcomer to the study of organisation is confronted with a wealth of literature on methodologies, perspectives, theories and critiques which are confusing to say the least. Scott (1981) and Pfeffer (1982) give good accounts of the different paradigms and perspectives on offer, but as Scott argues:

> "Sociology has been described as a 'pre-paradigmatic' discipline; we are still waiting for our Copernicus and our Newton. Thus...organisational perspectives are probably, at best, only primitive pre-paradigms. Nevertheless they do supply varying models of organisational phenomena, and each rests on assumptions that cannot be verified by scientific investigations. As we have seen, one perspective does not so much invalidate another as replace or supplement it."
>
> (pg. 122)

Scott goes on in a useful exercise of combining perspectives, in a similar vein to Pfeffer (1982) who incorporates the importance of 'power' in organisations.

Sociologists are still a long way from adequate paradigms or models of organisation. Nevertheless it is necessary to explore the theories which have dominated the thinking of researchers and have influenced the perspectives of managers towards formal organisation. The field of study of organisations emerged in post-industrialised society at the turn of the century. Within sociology the field of study can probably be dated from the translation into English of Weber' definitive works (1946 tr. and 1947 tr.). When these translations became widely available a whole range of sociological debate and inquiry was begun with critiques of Weber's bureaucracy notions of rational models and so on. The contemporary works of Fayol (1946 tr.), Taylor (1911), Urwick (1943) and Brech (1955) for example, could now be re-addressed from a more academic viewpoint.

Apart from Max Weber, these early proponents of formal organisations were practising managers, officers in the army and later management consultants. Researchers such as Brech observed the commonsense rationales being applied by managers and provided theories which subsequently evolved into formal organisation prescriptions for managers. The administrative and management theorists like Fayol and Urwick were concerned with designing organisations; Urwick used an engineering/military analogy for the way to plan, design and construct the organisation. Roles and responsibilities could be defined impersonally and hierarchical authority structures devised. Here one meets the arguments over the span of control, how many subordinates can be effectively managed and so on, for example by Koontz (1966) and Jaques (1956). Taylor and his early disciples of scientific management, from which production engineering evolved were more concerned with job design and personnel selection and that management would be stimulated from below by the demands of the workforce for better planning and organisation. These formal organisation theorists shared the belief that organisations were rationally conceived and could and should be formally represented in charts and in definitions of procedures, roles and responsibilities and so on. They adopted a closed system perspective where the organisation is conceived of as independent of the external environment of the market, technology, other organisations and so on. They are rationality models since the formal organisation structure is the result of a strategy oriented to the pursuit of relatively specific goals. The theories rely therefore upon individual actions being capable of description and being controlled and that organisational goals can be defined and legitimised by the individuals' pursuit of them. The theories also conveniently avoid the issue of who determines goals and the strategies, as pointed out by Child (1972) and Thompson (1967) for example who refer to the role of 'strategic choice' and the actions of the 'dominant coalition' respectively.

Formal and Informal Organisations

Writers on formal organisation, especially the early exponents of what is regarded as the 'classical school' of formal organisation, ignored or underestimated those aspects of the organisation not prescribed or described by the formal organisation. Fox (1971) provides categories of norms (rules or standards or patterns for action) which govern the behaviour of organisations. The first major category, is normally defined by the 'formal organisation' and consists of:

> "explicitly enunciated rules formally promulgated by those in superordinate positions. These rules are likely to cover most aspects of the work sequence - recruitment, training, work roles, relationships of super- and subordination, financial and other rewards, promotion, discipline, dismissal, production methods, the use and maintenance of the material technology, accounting and other control techniques, and of course many other aspects not requiring specific mention here. Some of these rules will be wholly or partly determined by law emanating from an external political agency and, varying with the society, covering such issues, perhaps, as safety, welfare, production standards, or terms and conditions of employment."
>
> (Fox pg. 29).

Other categories of norms exist, normally referred to as 'informal' organisation. Fox continues:

> "Another category of norms consists of explicitly enunciated rules formulated and articulated by subordinate groups - for example by groups of craftsmen or professionals who may bring certain self-regulating practices to bear upon their own role-behaviour. A further category comprises informal understandings generated within superordinate and subordinate groups. While not as explicit as

articulated rules, they may nevertheless effectively govern behaviour-indeed may do so more effectively than explicit rules. This category includes customs, conventions, and social *mores*. Finally, organisational norms include formal rules and informal understandings that are concerted and jointly sponsored by superordinate and subordinate groups."

(*op cit* pg. 29).

Fox ends his clear description stating that:

The question of the extent to which the various constituent groups of the organisation are governed in their behaviour by these different types of norms is of course a matter for empirical enquiry."

(*op cit* pg. 29).

This thesis would concur with the preceding sentiments, however formal organisation remains the focus of attention or a starting point for many writers and practising managers. Formal organisations are by definition capable of written description and the intended rational strategy is crystallized in the ubiquitous organisation chart. These organisations are characterised by the form of language that is used by the theorists and managers. This language connotes the image of rational calculation: information, efficiency, optimisation, implementation, design and so on. The attraction of these theories of management for practising managers can be understood, especially those drawn from engineering or scientific backgrounds. Their only exposure to organisation theory has been limited to these theories at college or university and in-house training courses. Exposure to the 'human relations school', 'management by objectives' and so on is such as to reinforce their conceptions of formal organisation and how 'informal' organisations can be absorbed or managed within the formal organisation.

McGregor (1960) points out the 'possibility of formal organisation being altered by personalities' and as early as 1939 Roethlisberger and Dickson (1939) in describing the informal organisation state:

"Too often it is assumed that the organisation of a company corresponds to a blueprint, plan or organisation chart. Actually it never does."

(pg. 551)

Early studies believed that informal structures characterised only the lower strata of the firm but Dalton (1950) proved differently that managers and executives were not immune; this work is supported by the writers of the Human Relations School, for example see Mayo (1949).

Nevertheless, formal organisation theorists like Urwick believed in the logical drawing office approach he advocated to designing rational organisations where the planner of organisation must take into account the human element. His 'temporary deviations from the pattern in order to deal with *idiosyncrasy of personality* must be minimised by careful prior planning' (author's italics).
Within the formal organisation theories there are limitations on how far actions can be described or controlled, again this is recognised in the language used for example: constraints, authority, rules, directives, jurisdiction, performance programmes, coordination. There are problems therefore, which must be catered for, say the proponents, by proper, thorough organisation planning with careful attention to rules and so on.

In addition to coping with the informal organisation and personalities within it, the formal organisation has to adapt to change in its external environment. These changes may be in technology and the market (types of product and demand) and the social/political *mores*. Studies by Crozier (1963), March and Simon (1958), Merton (1940), Selznick (1949), Gouldner (1954) and Burns (1966) all highlight the dysfunctioning of formal organisations and bureaucracies when trying to adapt to change. When presented with problems in dealing with an uncertain environment formal organisations perceive the main fault as failure in coordination and communication. The formal organisational solutions to such failures is to perpetuate more formalised procedures, appoint coordinators or committees and create more branches of the hierarchy. Empirical studies conducted by Burns and Stalker (1961), Thompson (1967), Lawrence and Lorsch (1967), Blau and Scott (1962) for example suggest that reliance on the formal organisations and further formal solutions lead to further problems.

On the basis of the type of empirical evidence in the studies above of other industries and organisations and the inherent weaknesses and limitations of formal organisation to describe the whole of the functioning of the organisation, it would be postulated that the solutions recommended by the Bragg committee (1974, 1975) and the Falsework Code of Practice (1982) would be of limited success. This thesis maintains that the efficacy and acceptance of formalisation as a mechanism to control quality is more a function of that part of the informal organisation described by the occupational order.

Many sociologists dismiss formal organisation theorists because of their prescriptive content, sweeping generalisations and for their treatment of 'formal' and 'informal' structures. Nevertheless the formal organisation or closed rational system is constantly referred to as a basis for discussion and criticism when introducing or comparing new paradigms or models. There is also use made of the 'informal' (although not in quite the derogatory sense of the early theorists) category in another guise for example the 'sentient system' - Miller and Rice (1970), or the 'adaptive system' and 'system of personal relations' by Higgin and Jessop (1966).

Matrix (or project) management and organisation (for example see Kingdon (1973) and Management by Objectives (see Humble (1969)) also keep the notion of formal organisation alive by attempting to formalise or regulate 'informal' activities.

For many theorists the notion of a 'formal organisation' is a heuristic device. Practitioners (and researchers) know or suspect that the organisation chart cannot depict correctly how the organisation works but it does represent the intended control strategy, the number of production staff and functional specialists. There are measures to be made of the amount of documentation, degree of specialisation, routinisation and so on which can be compared from firm to firm or even industry to industry (the works of the Aston programme, Pugh et al (1963, 1976a, 1976b) are addressed later and provide the basis for describing formal structures). At the very least the list of duties and responsibilities and the organisation chart provide a good starting point for discussion and interview in any research project.

Managers and theorists, such as Drucker (1968) and Humble (1969), still resort to the formal structure in order to manage and control. Most managers' exposure is likely to be very limited and the misleading precision of formal structures holds attractions.

Organisational models need to be developed for example incorporating an open systems approach (Thompson (1967), Scott (1981)), and the influence of power (Pfeffer (1982) for example) perhaps combined with natural systems such that the influence of informal, external organisations and environments (market, technological, social, political) can be incorporated. As Scott points out, sociologists are still in a 'pre-paradigm' situation and a long way from definitive universal models.

Research Methodology

The collection of data on organisations, types of structure and variables and, in particular, the ethnomethodological approach which relies upon, and allows for, practitoners' views, involves a wide range of open, semi-structured interviews.

As a number of researchers were involved some form of structure had to be evolved in order for comparability of data. Previous research and case studies conducted by the author were used as a basis for typical questionnaires, which were intended for guidance only, as an *aide-memoire* to the researcher. A sample of the questionnaires appears in the appendix.

There are problems, however, in obtaining and interpreting data which have always taxed sociologists, in particular the dilemma of the researcher who also has to be a (subjective) practitioner in order to interpret responses whilst still maintaining objectivity. It is not intended to pursue the subject further in this thesis. The following texts provide good introductions and discussions on the problems: Bulmer (1977), Pfeffer (1982), Webb et al (1966), Benney and Hughes (1956) and Deutscher (1969/1970, 1973).

Choice of Models

This thesis will use the distinction of 'formal' and 'informal' purely for heuristic purposes in describing the effects of organisation control upon the attainment of quality. It is purely heuristic since as Fox (*op cit*) justly points out:

> "...the distinction frequently drawn in organisational literature between 'formal' structure, as officially prescribed by organisational leaders, and 'informal' structure, as created spontaneously by subordinates, may be confusing if it creates an impression of two systems. *There is only one organisation* - people cannot behave in two different ways at once."
>
> (pg. 33, author's italics)

In this statement, however, it is suggested that Fox is guilty of reification, giving a concrete reality to a phenomenon of organisation which does not exist. Organisations can only exist in the minds of people. It is true and Fox presents a cogent argument that at any point in time there can only be one line of action or behaviour. In pursuing or determining that line of action the members will operate or refer to several models of organisation including perhaps moral and religious considerations. In the construction industry its members certainly operate with the two models referred to below, the economic and occupational orders, which in many cases supplement each other but in others can be in conflict with each other and are subject to a degree of negotiation. For example, the resident engineer who has no economic authority over the agent on a construction site, may nonetheless, by virtue of his occupational expertise has occupational authority and the agent may defer to this authority in and over a particular process. The two orders or models co-exist and are continually being tacitly referred to by the members of the industry. Their interaction is explained below and in subsequent chapters on the falsework process and the type and effect of 'formal' and 'informal' control.

The model of the economic order facilitates the incorporation of the economic rationales that are applied in devising formal organisation structures and other means of control, and their cost. It also recognises that organisation(s) do not exist as closed rational systems and are influenced by other organisations, the market and the social-political environment.

The occupational order provides an academic model which enables the commonsense theorising of practitioners to be expressed and analysed and raises the status of the 'informal' organisation. Indeed the contention of this thesis is that the occupational order provides the explanation of how control is effected, and objectives desired by the economic order, are actually realised in the organisation and industry as a whole.

The term 'order' is used in social analysis to denote the subjective meaning of a social relationship when action is oriented to certain determinate rules or maxims. The bus queue is a consequence of what sociologists call an 'order' deriving from a mutual sense of fairness when demand exceeds supply. The exercise of control is effected through the understandings people have of the rules which these orders comprise. (For an excellent discussion of order in the social context Sharrock (1970) is recommended).

Each particular industry has its own 'occupational order' which may have currency only among practitioners in that industry. By contrast the 'economic order' serves as a guide for action throughout business and industrial life in general. People conform to an order for a variety of reasons from pure expediency, self interest, ideological, moral and so on; in the end an order only exists in so far as the people involved share some mutual orientation to the rules of the game.

The Economic Order

In the context of this thesis the term 'economic order' is used to describe formal organisation, which not only includes the formal economic authority relationships but also formal contractual and institutional ones. These are constrained or determined by the prevailing economic order of the market and the political and economic climate. Such factors are generally confined to the 'external environment' in traditional studies since they pose a complexity which cannot be analysed by their model. This thesis does not postulate upon the climate prevailing during the period of study (3-4 years), make comparisons with the past, or speculate on the future in terms of economic, political, social climate. This is not due to complexity or inability of the model but the restricted scope of the study, lack of data etc.

Formal control structures and contractual arrangements can, *prima facie*,be easily described and illustrated (charts, lists of responsibilities,specifications, contract clauses). The economic order 'simply' reflects what have become the facts of economic life. The economic order refers to the systems of rules and mutual understandings through which people engage in buying and selling, hiring (and employing) and borrowing. It is seen as legitimate that the ownership of resources confers rights of economic control, these may be delegated without the owner losing ultimate control. The fundamental concept of ownership is also extended to the ownership of a corpus of knowledge later on when discussing occupational control. The basic rule of the economic order of the market economy is that each dealer in the market acts in accordance with what he sees as best suiting his economic self-interest and expects all others with whom he deals to do likewise. The necessary pre-conditions for this pursuit of self-interest is freedom of the individual which is guaranteed by the state and protected by the legal order (contract, statutes and so on). The ideology of the economic order of the market is justified by its proponents in terms of the efficient allocation of scarce resources. Apart from the notion of freedom of the individual an absolutely essential ingredient to the proper functioning is competition. The ideology of the market is savagely attacked by Marx and his disciples and many others on political, economic and social grounds. Selucky (1973) gives a good summary of such views. The market can be seen as a self regulating mechanism between the various producers, consumers and users.

Within a firm, economic control of the owners is achieved by the distribution of authority, by the employment relationship of superordinate and subordinate. Authority is the basis for control when those over whom control is exercised concede that the superior has the (legitimate) right to do so. Economic control is effected through a hierarchy of economic authority spreading from the chief executive downwards to encompass all employees. This type of authority relationship whereby the owners of economic resources exercise economic control over employees is quite distinct from the market relationship whereby economic control is exercised over people through the impersonal medium of the market. The bargaining that goes on between a potential employee and a potential employer is certainly (in a market economy) a market relationship, where the wage or salary that is to be paid by the employer is determined by the forces of supply and demand. Once the bargain has been struck, the relationship ceases to be a market relationship and becomes one of subordination to the employer's economic authority.

Economic authority is the publicly recognised right of a person filling a particular position to make decisions and give instructions. Titles such as General Foreman, Site Agent and Contracts Manager are positions in the hierarchy of authority and these roles may be filled by people from a range of different occupations. Whilst some consideration is given to occupational (technical, trades) expertise, (see below), the distribution of economic authority is mainly concerned with managerial ability.

Although subordinates may disagree with the actions of such managers, they will generally concede that a person in this position has the right to decide the what, where, when, and who of everyday practical activities on site, and to expect obedience. Whether the person in a position such as foreman is generally understood to decide and control how the subordinate carries out his task or operation depends on a number of factors pertaining to the occupational order.

The employment relationship which ensures economic control on the basis of economic authority is recognised and preserved by law in the contract of service. An alternative also exists for the individual and firm alike which is the contract for service or employer:independent contractor. Here economic control is ensured by the market. This relationship between client and contractor, contractor and sub-contractor and self-employed individual relies upon trust and reputation; it therefore imposes problems of economic control of day to day activities. Site control which relies upon the market or contractual means to order the activities of sub-contractors is difficult and the authority control structure must take account of this. The data in this thesis show that main contractors and sub-contractors alike recognise and report the problems of control. Their views may not be reflected in the strategy of the executive who rely upon the market as the control mechanism and may reduce the capacity for supervisory staff directly involved in production control.

This thesis will describe the formal structures in terms of the distribution of economic authority and the superimposed institutional and contractual arrangements. The model explicitly recognises that choices of formal structure will have an associated cost as will the implementation of the type of formalisation advocated by the Code of Practice.These choices will be evaluated (economically) on the basis of the effective return.

The Occupational Order

In contrast to the model of the economic order, the occupational order is more difficult to articulate and is dealt with here in more detail, illustrated by data. A more complete treatment is given in Birch (1977) and Burrows (1984,1988).As in the case of other 'informal' organisations the occupational order is part of the commonsense understandings of the personnel working in the industry; they are unexplicated and tacitly assumed; there is no need for them to be described or conceptualised in an academic model as Bittner (1965) points out:

> "We must attend to the rich and ambiguous body of background information that normally competent members of (the industry) take for granted as commonly known. In its normal functioning this information furnishes the tacit foundation for all that is explicitly known, and provides the matrix for all deliberate considerations without being itself deliberately considered. While its context can be raised to the level of analysis, this typically does not occur."
>
> (Bittner 1965, p268).

The main problem for the researcher is gaining access to what, for the initiated, is so thoroughly taken for granted. The researcher has to be a practitioner while still retaining or constantly addressing his objectivity. In discussions with practitioners a number of themes can be frequently identified. Occupational labels are used differently to those labels or titles like General Foreman or Agent which imply a position in the economic hierarchy. These occupational labels are, in essence, a form of organisational device referred to below. 'Building' and 'civil engineering' are held to be intrinsically different. These differences cannot be fully explained in terms of technology. Whilst there are indeed institutional or contractual distinctions made in the conditions of contract and methods of measurement, these differences can be better described in terms of how economic control reflects the different occupational orders.

In civil engineering (below) it is easier to depict the structure of the occupational order since it is reflected and recognised by the economic control structure. Different firms develop a certain ethos or tone. Consciousness of the 'way we do things here' is often sharpened when respondents contrast it to other firms they have worked with. Frequently this contrast takes the form of a struggle between occupations competing for economic control.

In adopting an ethnomethodological approach to organisation, importance is placed upon how practitioners perceive their role and position in the production process relative to others; it is this perception and commonsense understanding which guides their actions. Whether those perceptions are legally valid (for example in terms of sub-contract responsibilities) or formally recognised is irrelevant since they act in accordance with this perception and in accordance with the commonsense expectations of others.

The occupational order is part of what formal organisation theorists would term the 'informal'. The occupational order comprises a set of mutual understandings, shared rules of conduct in which the authority or right to prescribe how a job is to be done is vested in the individual who <u>owns</u> the appropriate body of knowledge or skill. This ownership is determined by the individual's membership of the appropriate occupation. The distribution of authority within an occupation is based upon seniority, in terms of age, experience and demonstrated competence. The occupational authority is non-hierarchical within or between occupations. This occupational order is unique to a particular type of industry unlike the more ideological economic order which is universal and whose nature of ownership of resources changes with political structure: capitalism or communism or cooperatives, for example, but in these, some authority rights of superordinate over subordinate still generally apply.

Higgin and Jessop (1966) in one of the very few studies of the construction industry, use the distinction 'formal' and 'informal' in a good brief study of the building industry. They still, however, adopt a prescriptive approach and advocate rational responses, attempting formal solutions via contractual means for problems of design and construction and separating those informal structures which are conducive to the formal organisation (adaptive systems) and those which run contrary (system of personal relations); it should be noted that their study brief was to provide potential solutions.

Stinchcombe (1959) addresses the importance of the crafts to the industry, so fundamental to the model of the occupational order, but misconstrues the existence of a craft administration as a direct result of rational contractor organisations.The occupational order exists in order that the industry as a whole can operate, and exists independently of the contracting system, whether design and build, direct labour, management fee etc..

A number of economic alternatives and contractual arrangements have developed to suit the promoter who views his requirements as unique. In response to the demand for unique requirements from a vast multiplicity of promoters, there has developed a work force, manual and non-manual, filling a large range of occupational specialisms. Each promoter draws upon this large pool of workers, possessing a range of occupational skills to get a design and to get his 'unique' project built. To meet these conditions, the promoter's unique project is designed to be a ....

> "unique temporary amalgam of specialised occupational skills, each within the scope of one of the specialised occupations represented in the industry's total workforce."
>
> (Birch 1977).

When members of this temporary coalition have finished their work on one project, they disperse and take their skills into other unique, temporary coalitions that make up the unique project financed by other promoters. For example, a bricklayer may at one time be working on a small building for an owner-occupier of small house and at another time be engaged as part of a much larger workforce, building an office block or hospital for a public or private institution. He moves from project to project working perhaps on each one with people he may never have worked with before and may never work with again. It is generally economically irrational for a promoter or contractor(s) to employ permanent teams of designers and construction personnel, who move from site to site.

The necessary mix of occupational specialists are assembled by the requirements of the economic order. The mechanisms of economic control do not control how this mixture of people with different occupational skills actively cooperate in the work situation to get the job done. This concerted action is achieved through the occupational order which co-exists with the economic order. Under the conditions of continuous coalition and dispersal of the population of workers: engineers, architects, builders, bricklayers, steelfixers and so on, the occupational label is an organising device; the way of identifying strangers, to know what may be expected of them and how they are located in the work process. The labels are used in a way noted by Sharrock (1970,1974) which implies a relationship analogous to ownership, between the category of people which the label denotes and a specific body of knowledge. Use of the label is an organising device which signals rights, priorities, reciprocities. Thus there are patterns of authority relationship which describe how jobs are done and how concerted action is achieved. In the most simple terms the occupational order is the commonly understood set of 'rules' which define which particular occupational group has the right to decide how a particular operation is carried out.

It is necessary to define what is meant by occupation. The dictionary defines an occupation as a 'calling' or 'employment' or 'pursuit'. In the context of this thesis, terms like 'general foreman', 'contracts manager', 'site manager', 'agent' and so on do not refer to occupations, but to the positions in the hierarchy of economic control. It is possible for these positions to be filled by people from a range of different occupations. In the context of this model and this thesis, the term 'occupation' means a specialised activity undertaken by a group of people (or collectivity) that shares a 'common body of knowledge'. The phrase 'common body of knowledge' means the physical and mental skills, practical 'know-how', work practices and theoretical knowledge, obtained by practical training and/or experience often supplemented by formal education.

The term occupation refers only to practitioners of a specialised activity who are employed in a number of enterprises or projects and whose activities are not peculiar to the operations of a single enterprise. To use an example by Birch (1977): a typist whose skills can be applied in a wide range of organisations is, in the terms of the model, a member of an occupation, whereas a clerk whose body of knowledge is relevant only to one organisation's administrative system is not.

While members of an occupation are employed in many enterprises they are aware that it is the body of knowledge they share with other members of their occupation that shapes their activities and gives them their distinctive characteristics. Some will obviously be more competent with a greater breadth and depth of knowledge than others due to greater experience, motivation, ability or aptitude. Consequently a group of people of the same occupation will confer on the most experienced, competent member the right to decide how the job needs to be done and exert control over their activities. Occupational authority within a group, that is the right to exercise control over how the job is done, is thus based on the principle of seniority rather than on a hierarchical superior position in the economic control system as is the case with economic authority.

The skills, work practices, practical and theoretical knowledge that make up the body of knowledge of a particular occupation has been, and is, generated and prescribed by some human process. Using the analogy of the typist again, the occupational skills have been partly prescribed by the characteristics of type-writing machines as devised by the designers and production engineers employed by their manufacturers, and partly by the past and present members of the occupation of typists who have developed suitable skills for operating the machines, standards of performance and so on. The necessary body of knowledge that is the occupational skill of the typist has been largely prescribed by some occupational group(s), other than typists. This is largely the case in production engineering, manufacturing and other industries.

There are some occupations whose work process and body of knowledge have not been prescribed by parties outside their own occupational group. The body of knowledge of these occupations is understood to have been largely generated by members of their own occupation. This fact gives the occupational members rights in and over this knowledge analogous to ownership. It is this concept of ownership which is so fundamental to the model of the occupational order in construction and Sharrock (1970,1974) was the main source of inspiration. Membership of an occupation is therefore important insofar as it infers publicly recognised rights. Membership is therefore controlled by the occupation in the form of competence tests, apprentice schemes, technical and professional examinations etc.. An occupation's body of knowledge is not fixed and is always influenced by other parties. For example, the body of knowledge termed falsework has changed in content over the years and has been subject to more prescription by the manufacturers' engineers.

People share the commonsense view that ownership is a different thing to possession. As Birch points out, although a practising engineer may truly claim to possess advanced medical knowledge, his prescription for the treatment of a sick patient would not be preferred to that of a member of the medical occupation; ownership rights in and over a body of knowledge gives the owners the right to decide how the job needs to be done. They have occupational authority. In the case of traditional building, the agent as an ex-tradesman has ownership rights and occupational authority due to his seniority in his own trade; he will also possess knowledge in a number of other trades, gained from his experience. He will have occupational authority over those other trades by virtue of the fact that he is an ex-tradesman and knows how tradesmen operate; he will also know just how far he can tell these other trades how to do the job. In any assessment of quality or performance of an operation he has always to recognise that the standards are defined by the particular operation. In the same way when judging standards of, for example, brickwork, an architect claims to possess that body of knowledge owned by the trades group of bricklayers, it is they who define the standards of workmanship that can be achieved. The customary self-regulation of the craftsman is a particular facet of the occupational order. A contractor's work study engineer has commented:

> "You can instruct a bricklayer where and when to lay bricks but you can't tell him how to lay them."

In his design, the architect assumes (legitimates) that the occupational order will organise the production process to achieve the desired quality standards, which are in reality legitimately defined by the particular workgroup.

Civil engineering is a body of knowledge, largely generated and prescribed by members of the civil engineering occupation. Civil engineering is understood to be what civil engineers have made it. Civil engineers are therefore granted the 'right to decide' the nature of civil engineering and how it is performed. The operations comprise relatively few in number, the quality and performance standards of which can be defined with respect to clear, technical criteria, stipulated and based upon the body of knowledge owned by engineers. Part of this body of knowledge is the design and detailing of reinforced concrete. Steelfixers are members of the manual occupation who fix the steel reinforcement in position on site in accordance with an engineer's instructions. In a sense engineers exercise 'remote control' by pre-codifying their instructions in the form of detailed schedules and drawings. The essential skill of a steelfixer is understood to be the ability to interpret these drawings so that he may conform closely with the engineers' requirements. The steelfixers can thus be left alone to get on with their job, which on completion is subject to an engineer's inspection.

The civil engineer is thus in a position of occupational authority when matters of civil engineering are considered and members of other occupations defer to his decisions. Importantly this gives engineers the right to regulate their own work practices.

<u>Interaction of the Economic and Occupational Orders</u>

It has already been stressed that these models co-exist. The occupational order is assumed to operate by both the promoter and contractor alike,in achieving their economic ends. This thesis maintains that the occupational order enables the variety of formal contractual structures to be contemplated and describes how they operate. Furthermore the flexibility of formal structure (described in Chapter 13) predicated on a diverse, uncertain market comprising a variety of promoters and products relies upon the existence of the occupational order. In designing civil engineering works, the engineer assumes that the occupational order of civil engineering will control the production; that the engineers will have the occupational authority. These engineers will usually be incorporated into the economic control structure of the main contractor such that the engineer(s) also has economic control over production. (This contrasts to building where the engineer is just another specialist occupational role who may or may not have economic authority).

The economic control structure can be articulated fairly clearly and used to distinguish between building and civil engineering in terms of, for example, the occupants of the various roles. Similarly differences in technology, number and complexity of operations may be used as distinguishing characteristics. The reasons for such distinctions and differences in control are provided by the nature of the occupational order which describes who is in occupational control over a particular process. The economic control structure in terms of the occupants in various roles is a reflection/acceptance of the type of occupational order or 'culture' of the firm. Frequently differences in occupational control are evidenced by practitioners' comments of the dissatisfaction of their position in economic control.

The design engineer or client's representative's occupational authority is also recognised in the formal, economic order in the form of his contractual role. Civil engineering conditions of contract adopt a peculiar, almost unique form, in that the Engineer (a specific label) is a named person in the contract but who is not a party to that contract (see for example I.C.E. conditions (1979) or F.I.D.I.C. conditions (1977) of contract).

Thus the engineer, whether the designer or the contractor, has the right to control the production process and this is formally recognised by the economic order and strengthens his role in the economic control structure over production. In contrast in building, the architect draws upon the expertise of the building specialists of structural engineers, building services engineers, crafts and so on, and relies upon the occupational order to define and control, and achieve the standards of quality prescribed in his specification. The occupational specialists in design and production perform a service role to those engaged in the economic control.
In contrast to civil engineering , building generally comprises a multitude of operations performed by autonomous specialists and tradegroups (see for example Stone (1966), Phelps Brown (1966), N.E.D.O. (1978), National Board for Prices and Incomes (1968)

for descriptions and data). The standards of workmanship are defined by the particular occupational group, it is less clear to depict the nature of occupational control. The occupational (and economic, see below) control, changes from occupation to occupation. Here one particular group has authority, there another, at various stages in the production process. Whilst the economic control structure recognises the occupational expertise of those in the hierarchy, the people filling these roles can be from a variety of occupations: building engineers, quantity surveyors, tradesmen for example.

With the multitude of operations which comprise the building sector no one person or occupation can claim ownership (and therefore rights or occupational authority) of the number of trades and specialist bodies of knowledge, and at best can only possess some knowledge of standards and work practices prescribed by the particular occupation. In order to achieve concerted action and satisfy the economic ends of the contractor and promoter alike the organisation in building assumes:

> "You do not need to be a master of every trade but have the basic knowledge of every trade."

In this statement the general foreman, an ex-bricklayer, summarises how control is effected. That he has economic control, as a position in the economic control hierarchy, is accepted by the workforce.

The occupational order coexists with the economic order and in the day to day control transcends it; whether economic control is via the employment relationship or the market. Another agent, having spent 25 years as a bricklayer:

> "We're not really in a position to criticise the (supply and fix) sub-contract carpenter's judgement. Obviously if he's done something which I don't think is right, I'll tell him, we'll discuss it and come to a compromise. But I am only a bricklayer when it comes down to it and I have to rely on his expertise and judgement really. It's a *mutual confidence and trust really*."
>
> (author's italics)

It is the occupational order which provides the means of organising and controlling the many operations (in building and civil engineering) and in day to day management. Whether the workforce is sub-contract (and regulated by market relations) or not is irrelevant.

The common-sense differences between building and civil engineering are explained in terms of the nature of the occupational order. These differences are rarely referred to by practitioners; they do not have to be. Since economic control is usually easier to depict, frequently differences between building and civil engineering are expressed in those terms, in particular the role of the engineer.

A chief planner with a major contractor summarises:

> "Civil engineering jobs are run by engineers with labourers, whereas in building you have the whole hierarchy of the building trades."

In building therefore, the role of the engineer may be limited to a service role; the chief secretary in a regional office of another major contractor with obviously no direct experience of construction sites revealed the commonsense view:

> "In civil engineering the engineers are running the job."

Whilst engineers, and she referred to them as specifically 'building engineers' on building sites:

> "are there for setting out and a service to site."

Traditionally engineers in building perform the technical service role of setting out, concrete quality control with occupational authority for engineering operations such as reinforcement, once the concrete (steel) frame is erected their role is diminished. Over the last twenty years, some engineers on building courses have been trained specifically in building and can legitimately claim ownership of occupational knowledge in structural engineering, building services and so on and can claim to possess knowledge of the trades or specialist skills. This new breed of technically educated personnel can fill the traditional (economic) roles of the general foremen and agent but the nature of their occupational authority is different. By virtue of their technical education and general higher levels of education these building engineers and technicians are appointed as managers in the economic hierarchy. It is not necessarily due to their occupational authority that they are appointed as managers. The occupation of building engineer is still regarded as a service role. A number of sites and companies thus choose to 'employ' agency engineers and this is evidenced by the case study data.

Economic control structures are developed in order that the owners of economic resources can achieve their planned economic objectives. The control is derived from the ownership of economic resources. The control may be achieved by the employment and market relationships. In isolation, the economic control structure, for example the organisation chart, as a prescription for controlling the production process is pure fiction. The 'informal' organisation, in particular that of the occupational order is the means by which the fundamental material requirements of the promoter are satisfied in the most economically expedient manner. In the development of hierarchical economic control or market control, the economic order has to address the occupational order. In filling positions in the employment hierarchy or in choosing sub-contractors the executive organisations look to occupational expertise, managerial qualifications and so on. That the agent has the economic authority to fire an employee, withhold payment or terminate a sub-contract is publicly recognised. This economic control coexists with the control exercised by the occupations. In an example of a small building project cited by Birch (1977), the owner proprietors of the main contractor acted as labourers to the sub-contract electrician and plumber. Although they were in a position of economic control, in matters of electrical or plumbing work they deferred to the occupational authority of the plumber and electrician and acted under their direction; it was economically expedient for them to act as labourers rather than the sub-contractor employing labourers himself. At various times during the project the authority over an operation is vested in different people in different occupations.

In developing an economic control structure, the main contractor will have various policies in staffing and controlling his operations. He may also choose to adopt total sub-contracting. In the choice of policies he will have to take account of the particular occupational order and the range of expertise present or expected. Of note are the range of occupations other than engineers and trades who, strictly speaking are agents of the economic order, and are not directly engaged in the production process : Accountants and Quantity Surveyors. Whilst the accountant's body of knowledge has become the language of business and is used to exercise economic control over the broad policies of the (contractor) enterprise, that of the quantity surveyor is aimed at aiding the financial control of individual projects, incorporating knowledge of legal conditions of contract.

Terms like 'contracts manager', 'project manager', 'site manager', 'general foreman' and so on do not refer to occupations but to positions in the hierarchy of economic control that can be occupied by members of occupations such as engineers, builders, craftsmen and quantity surveyors. Policies on how these positions are filled will vary from enterprise to enterprise, based upon expertise, ability etc. and more importantly on the occupational order that exists. In civil engineering the dominant occupational control by the engineer is recognised in the economic control structure. The economic authority of the engineer as the agent or project manager is reinforced by his recognised occupational authority on all engineering matters. Economic control is in the possession of engineers on site. In building on the other hand the situation is not so clearly defined. Traditionally the agent and general foreman are ex-tradesmen, the importance of the occupational order being recognised. Their degree of economic control is usually restricted to the day to day control over hiring and firing but more and more control is exercised by head office in the form of the contracts manager or quantity surveyor. The quantity surveyor has the financial control over revenue and payments, as one agent, an ex-carpenter summarises:

> "I don't know the size of the job...it doesn't matter - it's the cost of doing the job in a proper manner that counts...the Q.S. has got all the information on prices."

and another: .....

> "The Q.S. is on the financial side to see if we are doing well or not. The day to day management is left to us on site."

Frequently it is the struggles or expressed frustrations in the pursuit of economic control that provide evidence for the different types of occupational control. For example, in the study by Birch and Seymour (1978) on large established firm traditionally engaged in building, experienced problems amongst its recruited civil engineers in its newly established civil engineering division because it tried to impose close centralised economic control (by quantity surveyors and directors) upon engineers used to a different culture. On one site in this study for example, a Chartered Engineer contrasted (resented) control of his building site where

> "head office keeps a very tight rein".

These conflicts are evident when a person moves to another division or another firm for example, the highways director of a major contractor comments:

> "Six months ago we had a Q.S. from building division transferred to our division and when he came he was horrified because in building the Q.S. was independent, the site agent was a tradesman who looked after keeping down the costs and the Q.S. looked after the income, the site agent doesn't know what goes on between the P.Q.S. and the Q.S. And he was horrified when he came because he was expected to work as part of a team - he lost his independence. The Q.S. had to be re-educated...it took us 12 months to train him in our ways...now the Q.S. and engineers work in teams."

The amount of economic control exercised by the agent and project manager depends on the policy of the enterprise, for example on centralisation of control, staffing and training; and on the ability of the person occupying that position. Today more and more managers are engineers or technicians by virtue of their (technical) education and their grasp of problem-solving and interest in financial control. The nature of the task of the site manager has also changed to one of contract negotiations, administration of sub-contractors and so on. As one chief quantity surveyor remarked:

> "We're trying to make the agent A-Gent...they're becoming more managers than builders."

There are also potential sources of conflict between these newer site managers who may resent the involvement of the quantity surveyor or head office.

Thus in summary the model of the occupational order (introduced by Birch) describes how control is exercised by various occupations. Occupational control comprises the set of commonsense understandings that: identifies which occupational group appropriately determines how a particular work operation needs to be done, and forms the basis for effective collaboration among an occupationally differentiated workforce. In civil engineering, where engineering operations predominate, there is tacit acceptance by other occupations and the manual workforce that engineers have the occupational expertise to decide how engineering operations need to be done. By contrast in building, the operations involving the various tradesmen and other specialists are on average proportionately more numerous and there is a tacit understanding that the specialist tradesmen have the occupational know-how to regulate their own particular work practices.

What is fundamental to the effective operations of the occupational order is the assumption of competence in the particular body of knowledge. In the case of civil engineering it is assumed that engineers have the competence to direct a relatively unskilled workforce; in building it is assumed that the variety of occupational specialists have the necessary competence to produce the required standards without the direction of other occupations or members of the economic order. In addition to this fundamental assumption of competence, is the facility to exercise that competence in the face of the economic order of competition and the exigencies of time and economics.

Conclusions

This chapter has described the evolution of organisation theory where the notion of 'formal' and 'informal' organisations developed. These organisations co-exist and are continually referred to by people in determining their lines of action. The models of economic and occupational orders are used in this thesis as versions of the formal and informal organisation; this distinction is purely for heuristic purposes. These models have been described and illustrated by data. The functioning of the economic and occupational order in relation to falsework will be addressed in more detail in the remainder of the thesis.

For some theorists and managers the formal organisation remains the means by which organisation can be described or prescribed. The Bragg and Code of Practice recommendations are (externally derived) formal organisational measures. The formal control structure described here in terms of the distribution of economic authority determined by the economic order, can be depicted and measured by reference to the works of Pugh *et al* . These forms of structure are dealt with in general terms in the following chapter. In terms of formwork/falsework, differences in formal structures centre upon the degree of formalisation with respect to the Code of Practice recommendations. Furthermore these differences can be compared to the levels of quality attained. The use of the model of the economic order also incorporates the various formal structures involved in the various contractual and institutional arrangements. These impinge upon the socio-economic structure of the falsework production process described in Chapter 14.

Fundamental to the effective functioning of the economic order and the various formal authority, contractual structures and so on is the occupational order, which, it is hypothesized, describes how concerted action is achieved and the construction process is defined and controlled. Each party in the production process has a perception of his own role and that of others and will act in accordance with these expectations and shared (tacit) understandings.

The methodology has, therefore, to combine the reporting of contextual, structural and contractual variables with the views of the parties involved, their perceived roles and expectations. These data must also be capable of providing the description of occupational control, for example in the assessment of competence. The general formal control structure of the contractor on site will now be addressed in Chapter 13.

CHAPTER 13

Economic Control Structure

Introduction

This chapter deals briefly with how the organisation of the (main) contractor on site can be described in the traditional formal organisation model. In this case this is represented by the distribution of economic authority. The structure attempts to achieve control to obtain the best economic return whilst providing a standard of product or service defined (with difficulty and however coarsely) in terms of quality, time constraints, safety and so on. The findings of Pugh *et al*, confirmed by the data presented here suggest that many of their measures of formal structuring: standardisation, formalisation, degree of functional specialisms are difficult to identify and measure and are largely irrelevant to a description of the formal organisation of the contractor on site. An explanation of these findings and observations (for what Pugh described as 'implicitly structured', 'low integrated technology' organisations) is offered (here and by various commentators) by referring to the socio-economic structure of the construction industry: the nature of the product, market, and the promoters.

Formal Organisation Structure

In order to be able to assess and judge upon its effect on quality, the formal organisation structure must be measured or depicted in some way. Similarly the degree of formalisation of procedures and pursuit of the duties in the role of coordinator recommended in the Code of Practice have also to be ascertained. The studies by Pugh and the means of analysis (1963, 1976a, 1976b) were concerned with measuring, describing and comparing formal structures, and have been of assistance. The extent of work carried out by these researchers could not be replicated in this research.

Pugh *et al* were not concerned with the market or 'products' of the organisations they studied or the wider social or political contexts in which they operated. The performance efficiency of these firms was also of no concern to their studies. It was not whether the formal organisation worked effectively or not, or whether it adequately described how the organisation actually functioned, but how structures of different firms were related to the contextual variables such as size, location and technology of production. Their study (1976a) of sixty firms was widely based, including a swimming pool, a bank, a school, a food manufacturer and a car factory. Based upon statistical calculations, a firm's structure could be predicted from an assessment of various contextual factors. To some extent these claims were upheld in the replication studies reported in 1976 (1976b).

The contribution made by the Aston School cannot be underestimated. Many organisation theorists and managers had previously described and referred to the 'formal organisation', offering little help in how structures can be empirically measured and compared. They therefore faced a difficult task of determining suitable variables and then measuring them. These measures included degree of specialisation of management functions, degree of line management control, degree of routinisation, formalisation, centralisation and so on. In attempting to describe types of bureaucracy, Pugh *et al* took up Weber's definitions and typology (1947 tr.) which *prima facie* provide good descriptions. In practice Weber's model was found to be imperfect; for example, where firms were found to be highly bureaucratised in terms of specialisation of roles but were highly decentralised.

Their conclusions of relevance here are that construction sites are likely to be 'implicitly structured'. This means that there would be a low degree of specialisation of management functions and roles within those functions. Corresponding to this lack of functional personnel such as quality controllers, work study practitioners, material schedulers, personnel managers and so on, there is a reliance instead on line management control. Indeed there would be very few specialists in their terms who perform a particular non-work flow (production) function and no other. Thus for example, a falsework coordinator would only be termed specialist if he were engaged solely in the control of falsework construction. Specialist functional roles would only be expected rarely and in few numbers on only the biggest construction sites in the form of planning personnel, and coordinators for example. The role of quantity surveyor is more blurred but strictly speaking, in terms of the production process, is engaged in the 'import-export' process of production referred to by Pugh (by ensuring payment) and is as such non-specialist. The absence of specialists also points to lack of routinisation and formalisation. Pugh *et al* concluded that it is these functional personnel who generate routines and formal procedures in order to perform their task more effectively. Pugh found that the generation of such procedures led to a form of impersonal, remote control by the organisation, where subordinates complying with procedures did not need day-to-day control by line management. In those industries with high structuring the line management could effectively control a higher proportion of subordinates. In contrast the construction site would require close line management control with a lower ratio of subordinates to superordinates. The main reason for this implicitly organised *ad hoc* structure, where personnel perform a variety of roles in contrast to a highly bureaucratised car factory for example, was the difference in technology of production. Building (construction) operations were in Pugh's terms, a non-integrated technology. In contrast to a food or car factory with their high degree of mechanisation, automation, computer controlled production, and so on where failures in one operation effectively stop the whole process, the construction site is essentially non-mechanised. Each item of plant is still controlled by one man and tasks are not highly integrated. A possible exception to this general statement is a high industrialised house building product where prefabricated, standardised modules are manufactured, scheduled, delivered and then assembled on site. Their studies showed a modest trend of increasing structuring of activities with increasing workflow integration. There is a much stronger correlation between increasing workflow integration and decreasing line control, more reliance being placed upon impersonal control.

Thus in the study of formal control structures examined below, the predicted form of structure would be, according to Pugh, and construction industry practitioners, one of a high degree of line management control and few, if any (in Pugh's terms) functional specialists. Why production technologies differ and how they then affect the formal structure or how the shape and content of the structure is determined by the market and economic climate, are explicitly and justifiably not addressed by Pugh *et al.* The description of the evolution of the traditional arrangements, the contracting system and the fissiparous nature of the construction industry are well rehearsed and focus upon the role of the promoter, his project, which the promoter defines as 'unique in total concept', lack of capital-intensiveness, evolution of the professional (design) specialists and so on (for example: Ball (1988), Birch (1979), Bowley (1966), Briscoe (1988), Burrows (1986), Dolan (1979), Fellowes *et al* (1983), Ward (1979), and Winch (1987)).

Structure of Authority on Site

Given the nature of the industry and the contractual arrangements of competitive tendering, contractors adopt policies or strategies to achieve a share of the market. A range of occupational specialists have developed who, within the context of the occupational order, enable the contractor and promoter to achieve his objectives. Some means of economic control is superimposed, via the authority relationship in the case of employees, or market relationship in the case of sub-contractors and self-employed workers. Sub-contracting may be seen as a desirable economic strategy in terms of employment costs involved in providing continuous direct employment (in particular to specialist labour), productivity, cash flow and financial risk implications. Some authority relationship is still required in order to control the sub-contractor on site. Comments made by supervisory personnel indicate that the threat of contractual sanctions are of little use in day to day management of sub-contractors, and it is frequently reference to the occupational authority structure which ensures cooperation. What types of authority structures or strategies are devised by contractors?

Of fundamental importance is that all contractors are, in traditional arrangements, competing on the basis of the same design. Opportunity for discretion in the choice of labour, materials and plant is limited, particularly in building. On large scale civil engineering projects, there may be limited opportunities in the choice of construction method, selection of plant and so on. Advocates of design and construct alternatives would add that they offer possibilities for more discretion and production efficiencies to be gained. On the whole, the main area of discretion is in the level of staff to be placed on a site. In the majority of cases the staffing level is determined as a percentage overhead and is therefore related directly to value. This is an obvious generalisation and there are always departures owing to the nature of the project, the desperation of the tendering contractor, and the perceived exploitation of claims for example that determine the tender price.

The figures 1-12 at the end of the chapter give examples of the empirical evidence for this. Pugh *et al* postulated that the low integrated technology, necessitated types of structures confirmed by this data. The structures depict the close line management control, low structuring of managerial activities and lack of pure functional specialists. The only functional staff to be encountered on sites in the sample were typically the quantity surveyors, office manager and clerical staff, though even these in Pugh's terms may not be regarded as functional staff. On the very large sites, for example, Case study 30 (Fig. 12), the planning role might be regarded (in Pugh's terms) as a functional one where a specialised service of planning is provided to line management and the planner performs no other functional or production duties.

Standardised routines, documented procedures and roles etc., defined by Pugh and typically generated by functional specialists, are not devised or implemented by the line managers forming the formal organisation on site in their control of each of a number of tasks. Such measures performed by Pugh *et al* were not relevant therefore, or needed, to further measure the formal structure on sites in this study. At head office level such measures are difficult to obtain and the degree of structuring is far less than organisations of comparable size in other industries. Only the office organisations of the large scale multinational firms demonstrate the types of personnel bureaucracy described by Pugh as occurring in other industries.

Staffing levels are constrained, by competition and also the structures need to adapt to different sizes (values) of project. The data presented below confirm the study of 12 firms undertaken by Birch and Seymour (1978). In their study a variety of firms with a variety of projects were studied in relation to their administrative, (authority) structures.

Large firms and small firms adopt similar strategies in accordance with the value of the project. Reference to the sample of organisation charts (at the end of this chapter, Figs 1-12) demonstrates that the levels in the hierarchy simply increase with value. A contract of £300,000 for example, in Case No.34 (Fig.1) is staffed by a site agent, engineer and general foreman who control a variety of sub-contractors; the site agent also controls 3 other sites from this one. There is only cursory interest paid by head office. It was reported that the agent might next move on to a contract worth £5 million with a position entitled assistant project manager, where he would be responsible for a similar proportion (value, number of men, activities) of work but be subordinate to a project manager (see for example Case No. 6 structure). Case studies 4 (Fig.3) and 6 (Fig.6) are by the same main contractor. On case study number 4, a visiting contracts manager is supported by a site agent or general foreman (depending on who is being interviewed!) and a young trainee contracts manager. The company policy is to divorce the purely production (trades) function and the planning, buying and financial functions. On case study number 6, of double the value and duration, a contracts manager is resident on site and referred to as project manager and is supported by two general foremen. Two quantity surveyors are also seen as necessary on site.

Case studies No.22 (Fig.8) and 36 (Fig.9) are sites controlled by separate divisions of the same contractor operating in different areas. The site agent and section manager on site number 22 are both engineers, indicating a situation where the positions in the economic hierarchy coincide with those of the occupational order (as is also the case of site number 26 (Fig.7)). The division in case number 36 has an ex-tradesman as project manager calling on engineers to provide technical support. The parent firm of these two sites, 22 and 36 attempt to preserve some distinction between line and staff personnel in accordance with a management consultant's formal prescription some years ago.

The data on formal structures confirms the previous research of Birch and Seymour (1978). The structures may be regarded as a series of interlinked modules. Large projects incorporate several modules of hierarchical structures. An agent on one project of £5 million with 10 staff, moves to another project of £10 million as sub-agent controlling a series of sub-contracts, work packages, subordinates and so on. The economic authority structures are therefore flexible to cope with the variety of projets. In the case of large scale projects the structures resemble that of a head office of an individual company. Generally civil engineering divisions of contractors operate in such a way that the large scale civil engineering project is undertaken by a self-contained unit on site complete with the functional support activities of buying, personnel and so on performed on site and not by head office.

Data from the 54 sites indicate the preponderance of the traditional contracting arrangements referred to earlier (one site was a design and construct 'package deal', case No. 25 and one site was constructed by the Local Authority's public works department, case No. 33), although statistical representation is not claimed. Direct labour, design and build, and management fee arrangements suggest modifications to contractual relationships and economic control structures on site. For example the design engineer may be subordinate to the project manager in terms of formal (economic order) authority. Superimposed upon these formal relationships are those described by the occupational order, which it is suggested here would prescribe the nature of occupational authority, control and relationships irrespective of the formal or contractual arrangements, further research is necessary to confirm this hypothesis for other than traditional arrangements.

The figures and data describe the general, formal structure on site aimed at control of the whole production process. A separate formal structure cannot be identified for falsework/formwork since control of these activities is performed as part of line managers' general duties. A separate functional role of falsework coordinator is not identified (the coordination engineer on case study No. 16, Fig. 11 dealt with coordinating mechanical/electrical services subcontracts). The figures do indicate where choices have been made in the employment of operatives or firms to produce falsework. The formal control structure has to take account of these contractual relationships. Nine sites engaged direct labour for falsework construction; nineteen labour only sub-contractors (L.O.S.C.), and twenty six supply and fix sub-contractors (S/F.S.C.). Again such variations in market authority relationships are superimposed on the control structures, the process is described in more detail in chapter 14.

Value £ million	No. of supervisory staff on each site
<1	1,1,2,2,2,3,3,3,4,6,
1.1-2.5	1,3,3,4,5,5,6,6,7,
2.6-5.0	5,5,5,5,6,7,7,8,
5.1-10.0	5,5,6,6,7,8,8,10,
>10	9,11,11,11,20,21,25,40,

Table 1: Number of supervisory staff with respect to value range of main contract (on 42 sample sites).

Table 1, summarises data obtained from 42 sites on the authority structures depicted by the organisation charts. The figures for staff in the table denote the numbers of supervisory staff; purely functional staff are not included. Engineers are included as supervisory staff since they do not only perform a purely functional or service role, but also a production role. On none of the sites would a falsework, temporary works coordinator be defined as a functional specialist in the way defined by Pugh et al. Frequently he performs other roles (Chapter 15) also. In the same way planners are generally included in the table of supervisory, line management, staff since they are not purely functional specialists. Generally the only staff excluded are the very junior trainee engineers and quantity surveying and office administrators. In Pugh's terms the quantity surveyor performs a project import-export function, controlling payment and would not be regarded as a functional specialist. The distinction is a blurred and debatable one and for the purposes here the quantity surveyor is regarded as a functional specialist.

The figures suggest a crude linear relationship between staffing levels and value of work. The number of staff may also fluctuate in the familiar S-curve or Pareto curves as the project proceeds; the type and nature of roles tend to change.
Given the same size of job in terms of value, duration and general type of work, all contractors will adopt a very similar approach to staffing levels and supervision, and will have little choice if they are to compete for a tender. Once on site the economic order demands that the number of staff be re-appraised subject to availability and performance.

It is predicted that variations in quality between similar size sites cannot be simply explained by formal organisation structures which will be essentially the same. For example, referring to the matrix of variables in Appendix G, sites numbered 4 and 18 were of identical value, duration and staffing levels and similar in many physical respects but had different levels of quality of 'good' and 'inadequate' and wide differences in 'score' (Chapter 9). These differences cannot be explained by a different or formal organisational structure which was the same in both cases. Similarly sites 15 and 9 are also 'identical' but still achieved wide variations in quality.

Where the size of job warrants higher numbers of staff or where there is a little more opportunity for increased level of staffing relative to size of job then clearly there is potential for more control of quality and other activities. However the economic order demands that choices will be made to pursue those activities which are most economically beneficial to the contractor enterprise.
This chapter, and subsequent chapters, maintain that although the formal control structure does not ignore quality, it does not explain how quality is achieved. The 'informal' occupational order provides the means for determining the control of quality: by the performance and perception of the personnel filling the formal organisational and contractual roles. Furthermore it is this co-existent order which enables the flexible, modular formal control structures to be contemplated in the first place.

Conclusions

This chapter has applied the methodology and typology of Pugh and his colleagues to what is traditionally conceived of as 'formal organisation' and is focused on the contractor on site. In this case the economic order prescribes the objectives and character of the formal organisation and the structure is described in terms of control via the distribution of economic authority. In the construction industry the structure, predicted by Pugh, of the implicitly structured organisation using low-integrated technology is confirmed by the data. Explanations for this general non-integrated technology, and lack of capital intensiveness are based upon the interpretation of the economic order: the product, market, economic climate and so on found in references elsewhere and worthy of further research beyond the scope of this thesis. The control structure comprises low structuring of activities with absence of functional (management) specialists on site and relatively few in head office. Reliance is placed upon line management. As a consequence many of the categories and variables measured by Pugh are largely irrelevant or not identifiable. The standardisation and formality of procedures documentation, generated by the functional specialists in head office are usually confined to those relating to cost control (wages, materials, etc.) and not the production process. Line managers are expected to control the multitude of tasks which comprise the process without the need for specific procedures or detailed responsibilities for each task, and with little reliance on purely functional (managerial) specialists. Quality Assurance schemes (described in Chapter 5) are a departure from this generalisation where an attempt is made to delineate responsibilities and procedures for checking. One operation where formal control mechanisms and formalisation of procedures can be identified, measured and contrasted from site to site, is falsework (and formwork). Here the degree of formalisation (standardisation of routines and checking and documentation) can be measured and the appointment and performance of a specific role of falsework coordinator (still filled by a line manager in the vast majority of cases as described in Chapter 15) can be ascertained. Furthermore there exist standards in the form of the Code of Practice (in particular the draft Code of Practice) and some head office policies (see Appendix), written at the time of the Bragg and Draft Code Committees, which give detailed guidance and form bases for comparison. Such procedural, organisational devices encapsulated in the Code of Practice are generated, external to the particular organisation, by a group of (occupational, functional) specialists and commercially interested parties. In order to be implemented these devices would have to be accepted by those functional specialists in the head office and in particular the executive, who would also have to recognise the (economic) benefits of implementing these policies and superimposing them onto the existing formal organisation on site.

In strict formal organisation theoretical terms, the control structures on sites are essentially the same as each other. These structures have to be flexible, or modular, in order to cater for the market. Given the same size of job (particularly value), the control structure on site will be the same in terms of the number of levels and numbers of staff (line managers) in the hierarchy. This is a broad generalisation. Structures and roles will vary, of course, during the production process as tasks change and as contextual and technological variables differ from job to job. All practitioners will know that structure is one thing, the performance of individuals who operate that structure is another. The formal control structure in the case of construction reveals very little on the way the process is managed by essentially line managers with the requisite skills. Sites differ with respect to the individuals filling the respective (economic authority) roles in the hierarchy: their ability, personality, leadership skills and, of importance to this thesis, their occupational authority and nature of occupational control. Practitioners and commentators will also point to the contractual and professional arrangements which are relied upon to achieve (economic) control. These are superimposed upon the existing formal and informal arrangements. Chapters 12 and 13 have been largely concerned with the construction industry in general and site control of the overall production process. Reference has been made to how formal control of falsework might be measured and to the factors which might inhibit such formal control. The next chapter proceeds to describe the falsework/formwork production process in detail and its fissiparous nature and organisational complexity.

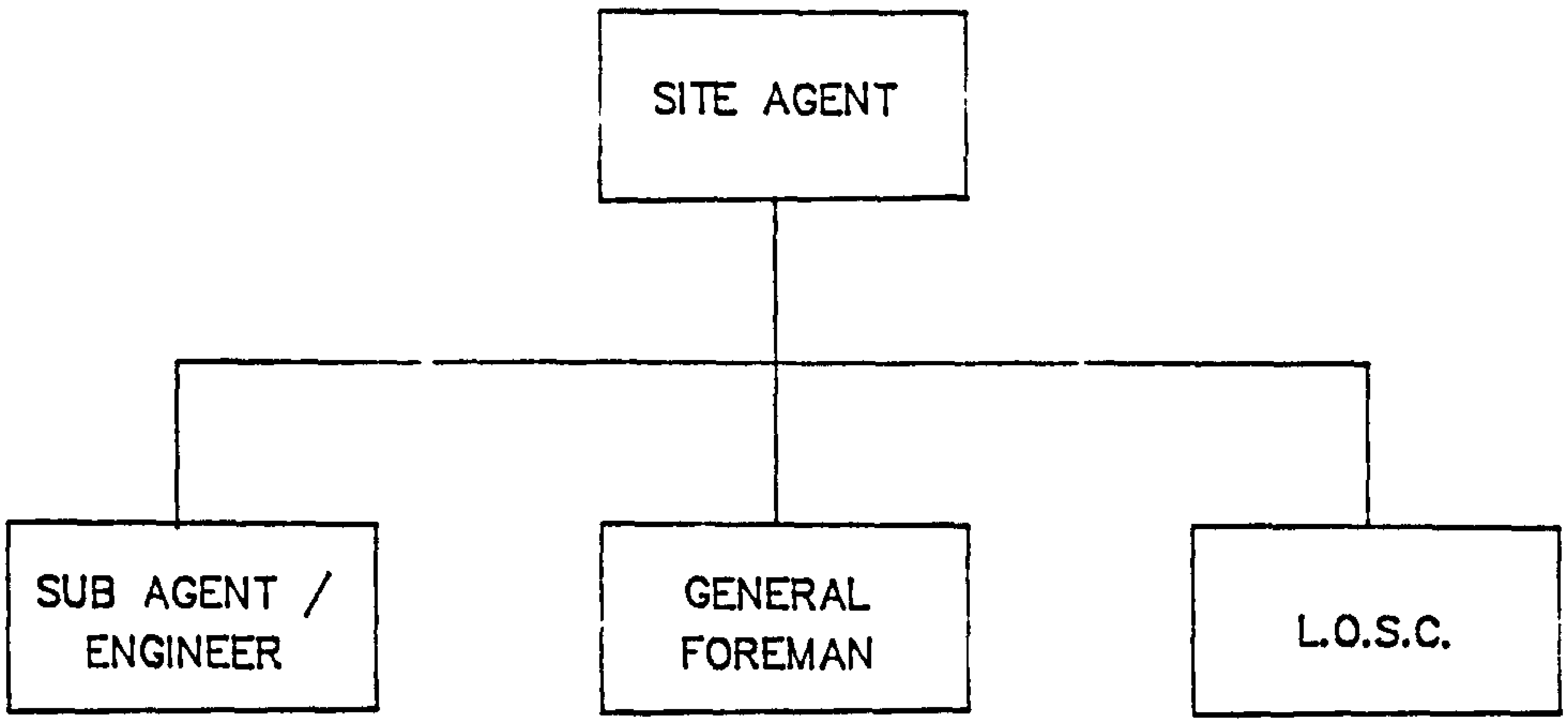

Fig. 1 : Case Study No.34 : Value 0.3 million : 21 weeks

(Note Site agent responsible for 3 other sites)

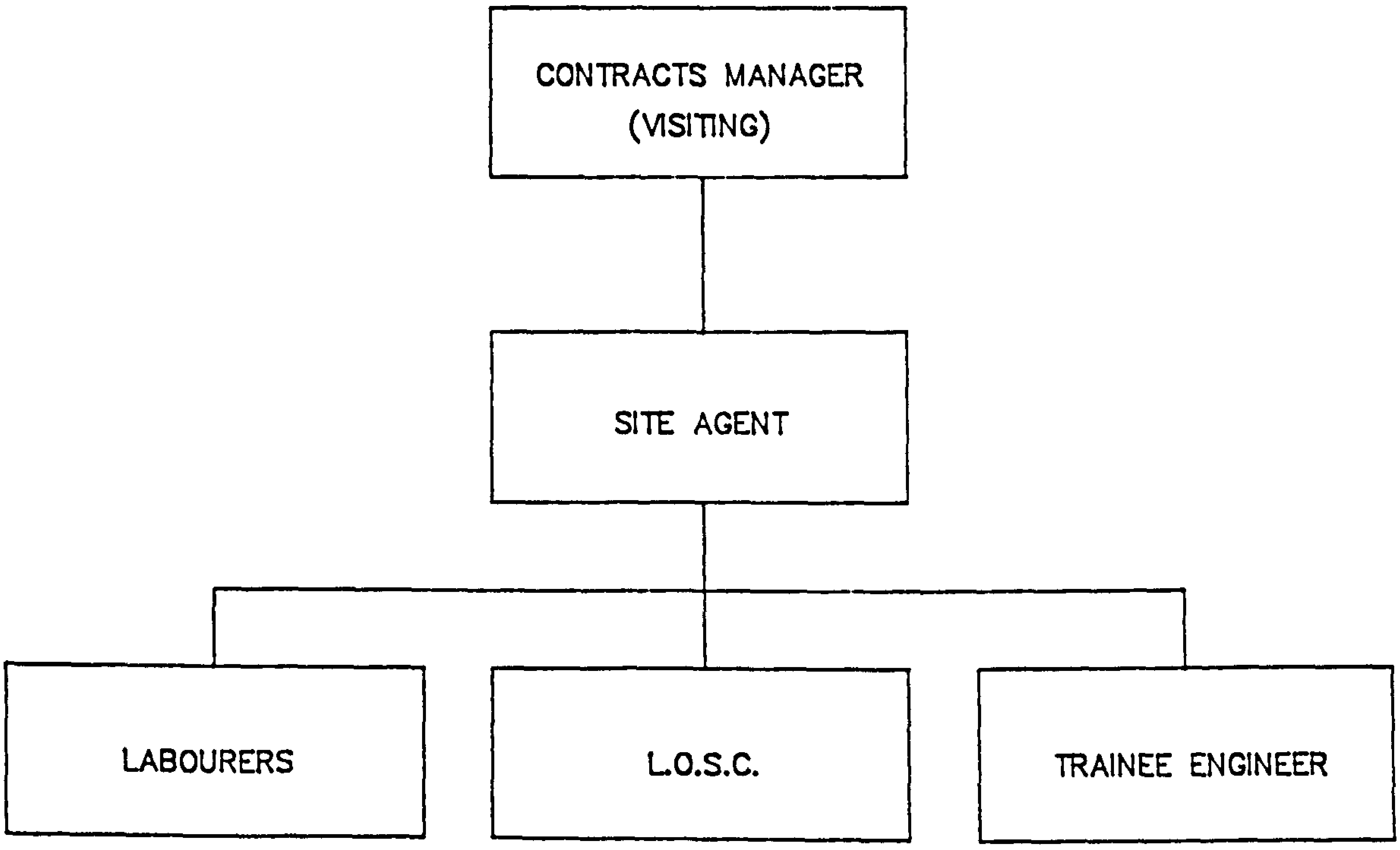

Fig. 2 : Case Study No.47 : Value 0.25 million : 40 weeks

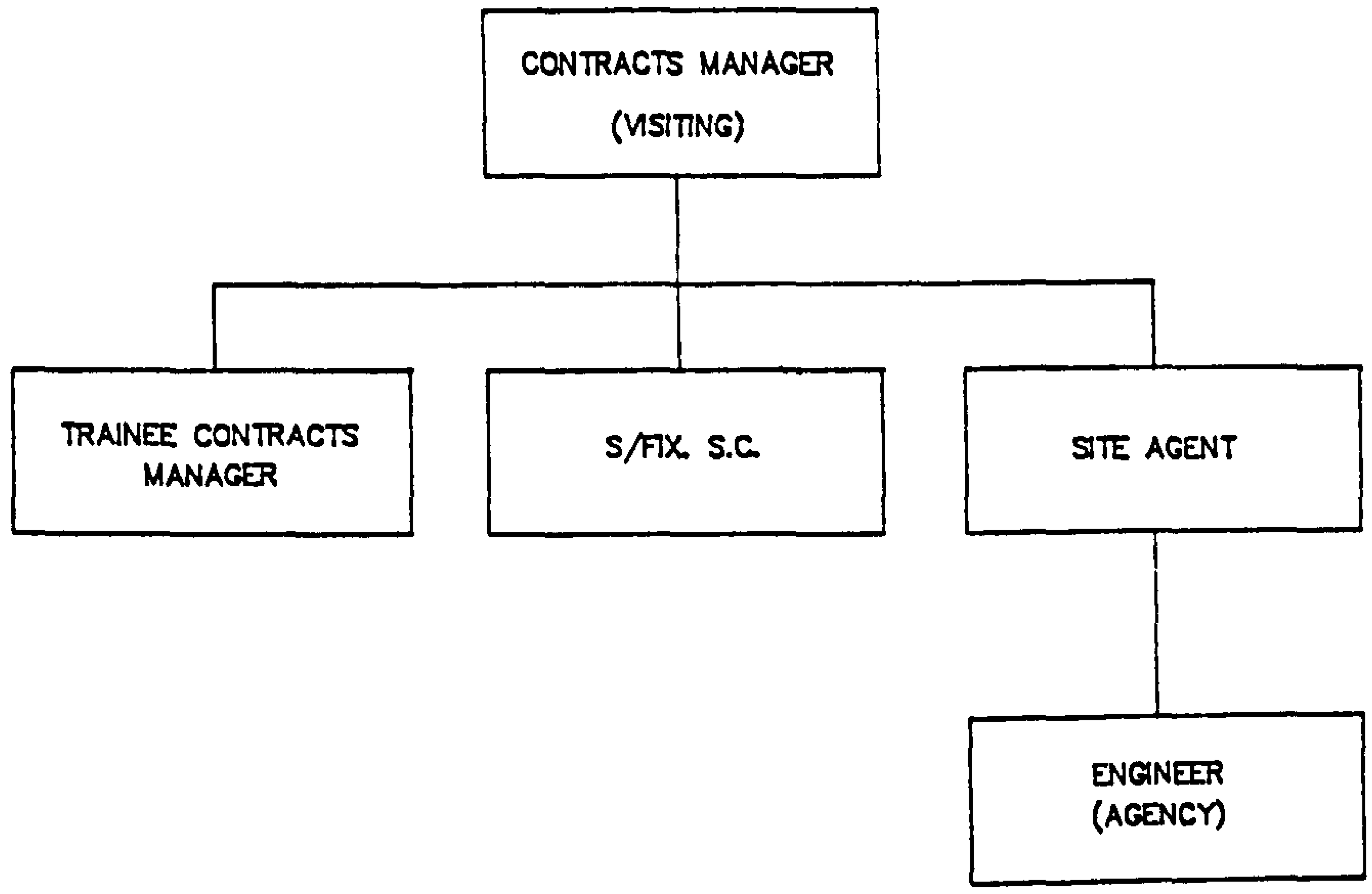

Fig. 3 : Case Study No.4 : Value 2.2 million : 70 weeks

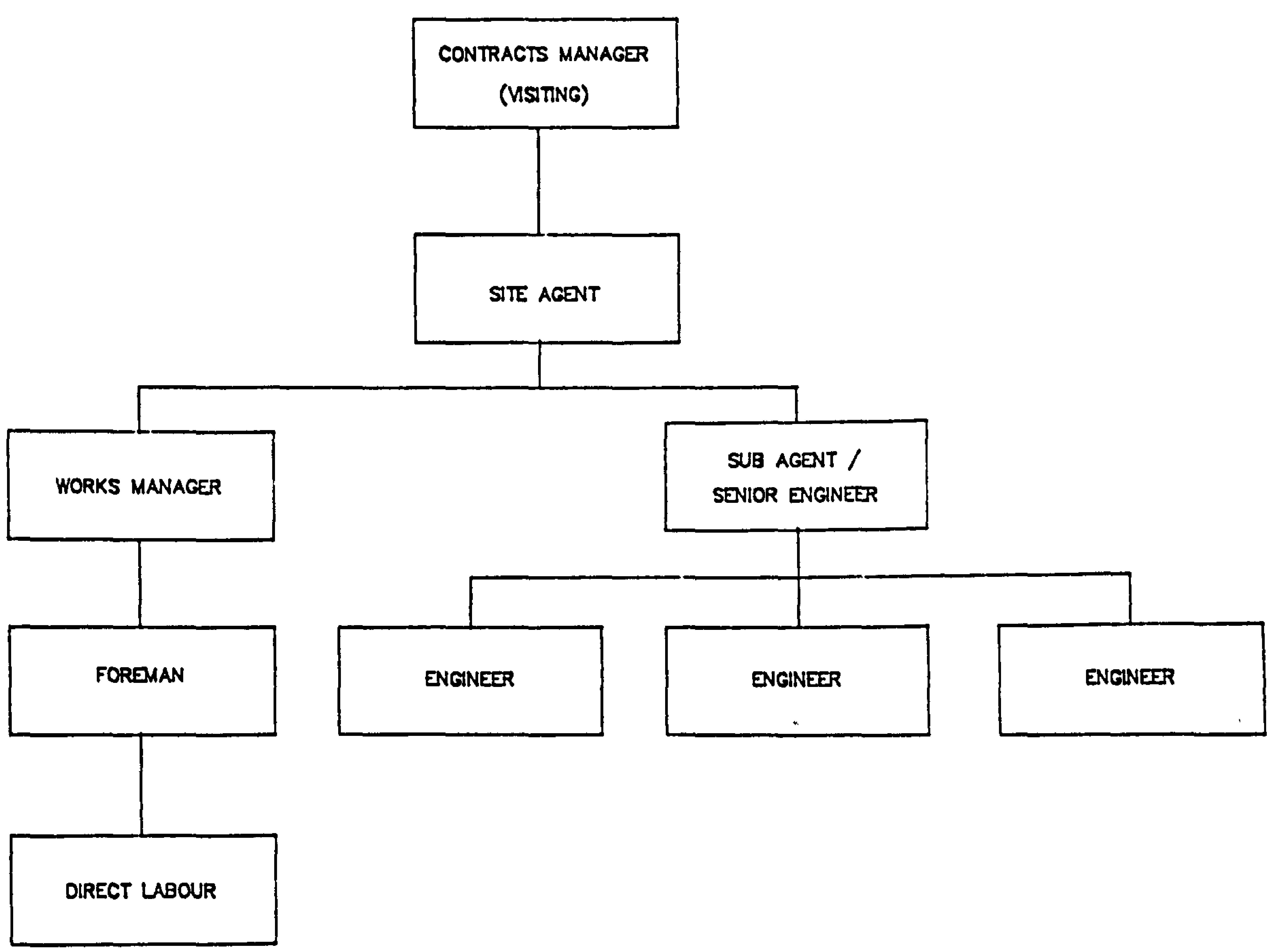

Fig. 4 : Case Study No.37 : Value 2.2 million : 80 weeks

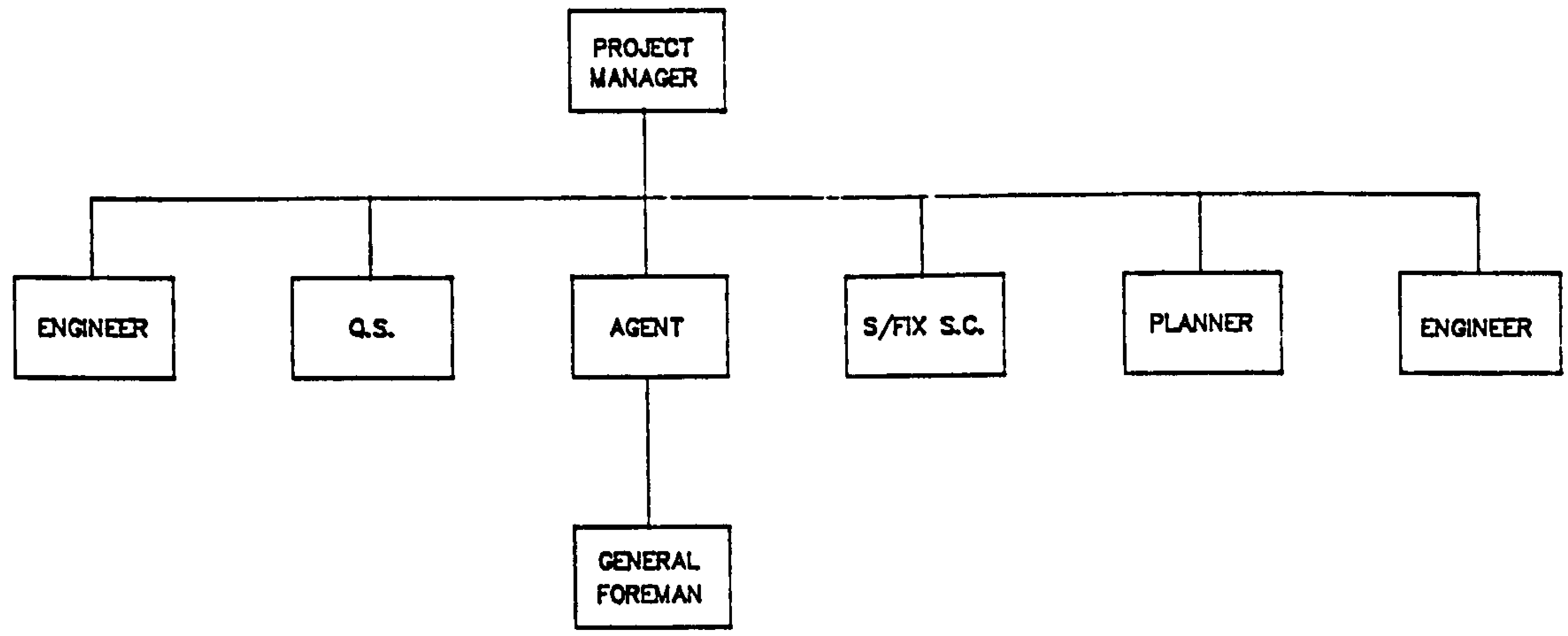

Fig. 5 : Case Study No.49 : Value 5 million : 160 weeks

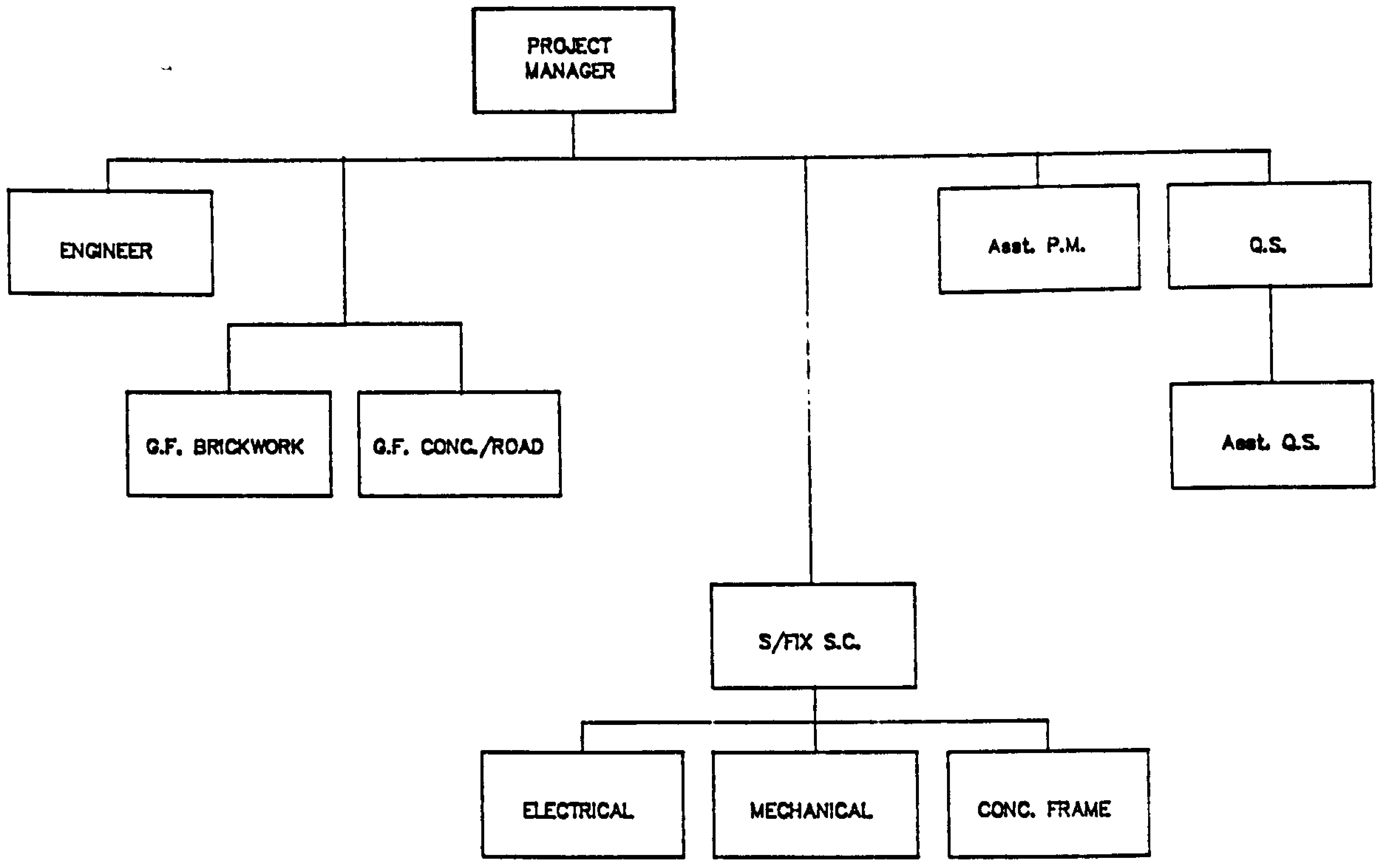

Fig. 6 : Case Study No.6 : Value 4.6 million : 150 weeks

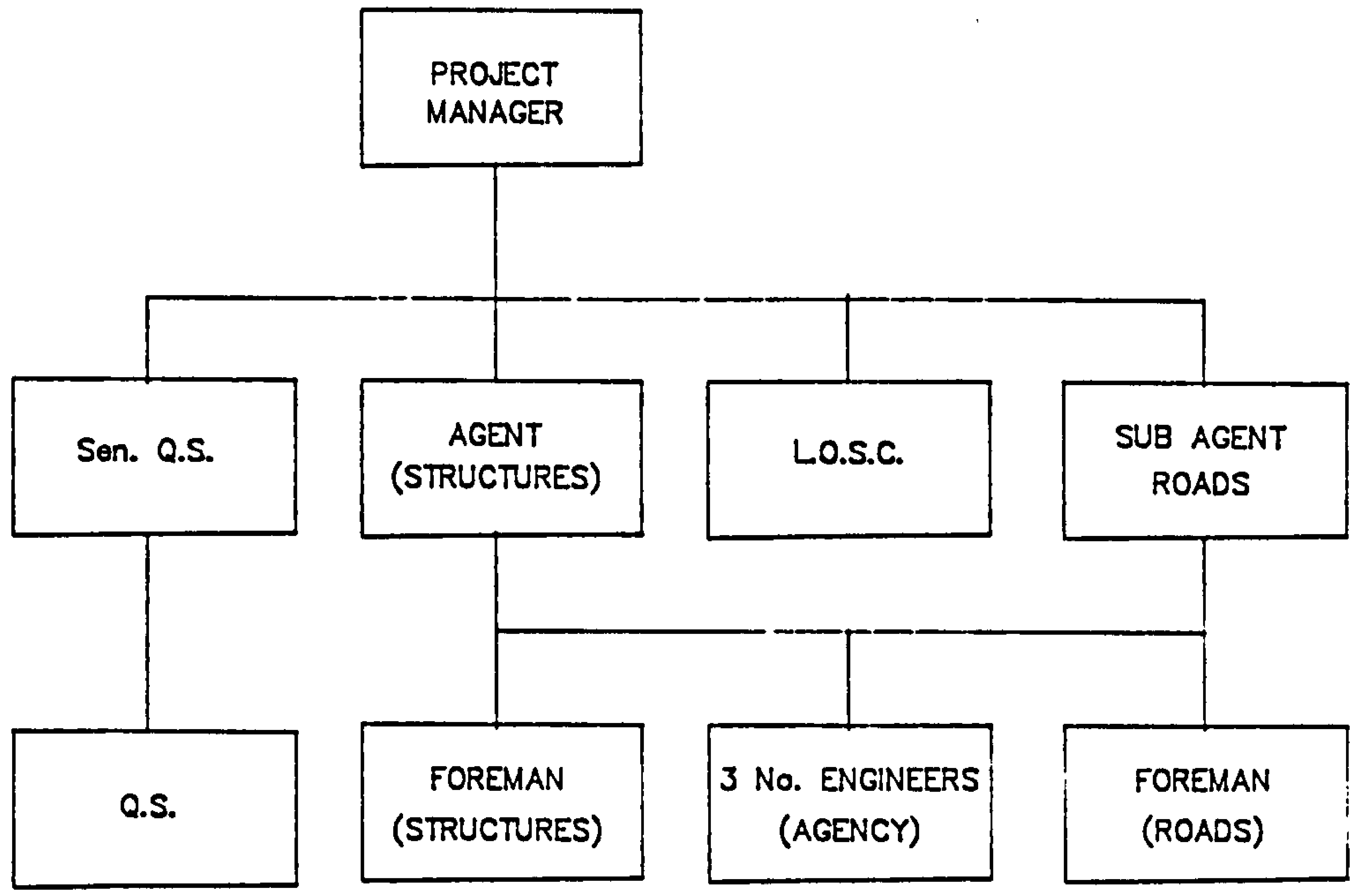

Fig. 7 : Case Study 26 : Value 3.3 million : 90 weeks

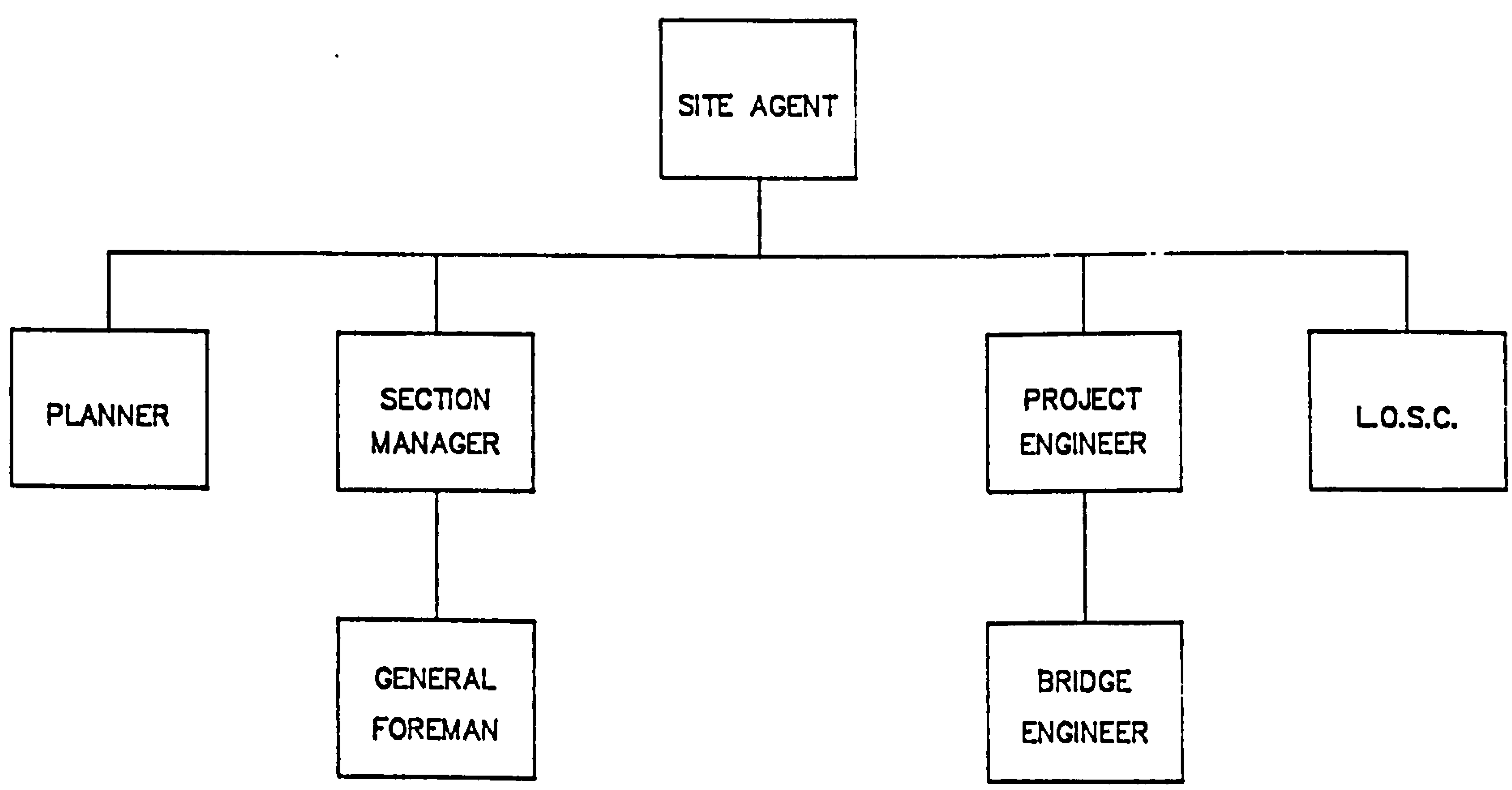

Fig. 8 : Case Study 22 : Value 4.3 million : 80 weeks

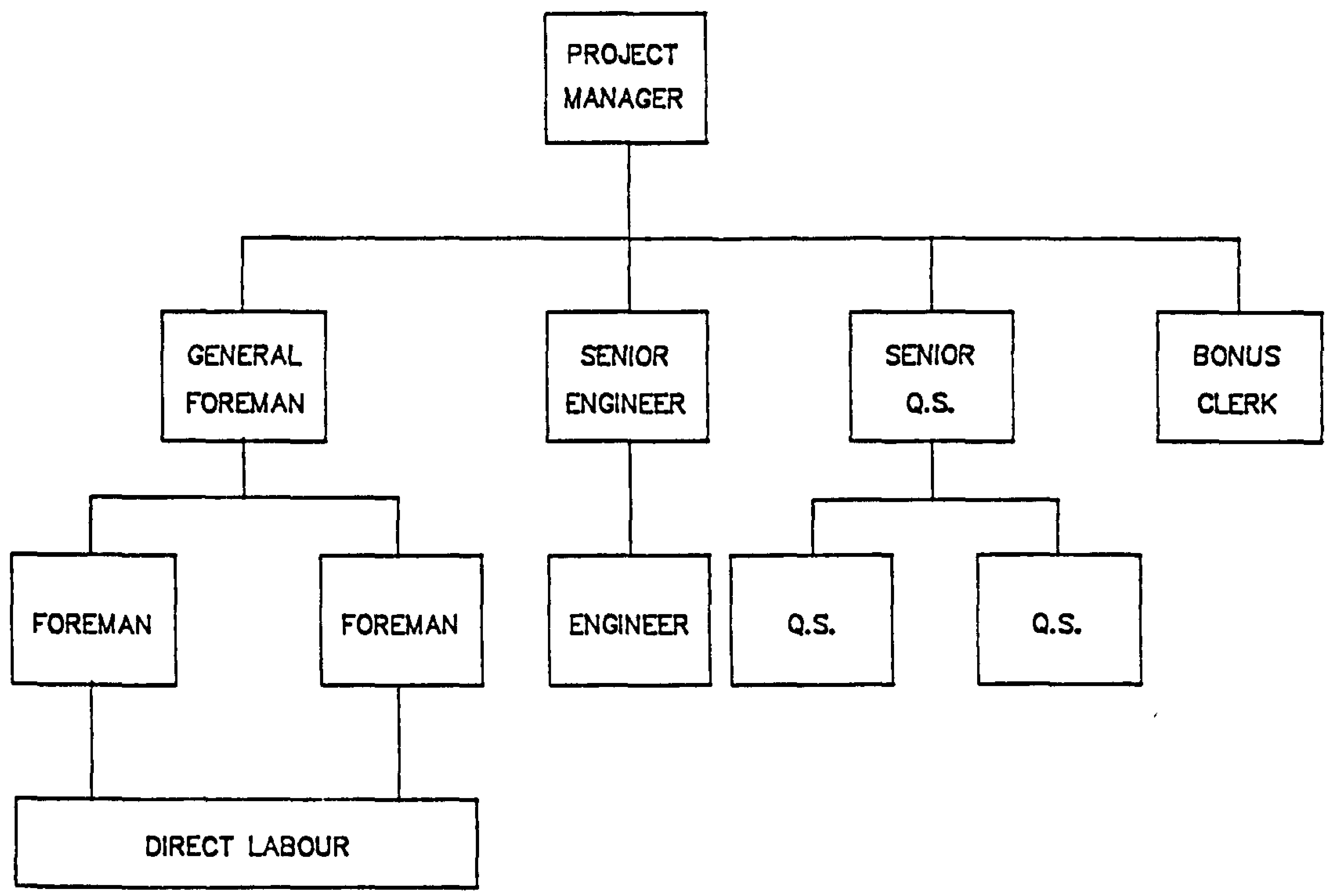

Fig. 9 : Case Study 36 : Value 5.5 million : 80 weeks

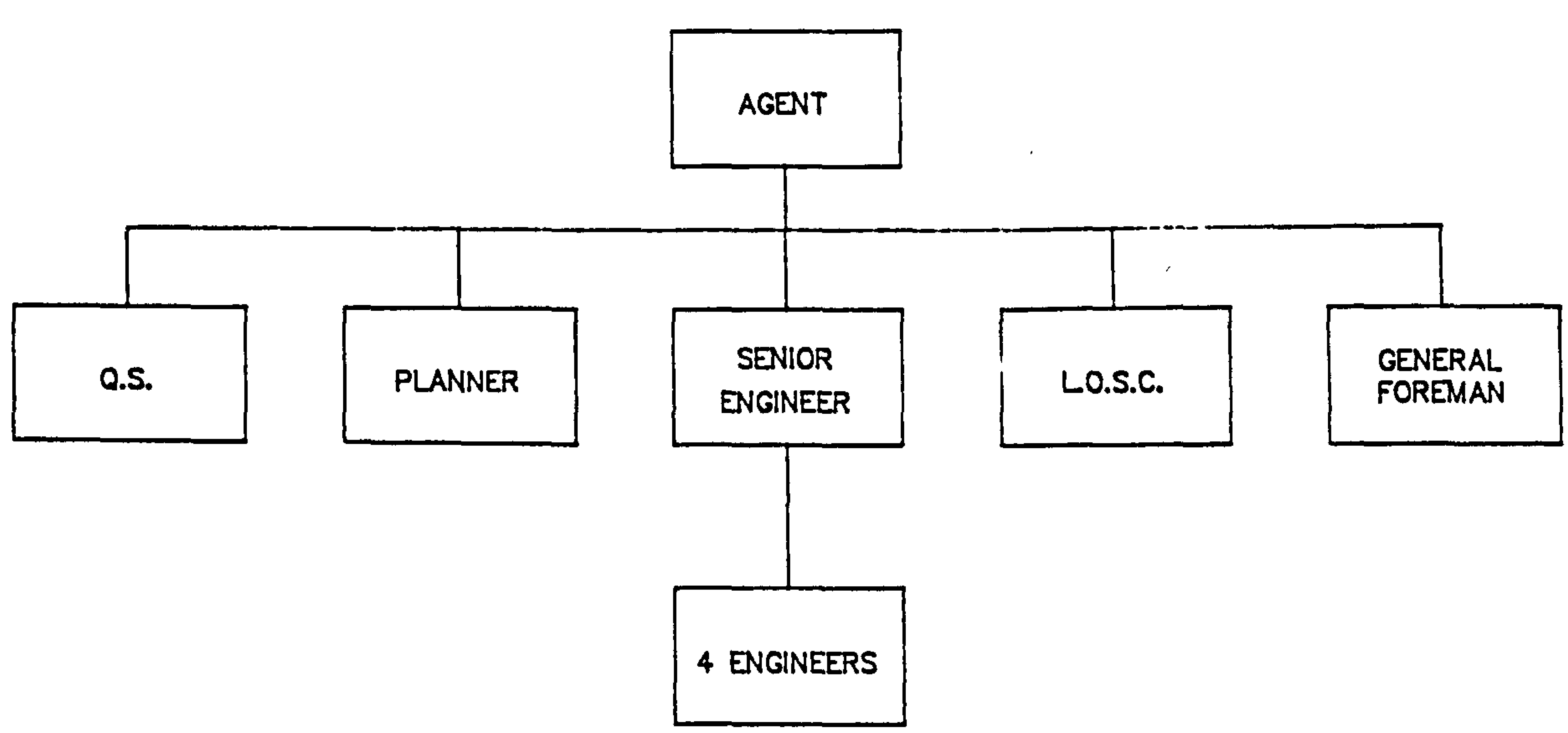

Fig. 10 : Case Study 25 : Value 8 million : 110 weeks

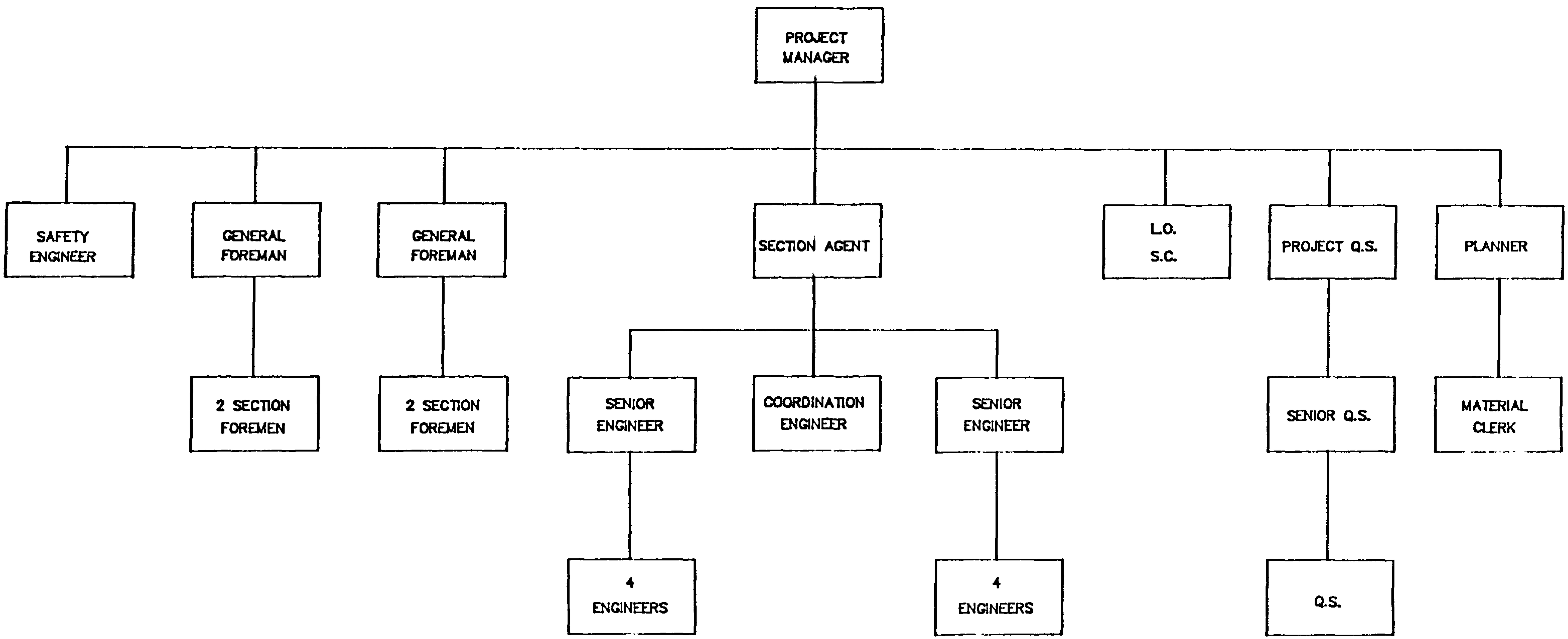

Fig. 11 : Case No.16 : Value 20 million : 180 weeks

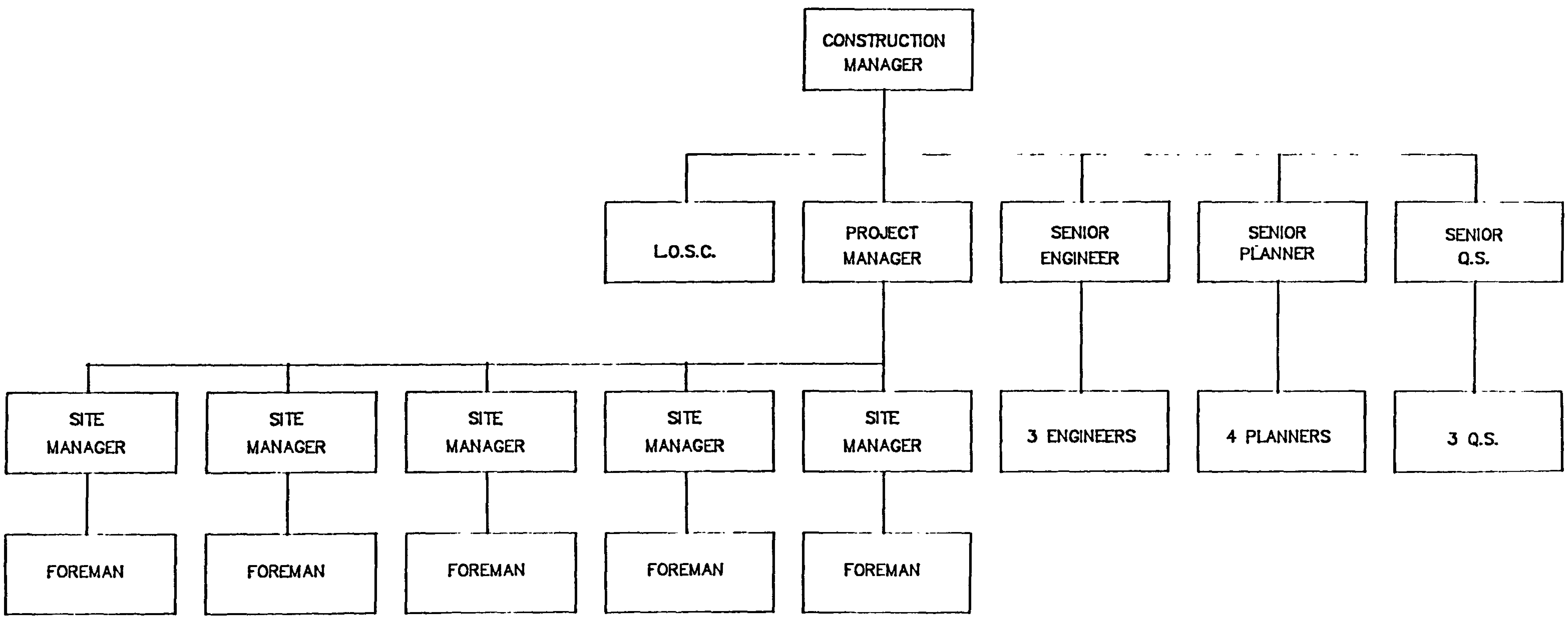

Fig. 12 : Case Study No.30 : Value 45 million : 130 weeks

CHAPTER 14

Socio-economic structure of the Falsework Production system.

Introduction

It can be argued that the fissiparous nature of the construction industry evolved as a consequence of the promoters' unique requirements. Formal (and informal) organisation has to cope with this phenomenon in order to achieve some form of control of production (quality, safety, time, economics). Economic control is achieved by authority or market relationships within and between organisations or economic units. Falsework as a microcosm of the construction industry is no exception. Just as the promoter has to translate his unique requirements into a design which has to be constructed, the constructor of falsework has to achieve the most economically rational solution. The economic sub-division in terms of management control structures applying to the general production process has already been addressed in Chapter 13. This chapter will now proceed to describe and illustrate how the falsework production process is defined and organised into tasks which are performed by a variety of workgroups and separate economic sub-units. This process generates an organisational complexity involving many legal, economic, physical, personal and organisational interfaces between workgroups and organisations, which are superimposed upon the formal structure addressed in Chapter 13. This organisational complexity poses problems of integration and control and Bragg and the Code of Practice suggest modifications to the authority (economic control) structure. Bragg also pointed to the problems of blurring responsibilities and liabilities and wide concern on training and safety due to the continued use of sub-contracting,views which are confirmed by many of the respondents here and various representative bodies.

The Falsework Industry, Process and Structure

Supply

As in the case of other industries the capital intensive formwork/falsework producers have evolved and developed products and strategies to suit the needs of a variety of projects and a variety of contractors, particularly those small contractors who could not afford to buy or develop support systems. Referring to Table 3 in Chapter 6, G.K.N/ Kwikform manufactured the equipment on 23 sites, R.M.D. on 11 sites and S.G.B. on 7 sites, the remaining 1 proprietary system being manufactured by Aluma. Although the sample is not strictly statistically representative, it is reasonable to postulate that three suppliers dominate the market for proprietary systems. The four main suppliers in the sample are continually innovating in terms of producing more of what they term 'idiot-proof' systems or cost-reducing, time-reducing systems. There is often some time-lag before some innovations are accepted; particularly when equipment has been sold previously. Thus many contractors still adopt their own tube and fittings for access scaffolding whilst the equipment is still usable; the better, quicker systems will only be used if the package of hire and (reduced) labour costs is cheaper. Referring again to Chapter 6, Table 2 indicates the dominance of proprietary systems, where 42 sites out of 54 used proprietary systems with either traditional or proprietary decking for formwork. Most innovations are taken up by those customers hiring the equipment which is by far the most common form of obtaining equipment.

Chapter 13 commented briefly upon the type of employment arrangements chosen by the main contractor. On 28 sites (9 direct labour, 19 labour only) the main contractor chose not to adopt supply and fix sub-contracting. Of these 28 sites, the main contractor chose to hire equipment on 16 and on 12 he chose to use his own stocks of equipment (11 sites using systems, 1 site using adjustable steel props). Of the sample of sites, the supply and fix sub-contractor rarely owned proprietary systems (on 2 sites out of 18) but owned the adjustable steel props or tubes and fittings used (7 sites and 1 site respectively). The vast majority of supply and fix sub-contractors are merely extensions of labour only firms who simply hire the equipment from suppliers and can

receive a design performed by them. They do not have to employ their own designers and rarely do so.
In common with other industries, the construction industry in recent years uses, in everyday language, the notion of the 'specialist'. The term is used more and more frequently to denote a sub-contractor or individual with some skill or expertise or to infer that skill or expertise exists. The term 'specialist' is misleading since its use, generally in the construction statistics and by commentators, includes for example, the supply and fix sub-contractors in the heating and ventilation, electrical and plumbing sectors of the industry. These sectors are quite often divisions of a highly capital intensive industry and comprise firms which perform work in other industries apart from construction. Many of these specialists are major contractors in their own right. Many specialists can assume stable workloads, and can adopt capital intensive, standardised techniques of production; they also tend to engage employees rather than self-employed, or labour only operatives.

Many of these specialists can be truly regarded as bonafide sub-contractors; they and the small jobbing builder largely account for the training of the apprentice trades in the construction industry. The supply and fix or labour only sub-contractor engaged in formwork and falsework can hardly be regarded in the same light in terms of capital commitments, training and employment, or as a specialist (see below).

Suppliers, when introducing a type of equipment must offer a design service also. Contractors cannot be expected to be experts in design using new types of equipment, or have access to the confidential test results held by the supplier. A number of suppliers in the early days of systems also offered a free service to train personnel on site in the use of their equipment, and that today is still a (albeit rare) possibility. The 'free' design and other services are seen as part of a necessary marketing strategy, which also encourages the development of supply and fix subcontracting.

The falsework process *prima facie* is quite a simple one; the contractor has to procure a design, construct and dismantle in the shortest time, to the required (minimum) level of concrete finish in the most economical way. At each stage in the process there are points where control of production and quality have to be monitored and controlled. The existence of suppliers or sub-contractors who can supply, design and erect the structure of formwork means that the contractor is faced with a multitude of options and organisations by which to achieve his objectives.

Subcontracting

In the sample of 54 case studies the main contractor chose to adopt labour only sub-contracting on 19 sites and supply and fix on 26 sites. The sub-contractor too may sub-contract packages of work, for example on 4 of the 26 supply and fix sites a specialist labour only falsework sub-contractor was employed. In addition to these formal sub-sub-contracts, there are a variety of employment or piece work arrangements open for the labour only or supply and fix sub-contractor.
Choices are made on the basis of economic rationality. Frequently explanations of the phenomenon of subcontracting are based upon market considerations and the costs of providing continuity of capital (use of plant, equipment and materials) and 'specialised' labour (required by emerging technology). Such arguments do not provide adequate explanations in the case of formwork and falsework (nor arguably for many other tasks). Falsework and formwork do not require much investment in capital in view of the facility for the hiring of equipment or (new) specialised skills in design (furnished by the supplier if needed. In terms of labour (and its costs) the erection of falsework (and formwork) has become a common, traditional operation. The types of skill necessary are not new skills but essentially those of the traditional joiner or scaffolder which have been modified (Appendix L). The falsework subcontractors (below) are not specialists in new skills and new tasks brought about by developments in technology (Like those for example subsumed under the general heading 'mechanical and electrical' such as plumbing, telecommunications, lift installation, refrigeration etc., which all require capital too. Other new developments such as curtain walling, suspended ceilings and raised computer flooring, in the author's opinion do not require new skills but slightly modified ones - those of a 'second fix' carpenter in these cases). It is postulated that major contractors should be able to guarantee continuity for common occupations and operations such as falsework (formwork). Respondents from main

contractors point to the difficulty of recruiting, and paying for the necessary expertise. Winch (1987) argues that subcontracting has little to do with labour shortages and workload but more to do with employment costs, flexibility (ease of hiring/firing) and productivity. Evans and Lewis (1987) report in their study that several contractors reported savings over employment of direct employees due to overheads and increased productivity, of between 20% and 30%. In the case of formwork and falsework typically the subcontract firms are organised on the basis of working proprietors (directors) who are ex-tradesmen (usually ex-joiners). These proprietors recruit and supervise and control the workers directly on site. They therefore have close knowledge of the ability of personnel and know the local labour market in terms of ability and cost of personnel. They can adopt flexible *ad hoc* piecework productivity arrangements backed up by the sanction of immediate dismissal. Frequently the subcontractors rely upon subcontracting to labour only firms, in the majority of cases to self employed individuals. Some subcontract firms employ a core of direct employees. It is generally held that it is not economically rational or logistically practicable for the subcontractor (like the main contractor) to train non-directly employed personnel. In direct employment the main contractor and subcontractor alike typically resort to 'pay and poach' strategies rather than invest in training (Winch, Evans and Lewis *op cit*, Briscoe (1989)). One of the larger supply and fix firms in this study was proud to announce that they had started two apprentices and there was no evidence of any other firm with apprentices.

Functional specialists in subcontractor organisations are limited to an office manager (usually referred to as the company secretary) and a quantity surveyor. In all but the largest of subcontractors the quantity surveyor is employed on a 'freelance' basis to estimate work; it is only when workload increases and sites become more diversified that constant work for a surveyor can be justified in measuring work and negotiating payments and estimating. These subcontractors (labour only and supply and fix) are not small in terms of turnover, for example a number in the sample achieve figures in excess of £3 million per annum, and some in excess of £10 million, and two firms are major contractors in their own right; their overhead costs and engineering expertise are still minimal. In terms of employment of operatives the subcontractors cannot be regarded as small, many engaging 70 or more in a mixture of employment arrangements. The quotations below illustrate the productivity, flexibility and cost implications:

> "Cost for cost the self-employed man will outpace a P.A.Y.E. man any day; once a man is self-employed he is dependent upon his own ability to keep his job and keep being paid. Pay more money ie. wages but by the time you've totalled up holidays with pay, guaranteed bonus, national insurance, payment for 'wet time', etc. it comes out better ie. as cheap or cheaper, especially when you consider the better production you get...also he's under a bit more pressure...the same pressure as we are as a company to the main contractor - he's a self-employed man - if he doesn't perform he goes, if we don't perform we go, the direct man is not under that type of pressure."
>
> (Sub-contract director)

> "...generally I would say that sub-contractors <u>are</u> faster than direct labour, but having said that when we look at a contract we put say ten of our direct men on the site - we know their capabilities, we know that they are not going to do anything stupid... and they're going to put the equipment up correctly etc., to the drawings, they're not going to cut any corners, they're going to provide a <u>quality</u> product in other words. The sub-contractor (self-employed) will not always do this because it's pound notes, so we mix them, the subbies put the pace in it, the direct labour making sure that the thing works, and it (the arrangement) works quite well actually."
>
> (Sub-contractor director.)

> "with the situation of our labour force at the moment of direct and sub-contractors, it is relatively easy to have a floating labour situation - naturally when you have a big job coming to an end you get men leaving anyway, they go down the road because there is another job starting - they work their own security out, they don't just stand there until the last nail is knocked in and then ask themselves where they are going - we're always being asked the question "Where are you going to next - have you got any work in?" If your turnover starts to fall your labour drifts away, they'll come back to you, I'm talking about sub-contractors. This is why it's very good to have sub-contractors from our point of view, like the main contractor sub-contracts his work to us, we have to do likewise - the tail-end of our workforce has to have this buffer situation, it secures our direct labour."
>
> (Sub-contractor director)

Whilst the considerations of direct employment costs, productivity and so on are important and dominate most of any explanations of the phenomenon, there other economic benefits to be derived. More detailed explanation is given elsewhere

(Burrows 1984, 1988) where a fuller acknowledgement is given to the views of the subcontractors themselves. These are addressed briefly below, illustrated by comments.

The subcontractor who knows the labour market intimately acts as a recruitment agency for the main contractor who thus avoids the task of the traditional general foreman, of recruiting and assessing the labour on site. In practice respondents express frustrations over the daily fluctuations in number and quality of the operatives attending site.

> "With sub-contractors you might have three men here one day, then one the next. You ask them why, and they say they've had a rush job on somewhere else."
> (Sub-agent).

The above is an expression of the loss of economic control in exchange for market control.

The subcontractor also offers a (free) pricing and estimating service to the main and subcontractor.
For example:

> "We get tenders from regulars and price new ones four times; if we don't hear anything after four jobs then we don't price any more - we're not a tendering service."
>
> (Sub-contractor director)

> "We find that we get our work in formwork from the same half dozen contractors. We quote for many others, they use our prices as a check for their own or to negotiate with their regular sub-contractors who don't price their own work."
>
> (Sub-contractor director).

If successful in winning a tender the main contractor has a wider choice of arrangements and different organisations who then know their commitments and who may be desperate for work, and negotiations on prices (improvements in margins) can commence:

"Generally a contractor will not place an order with us when somebody else is offering to do it cheaper. This might not be strictly true even if they say this, they've gone in on our rates and probably want us to do the job, we have a reputation and they know that we will respond, but they try to get a little bit more and our profits drop. This is when you're in a dilemma, do you want the job? How far do you go in reducing your prices? etc. - It's the buyer who is involved now, it's passed from the estimator to the buying department - unless it's a small company and it's the same person. The estimator says "Yes, we've gone in on your rates." and the buyer then starts to turn the screw and increase their profits! This is also the stage when a lot of other sub-contractors come in, they don't get involved as early as us, they hear who has got the job then enquire, they've already cut a great slice of overhead out. Some cases they say 'We'll do it for whatever you tell us we've got to do it for.'"

(Sub-contractor director).

"On a job this size you go to the firm which firstly has a reputation and secondly he's got to be competitive or cheapest and this involves bartering. Of course if he's coming to the end of a job and is looking for work he's going to be more competitive. The firm here, we use quite a lot, they're cheap. If another firm was say £10,000 lower then we'd ask these to go back and look at their own rates because they were not the cheapest."

(Contracts manager-main contractor).

The evidence suggests that the estimating process by the subcontractor is very 'hit and miss' and largely based on desperation tactics, and he makes the best out of the resulting contract :

"He (the free-lance Q.S.)probably says 'Well how desperate are you?' and if I'm running out I tell him - he'll try and get the job - spend more time - try to cut corners and make it a fine price. He's a professional so...we've changed estimators, we've had three over the last twelve months, we've thought their prices are too high."
(Sub-contractor director).

The inference here is that the estimator's performance is based on winning the job and not in determining the right price; the right price is the market price and the sub-contractor has to work to that price. That is:

Once we know the price, the time allowed, the number of men and our costs every week, we know how much we have to do each week and make sure we get work out of the men."

(Sub-contractor director above).

Another, relatively minor,advantage of subcontracting is the consideration of working capital (cash flow).The requirements for working capital are minimal in the construction industry (facility of plant-hire, interim payments etc.), and this is further encouraged in the provision of falsework and formwork, by the facility for hiring, which is paid for on credit, unless some form of bond is required for the more disreputable customers.

By employing sub-contractors the main contractor is further reducing his working capital requirements. This he achieves by undermeasuring the sub-contractor, withholding retention (a perfectly legitimate and acceptable practice in the industry and applied to the main contractor too) and paying the sub-contractor monthly in arrears. This practice is contrasted to where direct employees have to be paid weekly, in total without any stoppages.

The main contractor has to exercise care that his payment strategies are not too severe, and he may relax his methods in the case of small sub-contractors to avoid their bankruptcy.

Perhaps the most important explanation for the phenomenon of subcontracting in general and with particular reference to formwork and falsework lies in the allocation of risk and uncertainty. The economic, financial considerations referred to above can be better documented in terms of the distribution of risk, control and uncertainty. Financial risk is expertly summarised by one supply and fix sub-contractor:

> "Firstly he passes on the financial risk. If the contract runs off programme for any reason, other than exclusions in the actual sub-contract agreement, if there are particular labour problems in an area, it takes that risk out - in other words the contractor will gladly pass on any liquidated damages to the poor little sub-contractor - so the general contractor becomes in effect a management team which is the way general contractors are leaning any way...(quasi-management contracting)...also it reduces the overheads in that they aren't carrying any spare labour between contracts, they are <u>leasing</u> out a section of their works at a price they know at the outset, they can apply their profits and overheads, and very rarely do they lose out on that, if there's any loss to be made along the line, then it's the sub-contractor that makes it - not the general contractor - so in the days of working on much lower profit margins, then although they are working on these lower margins, it is a much more guaranteed profit margin, and that is basically why so much sub-contracting is going on today."
>
> (His emphasis)

The main contractor can never pass on his total contractual risk and responsibilities and could never recoup the whole of his (legally questionable) liquidated damages or damages for breach of contract. But evidence gained from interviews with subcontractors shows that the main contractor manages to pass on a good deal of perceived responsibility.

In the case of a supply and fix sub-contract the main contractor exchanges all of his economic authority for an authority relationship derived from the market. Thus he loses control of how the sub-contract is performed, but has the advantage of a programme and no worries about material wastage and usage. In the case of labour only sub-contracting some control is still possible over the programme of work and upon which activities take place, due to the control over the provision of material by the main contractor who decides what type and quantity of material and when it is delivered. Control over how many workers are on site and where they work is performed by the sub-contractor foreman, and not directly by the main contractor. The main contractor's concern about control frequently centres upon these matters and the lack of economic authority control over the competence of the workers or quality of their work. In reality the control by the market does not work in terms of the day to day relationships, but occupational control, although curtailed by the contractual market relationship, is still possible and ensures cooperation between contractors, sub-contractors and the workforce.

Of note to the hypothesis of this thesis is that only one of eleven civil engineering sites in the sample chose to employ supply and fix subcontractors (in contrast to 25 of 43 building sites); the reason for this is explained later but centres upon the nature of occupational control in civil engineering.

There is evidence, supported by the data of this study and the views of respondents, that subcontracting in general (which has been a traditional, identifiable feature of the construction industry in contrast to other industries) has increased over the last decade or so (Briscoe (1988), Leopold (1982), Hillebrandt (1984), Rainbird (1987,1988), Winch (1988), Langford and Chan (1987), Chalk (1984), Evans and Lewis (1987). These studies are not confined to the economic rationales and also point to deliberate government intervention by regulation and deregulation and the effects upon direct labour organisations and unions and the consequences for industrial relations, and (particularly for this study) training. The phenomenon and fears of the consequences in terms of training and collective bargaining are not restricted to the United Kingdom construction industry, for example in France: Bobroff (1989), Campagnac (1989), Italy: Villa (1988), West Germany: Weis (1987), Syben (1988), nor restricted to United Kingdom industry in general where cleaning, catering, transport, manufacturing, engineering and business services, apart from the construction industry use a variety of subcontractors, outworkers and self-employed personnel, (Rajan and Pearson (1987), Hakim (1985), Atkinson (1984), Marginson *et al* (1988), Pollert (1987).

The practice of subcontracting brings the problems, frequently reported by practitioners and commentators and echoed by the respondents interviewed, of control of productivity, quality, safety, site attendance and so on. Of particular relevance to this thesis where competence of those in positions of occupational authority is the crucial assumption of the occupational order (Chapter 16), is the provision of trained, competent personnel. Subcontracting by the main (and sub) contractors to predominately self-employed individuals prohibits formal or informal training. In cases where men are directly employed the vast majority of the falsework/formwork subcontractors known by the author and interviewed in the study do not avail themselves of the C.I.T.B. formal schemes and courses. Despite their having to pay a levy, it is not economic or practicable in short, medium productivity terms (since 1987 labour only subcontractors can no longer avoid a contribution to C.I.T.B., a percentage is deducted from the invoiced payment to the subcontractor which is forwarded to the C.I.T.B.), the same appears to be true for the main contractor (H.M.S.O. (1987), C.I.T.B. (1987), C.I.M.B. (1980)). On the job training, and informal 'master-pupil' relationships are not practicable (bearing in mind the mobility of personnel and variability of work and location), nor economic, particularly where self-employed or labour only personnel are engaged. The employer has to obtain the best economic returns from the personnel available and does not expect to have to train. The main contractor and the subcontractor alike engage personnel and devise the appropriate controls deemed necessary for the competence available or assumed. The evidence of this study would suggest that the competence assumed necessary in falsework/formwork may not be that high, bearing in mind the technology of the equipment. (Appendix L, Chapter 16). What is of concern to this thesis is that given the various standards of competence demonstrated in the sample studies (all but the lowest category of ability had served some formal apprenticeships or had been exposed to good practice for some time), these are likely to get worse as the lack of training begins to manifest itself, people retire, and workloads increase. Training is dealt with in more detail by Briscoe (1988), Rainbird and Clarke (1988) and Rainbird (1987). Their fears of skill shortages are now being echoed by practitioners who for example are calling for modular training (N.C.E. 1988).

The comments below, made during 1985/86 predicted the consequences of subcontracting and skill shortages.

> "Obviously sub-contracting might have a long term detrimental effect on the industry, because there are not the formal apprenticeships there used to be."
>
> (Project manager).

> "I suppose there will be a problem in future. Yes, I find problems now getting good blokes. It's for industry to sort out not a small subbie like me."
>
> (Sub-contractor director).

> "So these smaller units, labour only sub-contractors, small is beautiful, perhaps, manage to get the output. But we've also abrogated our responsibilities as managers and employers. If you look further along the line it's got to fail like management contracting, it's going to fail, because we've become more and more divorced from doing the work; less and less training, less and less input into the thing itself. So whereas in the short term it's got to be perhaps the only way we can go on working at the present time, it isn't going to be good for us in ten years time."
>
> (Site manager).

The site manager above goes on to say that these problems of training also extend to those in supervision; in that engineers and other trainee supervisors are unable to gain experience from the traditional foremen who are now being no longer required or available due to the practice of sub-contracting.

Design

There are choices to be made by the main contractor on whether to use his own material or hire it (already noted). These decisions will have an effect on who performs the design. The main contractor may produce his own design, use a consultant, rely on the supply and fix arrangement or obtain a 'free' design from the supplier. The supply and fix sub-contractor faces similar decisions.

On the 12 sites where the main contractor used his own equipment, 10 of the 11 using proprietary systems had some form of formalised design produced. Six of these designs were performed by the supplier as a 'free' design owing to the fact that the main contractor owned a great deal of equipment and also hired a great deal from time to time and had therefore some commercial advantage. It is not always a matter of strict economic, commercial bargaining but one of compromise of workload where many structures are involved (see below). On one supply and fix site, the sub-contractor performed the design himself using his own proprietary system equipment. On another, the supply and fix sub-contractor also relied on the free design service while using his own equipment. Any equipment which is hired will generally include a design scheme, unless an odd quantity of props are ordered for the support of infill panels.

Added to these decisions and arrangements for design, supply and erection of falsework, are similar ones concerning formwork. Formwork may be an entirely separate series of tasks. The distinction or dividing line between formwork and falsework in practice is difficult to draw. The bill of quantities and method of measurement make no distinction (Chapter 2) nor do many sub-contract agreements. In order to describe the organisational complexity of the falsework process which makes coordination difficult, the formwork process must also be addressed. The design of the formwork must affect that of the falsework and the performance of the finished structure. If these tasks are performed by separate groups, separate economic units and involve separate suppliers then there will be problems in coordinating and integrating the various interfaces. Such divisions also take place in the erection process. The boundary between where falsework ends and formwork starts is clear from a purely technical description given in Chapter 2, but not so in practice. In terms of task, and contractual liability the supplier's definition may differ from that of a designer(s) which may differ from that of the workgroup(s) erecting the structure.

For example the designer of proprietary systems may design up to the level of the forkheads, and down to the level of the baseplate. The design and erection and supply of formwork beams, decking, sleepers and foundation materials firmly lie elsewhere and the supplier-designer is careful to state the limits of his liability. (The designer will need to know of course, or assume the type of beams to be used in order to arrive at a sensible, safe grid layout. This necessitates the full comprehensive design brief recommended by Bragg and the Code which in practice however, is rare and leads to problems in achieving this interaction, integration of formwork and falsework design, site requirements and so on). In the case in the design/supply of proprietary system and decking, the layout of the decking beams will be included in the overall design of the falsework, and perhaps include the rest of the formwork decking, moulds and so on (but rarely the plywood).

Task Fragmentation and Specialisation

The erection of falsework on site may not be divided into the same tasks, either contractually (i.e. sub-contracts) or by group, as the design or supply. The same group of erectors may erect the whole structure including all the decking, formwork and edge beams (particularly where proprietary systems/decking is used). Alternatively falsework erection might comprise one group erecting the structure and another placing the primary beams or bearers and levelling the deck, the second group therefore have an effect on the adjustment of jacks, and fixity and layout (eccentricity) of the bearers.

There are clearly a number of contractual, economic and organisational interfaces involved. In order to describe the degree of organisational complexity, two variables were measured in the data: 'Task group specialisation' and 'Fragmentation'. Specialisation cannot be described in such a precise way as that by Pugh et al (1976a, 1976b).

In task group specialisation, scores are given based on a direct measure of the number of clearly identifiable separate workgroups amongst which the total falsework and formwork is divided. The maximum number of separate task groups was generally three, where one designed the falsework, a second erected the falsework and a third erected the formwork. A fourth task group who design the formwork separately was only included where it was a clearly identifiable group, for example a separate formwork consultant (this would also be reflected in the fragmentation score below, since it is a separate economic unit).

Some form of formwork design always takes place, frequently the task is performed by different workgroups. For example the edge formwork may be part of the recognised task and ability of the formwork carpenter, the main contractor may design part of the deck and the supplier another. It is impossible to distinguish clearly the number of separate tasks performed by different groups and thus a measure and score was not separately determined. The fact that these blurred activities take place by a variety of groups simply adds to the overall complexity. In the same way the design and construction below the level of the base plate (ground compaction, timber sleepers and so on) was not included in the measure. The 'task' of supply was not included in this measure since it is assumed that it is a common task to all sites. Where there is more than one supplier it adds to the number of interfaces and is dealt with in the measure of fragmentation.

Fragmentation is a more simple straightforward measure (although actual contractual liabilities and perceived responsibilities are by no means straightforward or universally understood by practitioners) based upon the number of independent economic units (firms) who participated in the process.
Tables 1 and 2 illustrate the degree of organisational complexity with respect to the measures of task group specialisation and fragmentation.

Task Group Specialisation	1	2	3	4
No. of sites in each category	6	28	18	2

Table 1: Task group specialisation - Number of sites in each category

Fragmentation	1	2	3	4	5
No. of sites in each category	1	20	25	7	1

Table 2: Fragmentation - Number of sites in each category.

It is also possible to combine the scores of fragmentation and task group specialisation. This is done in Chapter 15 where the combined score is compared with the degree of formalisation.

Bearing in mind that the tables underestimate the number of taskgroups involved (formwork, foundations, supply and fix and so on) they illustrate the degree of fragmentation and complexity involved in the provision of what *prima facie* is a straightforward simple task. The main contractor organisation is presented with the problem of coordinating and integrating across a number of interfaces between workgroups, organisations/economic units, and contractual limits.

The blurring of contractual relationships and liabilities was highlighted by Bragg and has been mentioned earlier in Chapter 3. A final illustration of the organisational, and contractual complexity is made by referring to Case No. 43. Here the supply and fix sub-contractor hired the equipment from the main contractor who in turn hired it from the supplier. The main contractor deducted hire charges from the sub-contractor's monthly payments. To assess the liability, responsibility for the design and performance of equipment is in this case far from simple. In terms of controlling the sub-contractor, the main contractor is in a dominant position. He can control the pace by hiring more material and pass on any charges. In effect he has all of the advantages of labour only and supply and fix sub-contracting combined. The sub-contractor is forced into such a bargain either because he is a bad credit risk or he is convinced that the main contractor can obtain better discounts. The suppliers welcome such novel (if complex) contractual arrangements since it means there is more certainty of being paid. This arrangement on site 43 is by no means unique; it appeared on one site in a study made leading up to this study, and suppliers confirm in personal communication that it does occur quite often.

In providing the design and facility for hiring of equipment, the suppliers have a particular role to play in the production process and how it has developed.

The Suppliers and Designers

The facility for hiring of equipment, thus reducing cash flow requirements for the customer, has meant that small contractors can compete with large ones in reinforced concrete construction. The larger contractors can still insist on greater discounts and can exert considerable financial power over the suppliers, however. The suppliers have thus facilitated the proliferation of specialist sub-contractors who supply and fix falsework; the material being hired from the supplier who frequently performs the design as well. A number of supply and fix firms (particularly in the London area) are (main) contractors in their own right, some with design staff and a few with their own equipment. Of more concern to the suppliers is the unintended consequence of producing 'idiot-proof' systems. A greater number of people now see themselves as capable of erecting systems as supply and fix or labour-only sub-contractors, and with the ease of hiring they face few obstacles to their objectives. In addition to the effects upon their reputation by sub-contractors abusing the equipment or erecting unsatisfactory structures, the suppliers also point to the poor credit rating of the sub-contractors. Sometimes main contractors will obtain orders or discounts on behalf of the sub-contractors, or 'bail them out' in times of bankruptcy. The suppliers together with the trades unions, present possibly the most unified, vociferous attacks on sub-contracting.

The suppliers adopt the organisational strategies and techniques of other capital intensive industries. The 'formal organisation' resembles that of other traditional manufacturing industries. The techniques of production engineering and scientific management are evident, as are the functional department structures of research and development, marketing and so on.

In comparison with other industries, conflicts exist between departments or informal alliances which formal theorists would also see as pathological or running contrary to the firm's objectives. The production departments are more concerned with more efficient use of material, standardised components and production methods, applying the techniques of scientific management and production engineering. Research and development are continually being pressed by their production and marketing contemporaries who frequently have conflicting demands. Research and development also apply the rationale of production engineering; they too aim for more standardised modules and more technically efficient systems in terms of structural integrity and performance and efficient use of labour. These developments like the 'trigger-brace', rapid-strike facilities, self-levelling systems are all 'production engineering' or scientific management solutions prescribed by the development engineers.

In contrast the group of falsework designers, who essentially are a function of the marketing system, deal with another type of industry. In their function as designers and checkers of falsework structures and negotiators with contractors and sub-contractors, they see the results of the developments of 'idiot-proof' systems, pricing strategies and so on. These engineers and technicians exist at the boundary between the 'rational' capital intensive industry and the 'irrational' construction industry. In a sense, with their marketing counterparts they perform the boundary control function described by Miller and Rice (1970).

The falsework designers play a crucial role in the suppliers' organisation. It is they who perform the design, check the structure, deal with technical problems and provide the essential feedback to production and research and development departments. They also prepare the scheme drawing and prices, and perform the sometimes protracted negotiations on prices with the contractor or sub-contractor or frequently with both parties. The senior design engineers in the company form the figureheads, representing the core of occupational knowledge, and represent the company on committees such as Bragg or the Code of Practice.

The majority of the designers are technicians trained in mechanical engineering, building and civil engineering on day release or block release at colleges. Some graduates in civil/structural engineering, notably in more senior positions in a company, have gained experience and achieved Chartered Engineer status, in contracting and consultancy before joining the suppliers, and spent many years in formwork and falsework from then on. Most design is straightforward and does not call for sophisticated structural analysis. Bragg, too, commented on this. The more problematic design factors, such as ground conditions or formwork, are delegated to the contractor for the reasons of insurance, liability restrictions and the lack of control, rather than their lack of ability. There is some mobility of the junior designers and detailers between the highly competitive three or four main suppliers. Many of the designers who leave, join a contractor's team of designers in its temporary works department. Some designers form their own design consultancies, although these are rare and in little demand, or form supply and fix sub-contractors. One such sub-contractor was formed by a group of designers made redundant by the merger (or more accurately takeover) by G.K.N. of Kwikform.

The design departments of main contractors also comprise a core of technical staff, supported by engineers undergoing training to achieve Chartered Engineer status, and supervised by senior engineers who form the engineering spokesmen for the company.

It is reasonable to postulate that the body of knowledge that comprises falsework design is greatly affected or defined by the engineers who exist in suppliers. These engineers consist of not only the falsework designers but also the mechanical and production engineers who also define the nature of the equipment and skills required (or are assumed to exist) for erection.

The whole corpus of knowledge of falsework design and construction is complex and made up of engineering and trades practice; the nature of trades practice, and the skills required have been transformed by the emergence of new types of equipment. It may be that in the future, all formwork and falsework will be proprietary, requiring no joinery or carpentry skills but only those necessary to assemble 'Meccano' construction kits. In these extreme circumstances the discretion is being taken out of the hands of the workforce and becomes more the prerogative of the engineer, as in the case of other industries.

The role of the falsework designers or suppliers is closely allied to (but often in conflict with) the marketing of the product. The designers offer a design service, and a back up customer service of checking structures if requested, and giving advice. They are also closely involved in the frequently protracted negotiation on price. The provision of a design is a pragmatic response. The customer cannot be expected to be fully conversant with the types of equipment and the capacity. Indeed knowledge of the equipment is jealously guarded since it represents considerable investment and commercial advantage over competitors. The customer (main or subcontractor) in many cases has little or no ability to perform a structural design in the engineering sense and be able to understand the Code of Practice design clauses. This is part of the traditional structure of the industry where small contractors do not need to employ specialists. The checking of structures and the advisory capacity are regarded as functions of marketing, of maintaining reputation and customer relations.

The costs of these services form part of the overhead costs of the supplier, which are eventually passed on to the customer. There are sources of conflict however, between marketing, particularly the sales division, and the design department. The fixed budget of the design department has to cope with whatever demands are presented by the sales personnel and whatever preliminary schemes and prices negotiated by the salesman. The salesmen range from, in one designer's words "a Mars Bar salesman", that is a salesman *per se*, to ex-technical personnel, and thus present a range of problems to the designers. The salesman may make rash promises based upon the simple areas of a structure and agree prices per square metre. The designer then has to perform a design, and determine the costs of individual members in order to arrive at that price per square metre. This process may be further complicated by the customer insisting on further discounts, offering further contracts and so on, or by the commercial manager insisting that the job be won at all costs. Since the equipment is invoiced monthly (if hired) based upon the prices of individual components, prices based upon square metre for example, of the whole structure have to be converted to individual elements. Furthermore the discounts necessary to be applied to list prices have to be agreed with the commercial or marketing manager. These list prices fluctuate monthly depending on marketing strategies, rates of return and so on. If a customer chooses to purchase a large amount of equipment he has in theory, purchased the rights to a 'free design' in perpetuity. Several very large contractors purchased large stocks of falsework systems equipment in the early 1970's when guaranteed workload plus the attractions of a 'free design' made the strategy economically rational. Thus designers are obligated to provide a service to these major contractors which puts pressure on the department. The marketing department points to the fact that these customers have paid for a certain element of the design costs as frozen in an element of the original price (although the original price and strategy was to increase the use and acceptance of the equipment and become a market leader); that the customers are committed to the equipment and will hire or buy more as workload fluctuates; that marketing and selling costs are not incurred in promoting the product to these committed customers and only a back-up service is required.

One strategy available to designers in the case where the material is owned by the customer, is to deal only when the customer has already obtained the construction contract and provide a service for the first three or four occasions perhaps giving further requests a low priority. Care and discretion have to be applied, of course, to these quite powerful consumers. Frequently the relationship with these major customers is more than a strict commercial one.

The designers have attempted to mitigate the situation by 'educating' the contractors in the design of systems. Frequently they form quite close links with the contractors' designers. To a certain extent they share a common interest in seeking recognition and status of falsework design within the industry. Together they comprise the majority of the membership of the Code of Practice, and Bragg Committees and other bodies and training courses. In the sense of the Miller and Rice studies, the members of the design groups form sentient groups (1970 *op cit*); in the context of this thesis the actions of the group of falsework designers gives a good example of where the 'occupational order' acts across organisation and commercial boundaries of the economic order. In some cases for example Cases No. 22, 48, 45, (see matrix of variables in appendix) where these large projects involve several different structures, the designers and main contractors and suppliers agree how much material will be used from stock or hired, and who is to perform which design and which drawings on a particular structure, based upon their workload and contract programme.

Some designers believe their status would be increased if a fee were charged for the design service. Those opposed state the practical and legal limitations involved in such a strategy if applied in the supply of equipment, and it would need a brave (foolhardy) supplier to adopt such a strategy first! Several contractors' organisations charge the sites for the design and checking service offered by the in-house departments. This strategy, it is claimed, encourages a more efficient organisation of the design department and the belief by the site personnel that the design department is not another overhead. There are, however, drawbacks to such strategies since, if such services are charged directly against site costs, they affect profit margins on site. The incentive for site to use the services (which nevertheless are there as a cost in any case to the company) is minimised, with the obvious consequences for site safety, and quality of the falsework construction.

The suppliers have had a considerable effect on the organisation and skills involved in the provision of falsework. On the whole the extension of service into one which involves the erection of falsework is rare. Suppliers frequently point to the fact that they are essentially manufacturers, responsible for product liability and that they are prevented from erecting structures by insurance and liability. As major organisations, sometimes existing in a wide range of applications to other industries, it is difficult to see the matter of insurance and liability as a major restriction. Two major suppliers already have flourishing 'contract divisions' where access scaffolding is 'designed', supplied and erected. Although supply and fix falsework is performed by one supplier, it is very rare and from studies made by the author the relationships between the contract division and the falsework department are far more strained than any between contractor or sub-contractor. The suppliers will still, though these days only rarely, offer to erect sample structures and 'train' operatives on site, although these 'offers' are restricted to those powerful customers or where innovations are introduced as, for example, case study number 2 where the sub-contractor was 'nursed' in his construction of 'flying forms' systems. One supplier, with the construction facility, foresees the possibility where they will have to pursue the 'supply and fix' strategy in order to raise the standards and credibility of the quality of falsework construction. They are concerned with the erosion of standards which, paradoxically, they are encouraging, by supplying what are (often mistakenly) perceived to be 'idiot-proof' systems, being erected by 'idiots' (Appendix L).

Conclusions

The organisation of the falsework production process mirrors that of the fissiparous industry at large. The requisite tasks involved have been divided and sub-divided into numerous groups, sub-units and separate economic enterprises. This has been described at length and illustrated by the data. The organisation relies upon the formal (economic authority) structure or, increasingly, upon contractual (market relations) mechanisms to achieve control. Bragg suggested that problems in quality were due to a large extent to the difficulty of integrating the economically and organisationally fragmented process where many interfaces exist between groups, organisations and economic units. Bragg also suggested that integration was hindered by the proliferation of (blurred) contractual and tortious remedies. The recommendation by Bragg and the subsequent Code of Practice call for formal organisational solutions in the form of formalised procedures and a formalised role of falsework coordinator with clear duties and responsibilities.

Whether or not the organisational complexity is recognised as posing a problem, or such procedures are adopted as a (successful) solution is addressed in the following chapter. It is worthy of note that nowhere in the research was there a falsework coordinator, or anyone else who exerted the overall integrating function as recommended by Bragg and the Code of Practice. In the measures used to determine the performance of the 'coordinator' and the incidence of permit to load, the definitions were limited to the degree of checking of the structure and not the whole integrating process of preparing and implementing design briefs, construction and dismantling.

Suppliers have played a major part in facilitating the economic sub-division. Small contractors and sub-contractors do not have to incur capital expense in design or purchase of equipment, and can rely (in some cases entirely) on the suppliers to check the structure. The designers and engineers with the supplier organisations also determine a large part of the corpus of knowledge of falsework design and have been instrumental in changing the nature of erection skills. With their contemporaries in the main contractors' temporary works departments, the suppliers' designers form an important element of the occupational order in falsework.

There are conflicts within the suppliers and main contractors' departments typically focusing on design, production and marketing. These design groups may exhibit the sentience described by Miller and Rice and form close working relationships across the organisational (economic) boundaries. This can also be described by the occupational order facilitating concerted action. Subcontracting has been described in some detail and has evolved as part of the economic rationality of (falsework/formwork) construction.

The practice attracts strong criticisms from practitioners, commentators and bodies such as unions, Health and Safety Executive and suppliers on the basis of quality and safety standards, training and production control. In the context of this thesis, subcontracting *per se* poses few problems to the description of control. It is true that the nature of economic authority changes and complexity and contractual relationships are superimposed but essentially the nature of occupational control is unaffected. For example Phelps Brown notes:

> Whether a building worker is employed or self-employed may make little difference in practice to his relations with management in the conduct of the work."
>
> (pg. 140-141)

Whether such employment results in the type of productivity agreements and sanctions referred to earlier in the quotations is another matter. In a sense the existence and nature of the occupational order enables the subcontracting to be contemplated in the first place. The economic order which includes and determines the economic authority and contractual relationships constrains the operation of the occupational order to varying degrees. Two important points emerge from the use of subcontracting in falsework/formwork which are discussed in more detail in Chapter 16.

Firstly the particular variant of supply and fix subcontracting potentially affects the functioning of occupational control in civil engineering such that it is almost universally precluded (one civil engineering site adopted supply and fix for a pumping station roof). Secondly, the effective functioning of occupational control relies, fundamentally, upon the assumption of competence being resident in those in publicly recognised positions of occupational authority. Lack of training exacerbated by this practice of subcontracting and dominance of self-employment, amongst other things (such as the institutional arrangements and structures for training and attitude of governments), suggests a future overall erosion in the levels of competence and therefore an undermining of the occupational order and effective control.

CHAPTER 15

Extent of formalisation and its implications for Quality

Introduction

The formal economic authority structure has been described (Chapter 13) together with the complex, fragmented socio-economic process of falsework/formwork production (Chapter 14). Problems in the control of the production process may be solved by existing formal economic authority, contractual, institutional means or indeed by the informal occupational order; or resort may be made to the externally derived solutions embodied in the Code of Practice. In adopting these externally derived measures, a problem of control has to be recognised in the first place, knowledge of the Code of Practice be present, and methods of formalisation be deemed acceptable, practicable and beneficial by the particular organisation (head office or site). Since 1975 some form of draft code or recommendations have been available. The data presented here will illustrate whether these and the subsequent Code of Practice have only been disseminated to a limited audience of interested receptive parties. In terms of formal organisation, therefore, the management and control of falsework/formwork can be measured and compared on the basis of their degree of formalisation; preparation and implementation of policies, formal procedures and the formal appointment of a specific role (coordinator). The degree of implementation and effectiveness can only be ascertained by close observation and interviews with relevant parties. Importantly, differences in formal organisation (formalisation of roles, checking procedures and so on) will be compared with the quality of workmanship attained on the various sites. The degree of implementation of the Code of Practice and its success is not only relevant to the hypothesis and conclusions on organisation in this thesis but also to practitioners who showed support to the study. The successful implementation of Quality Assurance will be affected, it is hypothesized, by similar factors to those dealt with in this Part 3, namely the interaction of formal organisation with economic, market derived and occupational authority relationships.

Principal Code Recommendations and their Implementation

The Code of Practice (and the earlier Bragg reports, draft code, and early head office policies) provides the main basis for establishing the degree of formal control of falsework. These formal organisational measures may be regarded as a (externally-derived) classical response of formal organisations and formal organisational theorists to problems of uncertainty and coordination in the formal organisation. The purpose of the Code and its recommendations are intended, according to Wilshere (1985) to:

> "regulate the sound practices which already exist in most of the industry."

and

> "to describe and quantify what is really required as a standard of performance and acceptance."

It appears *prima facie* that these requirements are not particularly onerous. However the data suggests that a significant proportion of firms and sites are unaware of, or disregard the Code of Practice.

Section two of the Code of Practice lists procedural recommendations for dealing with the whole falsework process. Furthermore the responsibilities for carrying out each element of work should be clearly defined and allocated and formally written down in order that they be communicated between the parties involved. In even the simplest of structures and organisational arrangements, the need for formalisation of procedures, though minimal in degree, is still a fundamental requirement. The delegation of responsibility and control of the process is seen to require the appointment of a specific role: the Falsework Coordinator.

The Falsework Coordinator is not required to be directly involved in any of the tasks associated with falsework. Initially he is required to ensure that responsibilities for elements making up the whole process have been allocated to individuals and to secure their acceptance, preferably in writing. He is to ensure that a comprehensive 'design brief' is prepared, that a proper design is undertaken which is independently checked, and that all parties, particularly the permanent works designer, receive a copy of the completed design drawings. During work on site, the Falsework Coordinator should make sure that checks are made on the falsework at the critical stages of erection. He must see that any deviations from the original design are referred back to the falsework designer for his approval.

The Code anticipates that the person filling the role may be directly involved in parts of the falsework process and recommends that:

> "to ensure the independence of checks, the Falsework Coordinator should delegate the task to another if he himself has carried out any of the activities requiring checking."
>
> (pg.9).

The Coordinator must have authority to carry out his tasks and to stop work if it has not been carried out satisfactorily. To facilitate this it recommends that a procedure for issuing a formal permission to load and dismantle the falsework be established. The rationale behind this according to Wilshere (1985) is that:

> "The permit to load means that a piece of paper is signed. While this enables a finger to be pointed should something go wrong, its main purpose is to get all the actions needed, completed properly before loading starts. The act of signing concentrates the mind, and so a careful check is done."

The Code clearly indicates that the 'implicit' and sometimes *ad hoc* method of organisation control is in need of reinforcement by more formalised control procedures. As more than one organisation or enterprise is often involved, it emphasises the importance of each party's responsibility being clearly defined, whether it be in relation to design, materials, erection or dismantling. The list of procedural recommendations is preceded by what is referred to as an 'Important Note'. This emphasises that the procedures are for guidance only and can be implemented in different ways to achieve the necessary standards by different management arrangements. The Code says:

> "The details of procedures and responsibilities will be influenced by various factors, including the size of the scheme, and/or of the organisation(s) responsible, and the terms of the contract under which the work is being performed."
>
> (pg.7).

The extent of the adoption of formal procedures is addressed in this thesis by defining variables below: (the appendix gives the full list)

Falsework Policy: Yes(Y) No (N)

Evidence was found on site of the main contractor having a formal, documented falsework policy. No evidence does not necessarily mean that a policy does not exist but that it is not disseminated to site.

Falsework Coordinator:High(H) Low(L) None (N).

'High' means the appointment of a Falsework Coordinator who carries out the site checking duties envisaged in the Code of Practice. He has acquired the necessary training and experience and effectively carries out his duties on site. He has a good knowledge of the Bragg Report and Code of Practice. He may or may not be an engineer. A high score does not necessarily mean that he is performing the full integrating function envisaged by Bragg and the Code of Practice, in design, erection and dismantling.

'Low' means that the designated Falsework Coordinator has not acquired the appropriate level of experience and is less able to carry out his duties than someone who scores 'High'. He has scant or no knowledge of either Bragg or the Code.

'None' means that there is no Falsework Coordinator. On two sites a F.W.C. came into existence at the question whether there was one. Subsequent interviews revealed that effectively no appointment had been made.

CASE STUDY NO.		20	22	36	28	4	8	10	41	48	40	29	34	38	15	26	6	17	37	45
VARIABLES																				
1	Size of Contractor	L	VL	VL	M	M	VL	L	VL	VL	L	M	VL	L	VL	M	M	VL	M	VL
2	Building/Civil Engineering	C	C	B	B	B	B	B	C	C	B	C	C	B	B	C	B	B	C	C
3	Location	L	M	NE	EA	M	M	WW	L	N	WW	EA	NE	M	N	EA	N	L	NE	WW
4	Size value of contract	M	M	L	S	M	L	M	VL	VL	L	L	S	M	M	M	M	M	M	L
5	Duration	M	M	M	S	M	L	M	M	M	M	M	S	M	M	M	L	M	M	L
6	Technical complexity	H	H	M	M	M	M	L	H	H	M	L	M	M	M	H	M	L	H	H
7	Changes to method statement	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	Y	Y
8	Potential for design/training	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y
9	Policy (evidence of)	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	Y
10	Falsework co-ordinator	H	H	N	N	N	L	N	H	H	N	H	N	H	N	N	N	N	N	H
11	Permit to load	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y	N	N	N	N	N	Y
12	Formal checking	H	H	L	N	N	N	N	H	H	N	L	L	H	N	L	N	N	N	H
13	Routine checking	H	H	L	L	H	H	L	H	H	L	L	H	H	L	H	H	L	H	H
14	No. of engineers on site	M	L	L	L	L	H	L	M	H	L	M	L	L	L	M	L	M	M	H
15	Employment status of erectors	LO	LO	D	D	SF	SF	SF	LO	LO	SF	LO	LO	SF	D	LO	SF	LO	D	LO
16	Sub suncontractor	O	O			O	O	Y	O	O	O	O	O	O		O	O	O		O
17	Selection of subcontractor	R	C			R	R	CR	C	C	RC	RC	CR	CR		C	CR	C		C
18	Type of erectors	S	S	S	J	J	S/J	S	S	S	L	J	J	S	J	L	J	S	J	S
19	Competence of erectors	H	M	H	H	H	H	H	H	H	M	M	L	H	M	M	H	H	L	M
20	Fragmentation	4	2	2	2	3	2	5	3	3	3	4	2	3	2	3	3	4	2	2
21	Task group specialisation	4	2	2	2	2	1	3	3	3	3	3	2	3	1	3	2	4	2	3
22	Supplier of equipment	H	O	O	H	H	H	H	H	O	H	H	O	H	H	H	H	O	O	O
23	Proprietary brand equipment	3	3	3/4	4	3	2	2	3	3	1	2/3	3	3	2	2	3	3	6	3
24	Type of predominant fwk system	1	1	11	3	2	1	2	1	1	2	1	1	2	1	1	1	1	1	1
25	Additional props/tubes & fittings	P		T				P												
26	Availability of drawing	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
27	% penalty score	0	0	0	0	1	2	2	3	4	4	5	5	5	6	6	7	9	9	9

TABLE 1 'GOOD' QUALITY SITES : VARIABLES

CASE STUDY NO.		52	3	53	42	14	25	46	11	31	5	32	30	12	49	33	47	13	51	1
VARIABLES																				
1	Size of Contractor	VL	M	L	S	L	VL	M	VL	L	VL	L	L	L	L	S	S	L	M	M
2	Building/Civil Engineering	B	B	C	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
3	Location	M	M	M	N	M	EA	WW	WW	NE	M	NE	M	M	WW	NE	M	M	M	WW
4	Size value of contract	L	S	S	S	L	L	L	M	M	L	VL	M	M	M	S	S	M	S	M
5	Duration	M	M	S	S	M	M	L	M	S	L	M	M	M	L	M	S	M	S	M
6	Technical complexity	M	M	L	M	M	L	M	L	M	M	M	M	L	M	L	L	L	L	M
7	Changes to method statement	N	N	N	N	N	N	N	N	Y	N	Y	Y	N	N	Y	N	Y	N	Y
8	Potential for design/training	Y	N	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	Y
9	Policy (evidence of)	Y	N	Y	N	N	Y	N	Y	Y	Y	N	N	Y	N	N	N	Y	N	Y
10	Falsework co-ordinator	H	N	N	N	N	H	H	H	H	L	N	N	N	N	N	N	N	N	H
11	Permit to load	Y	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	Y
12	Formal checking	H	N	N	N	N	L	H	H	L	L	N	N	L	N	N	N	N	N	H
13	Routine checking	L	L	L	L	L	H	L	L	H	H	N	H	H	L	L	L	L	H	L
14	No. of engineers on site	M	L	L	N	L	M	H	M	L	L	H	M	L	M	L	N	L	L	L
15	Employment status of erectors	SF	LO	SF	SF	SF	LO	SF	SF	D	LO	SF	LO	LO	SF	D	LO	SF	LO	SF
16	Sub suncontractor	N	N	N	N	N	N	N	Y		N	N	N	N	N		Y	N	N	N
17	Selection of subcontractor	C	CR	C	C	C	CR	CR	C		CR	CR	CR	C	CR		C	C	C	CR
18	Type of erectors	S	J	J	J	S	S	L	S	S	J	S	S	J	J	J	S	J	L	J
19	Competence of erectors	H	H	M	M	H	M	M	H	H	M	M	M	L	M	L	M	M	L	M
20	Fragmentation	3	3	3	3	3	2	3	4	2	3	2	3	3	3	2	4	3	3	3
21	Task group specialisation	3	2	2	2	2	3	3	3	3	2	2	3	2	2	2	3	2	3	2
22	Supplier of equipment	H	H	H	H	H	O	H	H	O	O	H	O	H	H	H	H	H	H	H
23	Proprietary brand equipment	3	1	1	1	3	3	1	3	2	3	5	3	1	1	3	3	2/3	3	1
24	Type of predominant fwk system	1	2	1	2	2	1	2	2	1	2	4	2	1	1	2	1	2	2	2
25	Additional props/tubes & fittings					P	T							P			P	P		P
26	Availability of drawing	Y	Y	N	Y	Y	N	Y	Y	Y	Y	N	Y	Y	Y	N	Y	N	Y	Y
27	% penalty score	10	11	12	16	17	18	19	20	23	24	24	25	26	26	26	27	27	27	28

TABLE 1 'FAIR' QUALITY SITES : VARIABLES

	CASE STUDY NO.	39	19	54	27	50	43	24	9	44	18	2	23	21	7	35	16
	VARIABLES																
1	Size of Contractor	L	S	L	VL	S	L	S	L	S	VL	L	S	L	L	S	L
2	Building/Civil Engineering	C	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
3	Location	M	WW	L	EA	M	WW	EA	WW	M	L	M	EA	L	M	NE	N
4	Size value of contract	M	S	L	M	S	M	S	M	S	M	M	M	VL	M	S	VL
5	Duration	M	M	M	M	S	M	M	M	M	M	M	S	M	M	M	L
6	Technical complexity	L	M	M	M	H	M	L	L	M	L	M	M	H	L	L	L
7	Changes to method statement	N	Y	N	N	Y	N	N	N	N	N	N	N	Y	N	N	Y
8	Potential for design/training	Y	N	Y	Y	N	Y	N	Y	N	Y	Y	N	Y	Y	N	Y
9	Policy (evidence of)	Y	N	N	Y	N	N	N	Y	N	Y	N	N	Y	N	N	Y
10	Falsework co-ordinator	H	N	N	N	N	N	N	L	N	L	N	N	L	N	N	L
11	Permit to load	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
12	Formal checking	H	N	N	N	N	N	N	L	N	L	N	N	L	N	N	L
13	Routine checking	H	N	L	L	L	L	N	L	L	N	L	N	L	N	N	L
14	No. of engineers on site	M	N	L	H	N	L	N	L	N	L	L	N	L	L	H	H
15	Employment status of erectors	LO	LO	SF	SF	D	SF	D	SF	SF	SF	SF	SF	SF	SF	D	LO
16	Sub subcontractor	N	N	N	N		N		N	N	N	Y	N	N	N		N
17	Selection of subcontractor	C	C	RC	C		C	CR	CR	C	CR	C	R	CR	CR		C
18	Type of erectors	J	J	J	J	J	J	S	SJ	J	J	J	J	J	J	J	SJ
19	Competence of erectors	M	L	H	L	M	L	M	M	M	L	M	M	M	L	L	M
20	Fragmentation	3	2	2	2	2	3	2	3	3	2	4	3	2	2	1	4
21	Task group specialisation	2	2	1	1	2	2	2	2	2	2	3	2	2	1	1	3
22	Supplier of equipment	H	H	H	H	H	H	H	H	H	H	H	H	H	H	O	H
23	Proprietary brand equipment	3	1	4	4	4	2	1	1	4	4	1	4	4	4	1	3
24	Type of predominant fwk system	1	3	3	3	3	2	1	1	3	3	1	3	3	3	3	1
25	Additional props/tubes & fittings	P															
26	Availability of drawing	Y	Y	N	N	Y	Y	Y	Y	Y	N	Y	N	N	N	N	N
27	Penalty score	32	32	32	33	33	38	39	40	40	41	42	43	45	55	67	74

TABLE 1 'INADEQUATE' QUALITY SITES : VARIABLES

Permit to Load:Yes(Y) No(N)

'Yes' means there is evidence of a Permit to Load system on site and it is effectively used.

'No' means there is no Permit to Load system or that there are the necessary forms available on site, but they are not used.

Formal Checking: High(H) Low(L) None(N).

'High' means that the site operates with a well-defined company policy and procedures regarding falsework; they are well-documented and evidence was available on site. Usually forms for Permit to Load and Permit to Dismantle are available and used but not necessarily. What is recorded here is the evidence of formal procedures and duties for checking the structure. Usually a F.W.C. is associated with this level of checking but to qualify for this category there need not be one.

'Low' means that although the company or site may have a policy and required procedures, actual evidence of them on site was limited.

'None' means that there was no evidence on site of any company policy or procedures, no Permit to Load or formal records kept of falsework activity.

The above variables were ascertained from interviews with various personnel and evidence obtained (by interview and observation) of what actually occurred, as opposed to what was said or prescribed. Table 1 shows the scores of all of the organisational variables. The full definition of the variables and their measure is found in the appendix.

PAGE NUMBERING AS ORIGINAL

Of those 54 sites in the study, only 30 had any evidence of a policy on falsework of even the basic description. A Falsework Coordinator was appointed on only 20 sites, and of these only 14 carried out their duties in a way approaching that envisaged by the Code. The coordinators did not necessarily use formalised procedures for checking the adequacy of falsework and a Permit to Load was only used on 10 sites. Formal checking procedures, not necessarily performed with a coordinator on site, were applied at a low level on 12 sites and at a high level on 11 sites. It can be seen therefore that the extent of formalisation is low and the actual implementation of procedures and roles are limited.

Some of the reasoning for the extent to which formalisation has been adopted will now be explored.

Head Office Policy

The adoption of any procedures on falsework will depend upon Head Office strategy. It is unlikely that the site manager will instigate procedures himself unless he has the support of his head office. Frequently respondents expressed comparisons with previous employers who adopted stricter (or more lenient) procedures, but did not have the authority to adopt them on that particular site. The acceptance of the policy on procedures will depend upon acquiescence of site to the problems of quality and their solution by procedural means. In the end this will depend upon how far the head office strategy is enforced by the executive management.

Many of the falsework (temporary works) policies were written at the time of the Bragg and Code committees and during a period when the Health and Safety Executive and Health and Safety at Work Act were being established. As one policy stated in 1974:

> "There is little doubt that eventually this procedure (advocated by Bragg) will become a statutory requirement. It can already be seen in the Health and Safety at Work Act."
>
> (Extract from Temporary Works Policy in Appendix).

These policies (see Appendix) closely resembled Bragg and the Draft Code recommendations and prescribed a comprehensive list of duties and responsibilities similar to Appendices C, F and J of the Draft Code (1975). Temporary Works was seen as a necessary part of the company's overall written policy on safety.

A temporary works policy was, and is, seen as a necessity by a majority of contractors who recognise that their reputation would suffer in the cases of collapse where absence of a policy or lack of compliance to a Code of Practice would be viewed seriously by the Health and Safety Executive, the client and the public.

The evidence of a policy would be expected to be related to the size of the contractor, and by inference size of contract. Tables 2 and 3 use the definitions of size explained in Chapter 6 and in the Appendix. On all the small contractor sites, 7 of the 10 medium contractor sites and 8 of the 20 large contractors there was no evidence of a policy. All of the 15 very large contractors had a policy evident on site. It may be surprising that a large proportion of the large and medium contractors had no evidence of a policy; it is likely that a policy exists at head office or in the parent company but it is not seen necessary to implement it in smaller divisions.
The fact that no evidence could be ascertained does not mean that a policy did not exist. No evidence could arise because head office or site did not deem it necessary on a particular site; or site personnel, as a function of head office selection strategy, were ignorant of the existence of a policy.

Head Office Policy	Size of Contractor				Total
	S	M	L	VL	
Yes	-	3	12	15	30
No	9	7	8	-	24
Total	9	10	20	15	54

Table 2: Policy and size of contractor.

Head Office Policy	Size of Contract				Total
	S	M	L	VL	
Yes	3	15	8	4	30
No	10	10	3	1	24
Total	13	25	11	5	54

Table 3: Policy and size of contract.

The importance of the existence of a policy is not at issue in this thesis, but a significant number of companies either do not see the importance of having a policy or do not implement it as part of a head office strategy.

For example one company without a policy:

> "We're such a small company that this sort of thing is done automatically, it's not always done specifically to the best of any one person's ability but these things just tend to happen in a small firm."
>
> (site manager)

is contrasted to another firm:

> "The policy of our company is that on every site there must be a Temporary Works Coordinator. The company always provide site with the main documents on safety, policy, the Code...plus regular courses, seminars on safety, temporary works etc."
> (site agent)

Indeed the above company has an exemplary policy, but such documents are not found on all sites with temporary works, or the policy fully implemented. What must be addressed, therefore, is the extent to which the policy, and the Code recommendations are accepted and implemented on sites.

Extent of Formalisation

Formalisation may be assessed in different ways by considering formal checking procedures, permit to load, and use of a falsework coordinator. What is important, with reference to the Code of Practice, is not who performs the control and checking procedures, or whether documentation in the form of permits are used, but whether the procedures take place or not and their effect on quality. Size, and technology (physical, technical complexity) might be expected to influence quality and the degree of formalisation. Staff have to be present to implement formalisation. Chapter 13 has suggested that staff numbers are constrained. Certain of the larger sites may have the staffing levels which facilitate the adoption of formal procedures,and the capacity to absorb the role of coordinator into the existing line management structure. On the whole, comparisons between size of contract, size of contractor and degree of formalisation will not yield unexpected results.

The tables below incorporate the commonsense distinction between building (B) and civil engineering (C) as defined earlier in Chapter 6. The relevance of this distinction will become evident and of particular importance in the next chapter.

Table 4 shows the extent of formalisation (formal checking and F.W.C.) with respect to size of contract, Table 5 with respect to size of contractor.

By collapsing the categories, by combining small and medium, and large and very large, there is an apparent, though slight trend towards higher formalisation with size. However, the trend is distorted by the larger civil engineering jobs performed by larger contractors and the most dominant trend is for civil engineering sites to adopt formalisation, in contrast to building sites. The distinction is part of the occupational order discussed in Chapter 16.

F.W.C.	S		M		L		VL		Total
	C	B	C	B	C	B	C	B	
None	2	11	2	14	0	4	0	1	34
Low	0	0	0	2	0	2	0	2	6
High	0	0	3	4	2	3	2	0	14
Total	2	11	5	20	2	9	2	3	54

Formal Checking	S		M		L		VL		Total
	C	B	C	B	C	B	C	B	
None	1	11	1	13	0	4	0	1	31
Low	1	0	1	4	1	3	0	2	12
High	0	0	3	3	1	2	2	0	11
Total	2	11	5	20	2	9	2	3	54

Table 4: Formalisation - size of contract.

F.W.C.	S		M		L		VL		Total
	C	B	C	B	C	B	C	B	
None	0	9	2	5	1	13	0	4	34
Low	0	0	0	0	0	2	1	3	6
High	0	0	1	2	2	2	4	3	14
Total	0	9	3	7	3	17	5	10	54

Formal Checking	S		M		L		VL		Total
	C	B	C	B	C	B	C	B	
None	0	9	1	5	1	11	0	4	31
Low	0	0	2	0	0	5	1	4	12
High	0	0	0	2	2	1	4	2	11
Total	0	9	3	7	3	17	5	10	54

Table 5: Formalisation - size of contractor.

Most practitioners interviewed, refer to 'size' as a determinant of formal procedures; by this they mean number of structures or number of pours, which are measures of physical complexity. They recognised, of course, that a larger site will have the flexibility in staffing to adopt procedures. Smaller sites with one or two staff simply could not practically implement procedures and head office would have to be called in.

Technical (physical) Complexity: High(H) Medium(M) Low(L).

This is a measure of the erection difficulties likely to be encountered by virtue of the requirements of the falsework which reflect site conditions and the characteristics of the permanent works.

Thus poor and irregular ground conditions, heavy loadings, multi-storey construction, degree of exposure to wind, high lifts, non-rectangularity (in plan and elevation), irregularities and complicating features in the permanent works caused by the presence of service ducts, stair wells etc., are considered here.

Civil engineering bridge sites are almost always, by nature, technically complex; in this sample only two building sites are considered highly complex. Table 6 illustrates the degree of formal checking imposed with respect to technical complexity. Again, when the seven engineering bridge sites are excluded then there appears to be little correlation, contrary to the traditional 'commonsense' opinions.

	Technical Complexity						
Formal Checking	L		M		H		Total
	C	B	C	B	C	B	
None	1	8	0	20	1	1	31
Low	1	5	1	3	1	1	12
High	1	1	0	4	5	0	11
Total	3	14	1	27	7	2	54

Table 6: Formal checking and technical complexity.

Organisational Complexity

The Code of Practice and Bragg would suggest that formalisation is needed where there is organisational complexity and fragmentation. For the purposes of comparisons, organisational complexity might be measured by aggregating 'Task group Specialisation' and 'Fragmentation'. These measures have already been defined in Chapter 14. Adding the scores obtained from these two measures gives a conservative estimate of the degree of organisational complexity (chapter 14 suggested that there are additional tasks performed by various groups which are impracticable to isolate and quantify).

Scores of organisational complexity range from 2 to 8. Attempts to correlate across a wide band are difficult and Table 7 uses broader bands of Low 2 to 4, Medium 5 to 6, High 7 to 8 for organisational complexity and compares the incidence of formal checking.

	Organisational Complex.						
Formal Checking	Low		Med		High		Total
	C	B	C	B	C	B	
None	1	12	1	13	0	4	31
Low	1	3	1	5	1	1	12
High	1	0	4	4	1	1	11
Total	3	15	6	22	2	6	54

Table 7: Formal checking and categories of organisational complexity.

Over fifty percent of the sites of any degree of complexity do not implement any formal checking. Those that implement some degree of formal checking, do so evenly across the range of complexity. Thus organisational complexity is not a determinant of formalisation.

This may be disturbing news for those advocates, like Bragg, of formalisation; complexity and fragmentation is high and therefore poses problems for coordination and control. Formal organisational methods are being rejected however, either because site perceives there to be no problem of control, or low concern for quality, or they rely upon other means of control, for example by the market relationship and contractual sanctions, or indeed tacitly by the occupational order.

The implementation of the Code procedures

The adoption and implementation of formal checking procedures depends upon the strategy of the head office (beyond the scope of this study) and the commitment of senior site management. Procedures represent a cost to the organisation on site in terms of the time and effort required. It has been suggested earlier in this chapter that civil engineering sites appear to accept the need for control by formal means; this, it could be argued, is a function of the way the Code of Practice is written and disseminated and the nature of occupational control in civil engineering.

As suggested above, the existence of a policy does not mean that procedures will be adopted, or a coordinator will be appointed. The appointment of a coordinator in practice may be a nominal one in that he has neither the interest nor the ability to carry out his duties. Furthermore the coordinator may choose not to instigate formal checking procedures or permits to load; he will always be called upon to exercise discretion, and not hold up production.

The coordinator is essentially an administrative role to be performed by anyone of sufficient economic authority. It is very rare however, to see a coordinator whose sole function is that of falsework coordinator. Typically the coordinator is an engineer with some economic authority; his occupational authority by virtue of his falsework knowledge and ability is sometimes questionable. The Code of Practice recommends that the coordinator has authority (preferably formally via a permit to load) to stop production; in his dual role however, the pressures from production are always present. The following comments and discussion illustrate the range of ability and attitude of the coordinator and the rationales expressed for the decisions by site in implementing formalisation.

The Coordinator

The coordinator as a purely specialist role is seen as a luxury except in rare circumstances; the Bragg committee indeed recognised this fact but recommended that the coordinator should have the ability, time and authority to fulfil his role effectively.

> "My official title on the site is senior engineer, but really it is a mixture of everything, engineer, foreman, site manager, many things rolled into one."
>
> (senior engineer/coordinator)

The above illustrates the points made in Chapter 13 that the (line) manager deals with a multitude of (ill-defined tasks).

> "Doing 50-60% of what the company policy says would be realistic. It is all down to the actual time you can allocate to that actual activity."
>
> (sub-agent/coordinator)

> "Indeed yes. I think all the temporary works, safety aspects of the job, everybody has a keen interest in them but at the same time you have got to be producing something that is efficient. You have got to be making money so there are difficulties with temporary works because you cannot spend all of your time on them."
>
> (agent/coordinator).

As one company chief engineer pointed out:

> "In practice the coordinator as a pure administrator is a waste of money, overheads. The coordinator does make engineering decisions and performs checks himself and not simply makes sure that the check is done. He cannot be totally divorced from production. Discretion and pressures he may face? Well that's what you pay him for."
>
> (company chief engineer).

The production constraints upon an individual will depend upon the environment created by site (and/or head office) and the ability of the individual. Civil engineering sites appear to accept the recommendations of the Code of Practice and large sites have the number of staff to facilitate the appointment of a part-time individual.

For example:

> "There are no conflicts of interests. As a project engineer I am responsible for the engineering side. I am not responsible for the progress of the works, that is not my job. I have to ensure that we have the necessary drawings and information to get on with the job."
>
> (project engineer/coordinator).

Indeed this rather idealist view was evident on this bridge site where the contractor adopted a high profile in the coordinator and was able to maintain an organisational division of function and line personnel.

"The project manager may say 'You're the falsework coordinator, now I don't want to see you again for the next 2 years..it's up to you to sort it out.' On this job I am fortunate in that I had power given to me by the Project Engineer who has an interest and concern in temporary works, and safety etc..and wants it to be right and there is no risk to him, at the end of the day the buck will stop at him of course."

(senior engineer/coordinator).

"It's all very well in theory but in practice especially on a job like this where it is all going so quick that you end up if you're not careful that no one checks it."

(foreman/coordinator).

"..in theory the coordinator does the administration of checking and organising - in practice they are not too good - it works for the better with engineering-dominated companies but not as the chief engineer may think- it happens here at this company, where sites have got good blokes."

(company chief engineer).

The above statement also points to factors included in the 'informal' rather than the 'formal' organisations (see later).

He continues:

"The problem is finding the right person as the coordinator, obviously personal qualities and interests are important, on large jobs there is little problem, he will be technical and prepared to read the Code of Practice..on smaller sites he will be less technically motivated and more motivated by profit."

(company chief engineer).

The data obtained on the coordinator illustrates the extent to which policies on appointment and training differ. In some cases the nominated coordinator was in name only and had neither the ability, inclination nor incentive to perform his duties in spite of a comprehensive company policy.

"I was the unfortunate person to be appointed. I don't think it was done too well on this job to be honest. All of a sudden I saw a notice go up on the wall with my name as temporary works coordinator. I hadn't been involved with any of the meetings they had on the use and design of the table forms..obviously the manager couldn't appoint just anyone. I had training as a carpenter so it's got to be someone who has got an idea of what they're looking at."
(foreman/coordinator).

"On this job I am the temporary works coordinator. I was appointed because I am the only one qualified. I am a chartered engineer. Generally you do not have to be a chartered engineer, you need to have a good knowledge..you couldn't expect a graduate to do it, or just rely on training courses. Courses supplement experience not substitute for it. The Bragg report..it's just engineering commonsense. The recommendations which are set out are engineering judgements."

(area engineer).

The last sentence above illustrates the significance of engineers in the occupational order (see later).

The appointment of a coordinator can be part of a procedure or an extension to traditional company methods.

"On a job this size the agent is a chartered engineer but he has appointed me as coordinator, by formal letter making me aware of my responsibilities and so on. Under me I have graduate engineers who have been in design offices."

(senior engineer/coordinator).

"The responsibility is assigned to the site agent. I would make the appointment of agent and make him aware of his responsibilities regarding temporary works, he could delegate construction supervision but not his responsibility for temporary works and safety."

(contracts manager).

The agent on the site above expresses a slightly different view:

"Being in charge of the site, I automatically assume the role of coordinator. When you have a large job you would go through a procedure, but on a small job then providing you have someone competent on site the procedure is not really applicable."

(agent/coordinator).

On this site no coordinator was recorded since he did not perform the formal role.

The types of appointment and implementation of the role depend upon the type of site and the type of control assumed. Ability and experience are only considered important if the site wishes to exercise formal control procedures. Even on these sites specific training in falsework is not always deemed necessary by various coordinators:

"No I haven't had any formal training. It's very elementary stuff..bending moments..timber stresses."

"Purely on my past experience of checking falsework as a site engineer..no training except for the odd safety course where they told you what a temporary works coordinator was."

"No, not really. Most of the falsework design I have picked up has been in the job experience."

"When I first started doing falsework design there was no Code, people were using bits from CP112, BS449, so when I was in the design office I compiled my own manual."

"I actually read the Bragg report when I was in the temporary works office for 18 months..It certainly opened my eyes..we also had the Draft Code there as well."

Formal checking

The coordinator, or person or persons nominally responsible for falsework do not necessarily see the need for formalised procedures for checking.

Formalised procedures for checking, recording checks and ultimately issuing permission to pour or dismantle, incur costs to the organisation. Sites already immersed in highly formalised and contractual procedures may absorb and accept formalisation as a 'natural' part of contracting; other, more traditional (building) sites may resist.

As in the case of the appointment and performance of the coordinator, reasons are expressed in the form of the type of job, size of job etc..

Again there is a tacit recognition of a difference between policy and implementation:

"We operate a policy with a stipulated checking procedure and the coordinator should not allow work to start unless he has that paper in his hand - it works sometimes but let's be honest..paperwork is generally avoided - and it is usually the second thing to be filled in after the scaffolding register if something happens on site."

(company chief engineer).

The last sentence is a reference to a policy being investigated by the Health and Safety Executive on their visits to site, especially in cases where incidents have occurred.

Some respondents follow Bragg and Wilshere's belief that formal permits in procedures 'focus the mind':

> "You have to have a procedure on site so that everyone knows the standard they are expected to work to. I do not think you will get the same quality if you did not have a procedure."
>
> (sub-agent).

The respondent above did instigate a 'high' degree of formal checking; however the site exhibited 'inadequate' quality!

Frequently comments support the view that larger jobs with more fragmentation necessitate procedures and coordination - although the data presented previously does not entirely support this view:

> "If the site was half the size of this there would be an engineer and a general foreman. It is debateable who would be the site manager and coordinator. Once you've got a bigger site, then it is important that someone is delegated responsibility. Because it is so easy for someone to say 'I thought he did it' and the other to say 'I thought he was doing it.'".
>
> (site manager).

> "No we don't have a coordinator because this is a building site as opposed to civil engineering; it is not a complex falsework design..unless it is a big complex building job."
>
> (project manager).

Sites often adopt a pragmatic approach:

> "Issue a permit to load? No, it would be silly wouldn't it? My signing a piece of paper saying that I can pour. I do the checks or know that it's alright and I will allow the pour to take place, I am responsible in any case, I don't need a piece of paper."
>
> (site agent/coordinator).

> "I know a bit about Bragg and the Code. They recommend a coordinator and the loading permits. I think a large site with a lot of bridges with a lot of falsework going on I can see the value of procedures but not for a site such as this here where you've only got one structure and one pour. I shall personally look at everything on that pour..I shall take responsibility..I shall not be writing a permit to load when you've just got one pour."
>
> (project manager).

The above bridge site did not employ a coordinator or high formal checking but did exercise high routine checking of the pour indicated. However on the same site the assistant to the project manager had a different view: ....

> "In fulfilling my role as structures agent, I am responsible for the falsework to the structure but in fact the project manager has designated himself temporary works coordinator so he has ultimate responsibility. The client did in fact ask for clarification in this case and the project manager has written to them saying he will personally check everything to do with falsework. Obviously I've got to do it as well. He could have delegated it down to me, I don't know why he didn't, that was his decision. I've checked it anyway for my own peace of mind."
>
> (agent).

Apart from illustrating the confusion at times evident on site, the above statement points to high routine checking by various parties on site and the involvement of the client's engineer which also affects the operating environment.

Design

For the reasons explored earlier, in Chapter 5, for example, design is excluded from the study of the factors which control quality on site. Bragg and the Code of Practice, however, recommend that a design of some sort should be performed on all sites and that some form of design brief be supplied as the first stage in the falsework process.

Part of the full role of the falsework coordinator is to ensure that this brief is prepared, the necessary design checks performed, and a drawing provided on site.

In many of the cases where a falsework coordinator was appointed they had little involvement with the design stage and although they pursued their site checking duties admirably, in a sense they did not perform the full role of the coordinator (through no fault on their part). In many cases these coordinators who were also the checkers were performing the role of falsework supervisor (a role described by the Bragg and Code committees) and not the full administrative coordinator role. On no site could the coordinator be said to be fulfilling the full integrating role suggested by Bragg and the Code of Practice.

A full design brief and a final design which meets with actual requirements of the site is fundamental to the attainment of an efficient finished product. From background studies conducted prior to the S.E.R.C. study, adequate design briefs were the exception rather than the rule. Some suppliers claim never to have received a proper brief. The blame is not always placed upon the customer but their own salesman's eagerness to obtain work without disrupting his customer. Falsework designers in main contractors also bemoan the inadequate information given to them, frequently at the last minute, by site. These designers point to the lack of engineering knowledge on some sites where they are unaware of the kind of information needed to do a design.

Quality

It is maintained that the degrees of formalisation were defined and measured accurately with respect to what actually occurred on each site; these measures or scores can now be related to the standards of workmanship which were attained.

Contextual variables

Tables 8 to 10 show findings on the correlations between quality and three contextual variables: size of contractor, size of contract and technical complexity of the falsework. No strong conclusions can be drawn from these tables and they are presented for information only. From Table 8 poor quality is more likely to be found on sites with small contractors, though medium contractors appear to achieve better standards than large. In terms of contract size, small and medium sized sites tend to produce lower quality work (Table 9). Table 10 suggests that higher technical complexity is associated with better quality. However these findings are distorted by the normally high technically complex civil engineering sites, where, it is hypothesized laterin chapter 16, that it is the nature of the occupational order in civil engineering which has the most profound effect upon quality.

Little significance, therefore, can be attached to these findings because size or indeed technical complexity in themselves suggest nothing by way of explanation. Chapter 13 described formal structures of economic control, and size of contractor and size of contract are largely irrelevant since the formal structures will essentially be the same for a given size of job. Larger sites, however, may still have the capacity to adopt nominal procedures, proper roles and so on, should the need and these type of solutions be perceived for what are temporary structures. Larger contractors might be more mindful of their reputation.

	Size of Contractor				
Quality	S	M	L	VL	Total
Good	0	6	4	9	19
Fair	3	4	8	4	19
Inadequate	6	0	8	2	16
Total	9	10	20	15	54

Table 8: Size of Contractor and Quality.

	Size of Contract				
Quality	S	M	L	VL	Total
Good	2	10	5	2	19
Fair	6	7	5	1	19
Inadequate	5	8	1	2	16
Total	13	25	11	5	54

Table 9: Size of Contract and Quality.

	Technical Complexity			
Quality	High	Med.	Low	Total
Good	7	9	3	19
Fair	0	11	8	19
Inadequate	2	7	7	16
Total	9	27	18	54

Table 10: Technical Complexity and Quality.

Formal Procedures and Checking

The degree of formalisation provides the most useful (arguably the only practicably measurable) description of the formal organisational control of falsework/formwork. Sites have been distinguished and compared, earlier in this chapter, on this basis. Tables 11 to 13 show the findings on the correlations between quality and the three variables of formalisation: formal checking, permit to load and falsework coordinator.

Considering formal checking which could be considered as subsuming the other two formal measures, fifteen out of sixteen 'inadequate' sites had little or no formal checking. This could lead to a *prima facie* conclusion that formal checking or procedures are important in that absence of good formal procedures is reflected in poor quality. Perhaps common-sense would expect this to be the case : that some level of formal checking has the effect of raising the profile and concern in falsework. Personnel are more careful even if only cursory or inadequate checking is performed. Referring now to the 'good' category sites, only six out of the nineteen 'good' sites adopted high formal checking or procedures. Thus lack of formal checking does not necessarily preclude the attainment of high quality.

In short this is the main conclusion on formal organisational control of falsework: that something other than formal checking determines the attainment of high quality. For example, the general absence of formalisation on building sites, for reasons explored in Chapter 16, does not prevent the attainment of good quality.

Consideration of the use of permit to load or the appointment of a falsework coordinator in no way undermines the conclusion above on formal checking.

	Formal Checking			
Quality	High	Low	None	Total
Good	6	4	9	19
Fair	4	4	11	19
Inadequate	1	4	11	16
Total	11	12	31	54

Table 11: Formal Checking and Quality.

	Permit to Load		
Quality	Yes	No	Total
Good	6	13	19
Fair	3	16	19
Inadequate	1	15	16
Total	10	44	54

Table 12: Permit to Load and Quality.

	Falsework Coordinator			
Quality	High	Low	None	Total
Good	7	1	11	19
Fair	6	1	12	19
Inadequate	1	4	11	16
Total	14	6	34	54

Table 13: Falsework Coordinator and Quality.

Contractual Provisions

The contractual controls or requests for procedures which may be exercised by the promoter via his representative have not been specifically addressed so far,but may be regarded as formal means of control. The promoter may insist upon various duties to be performed on his behalf by the representative when engaging him as a consultant or employee. The standard forms of contract I.C.E, J.C.T, and G.C.Works 1 (not encountered in this study) all give varying degrees of power to the engineer, architect or superintending officer. The representative can always question, contractually, the execution of the temporary works if he believes that it is detrimental to the permanent works. The attention, if any, is upon design. The representative may request construction methods and design calculations from the contractor. It is implied that such submissions need the consent of the representative. If the request can be proved to lead to additional expense on the part of the contractor it will be paid for as a variation. Such arguments are unlikely to be convincing since the contractor must perform some design and calculations as a necessary part of his planned method and the submission of calculations can in no way incur expense. Delay in 'approving' the method may however constitute a case for extension of time.

The I.C.E conditions go further than the general powers and give specific attention to temporary works. Clause 14(2) stipulates that the contractor shall submit details of his design and calculations if the engineer requests. Clause 14(3) also expressly states that approval has to be given, whilst unnecessary delays in giving approval will be paid for under Clause 14(6). It is of course a part of the engineer's discretion as to when he exercises his powers under the latter clause.

Clauses can always be added to the standard contract conditions in the form of the tender agreement and instruction to tenderers. One such clause used by the Department of Transport and Local Authorities is the Clause 8A addendum to the general clause 8 in the I.C.E. conditions. Such an addendum could be made in theory on all contracts, provided there are the means (ie the people with the necessary ability and contractual authority) to implement it. Clause 8A will identify a particular structure or structures which is deemed of particular importance as regards the permanent works, safety, or affect other organisations and their property, such as British Rail, British Waterways, and members of the public. On these structures an independent check of the design and calculations is to be made by an

> "Engineer with appropriate qualifications and experience who has not been concerned with the original design of the element of the contractor's erection proposals and details of the temporary works."

This check will be formally documented in a certificate, the wording of which is frequently given in a sub-clause 8A(2), which is submitted to the engineer/client's representative.

This procedure follows closely that recommended by Bragg (1974, 1975a) except that the checking engineer does not have to be chartered in order to possess the relevant expertise and experience.

Examples of a typical Clause 8A and completed certificate appear in the Appendix. Site numbers 22 and 48 were subjected to Clause 8A checks implemented by the Department of Transport via a consulting engineer.

These checks relate to design and not exactly how the operations are carried out and therefore strictly speaking are beyond the definition of quality used in this thesis. Where such measures lead to more checking (formal or otherwise) by the main contractor or the client's representative they were reflected in the measure of formal checking. It is reasonable to postulate that where an engineer applies Clause 14 or Clause 8A it raises the profile of temporary works and falsework and more attention is paid all around which was the intention of Bragg. Irrespective of any informal checks by the client's representative or his apparent consent or qualified approval to a scheme, the responsibility for the design and execution of the temporary works and their effects upon the permanent works lies firmly with the main contractor. The main contractor and client's representative would not wish it any other way.

The main point to be made here is that the existence and implementation of formal controls by the client or his representative is a function of the occupational order. In civil engineering the engineer has occupational control and this is reflected in the conditions of contract which are written by engineers (and lawyers). The importance of a particular temporary works structure is recognised by the engineer who is part of the client body or a consulting engineer engaged by the client. It may then be deemed necessary to devise and implement more formalised checks of design via 8A checks. In the case of general I.C.E. contracts the issue of temporary works is deemed of importance and the contractor can expect to have to submit calculations if requested. Irrespective of specific contractual conditions the engineer in a position of economic control as client's representative has the power to exercise his discretion and will do so. Therefore if the superintending officer (S.O.) on G.C.Wks 1 is an engineer, he will address his body of engineering knowledge when requesting whatever he sees necessary for the safe execution of the works. If the S.O. is not an engineer he is unlikely to be too concerned.

The engineer's position of occupational authority in civil engineering is recognised in the economic control structure of the contractor's organisation on site. It is also recognised and paid for in the appointment of client's representative.

Conclusions

In conventional formal organisation terms there is little structuring of organisation or (managerial) functions on site (chapter 13). Measures of formalisation (in terms of policies, formal checking and appointments etc.) are the only useful, applicable ones which can compare the formal control with respect to falsework and formwork. The Code of Practice and allied documents provided the basic reference tools in this respect. The findings show that formalisation has only been adopted to a limited extent, and, where it has, the conformance to a given policy or the Code of Practice is sometimes nominal.

Formalisation can be regarded as a traditional (classic) response of formal organisation theorists (and practitioners) presented with a problem of control: generation of further formal devices. These solutions rely upon the assumption that the formal organisation structure exists and adequately describes and prescribes the control and that the requisite personnel are present. The formal structure discussed in Chapter 13, with its lack of functional specialists and roles, would tend to hinder the incorporation and implementation of formalisation, especially if it is derived externally. Furthermore, the organisation (head office and site) has to perceive a problem in the first place and accept formalisation as the best solution, in preference to existing formal, contractual and indeed 'informal' arrangements. Formalisation implies that specific (trained) personnel operate the structure, who have the (economic) authority for example to stop production.

The data show that the coordinator may be appointed without reference to his ability or training. In the majority of cases where appointed he is a line manager (who may perform a technical function) presented with pressures from production. The overall integrating role from design brief to dismantling (envisaged by Bragg and the Code of Practice) was never encountered in this or other previous studies, nor the purely functional administrative capacity. In the cases where the coordinator played a positive role, they were not independent checkers or administrators of the formal system and acted in a role more akin to the falsework (temporary works) designer or supervisor, (roles omitted in the Code of Practice but delineated in Bragg, the draft Code and early policies on temporary works) frequently checking themselves. The coordinator sometimes rejected formal checking and documentation, in favour of a more *ad hoc* system, which nonetheless still ensured adequate checking.

For reasons explored earlier (Chapters 12 and 13) and confirmed here, size and technology cannot explain formal structure or the extent and degree of formalisation adopted. Differences between building and civil engineering point to possible explanations provided by the occupational order, for the variation in formalisation.

Civil engineering appears more receptive towards the problems and solutions discussed by the Code of Practice (and Bragg). The structure of occupational authority in civil engineering is reflected in the structure of economic authority. Formalisation is more easily absorbed into an existing structure where formal controls are already a feature of production. Formalisation of falsework is not a dramatic departure or extension to existing procedures. The Code of Practice was written by engineers in largely engineering terminology. Thus those in occupational (and economic) control in civil engineering (engineers) are more likely to interpret, understand and accept the recommendations of the Code of Practice and implement formal solutions and adapt their control. It is reasonable to speculate that engineers have accepted the criticisms made by Bragg and have set out to remedy the situation and restore their image. Engineers on civil engineering sites show interest in falsework formal controls; the quality in civil engineering, (particularly bridges) seems to confirm this.

Building on the other hand, has a less identifiable formal structure and more disparate occupational control by no one particular, clearly identifiable workgroup on every site. The necessary body of knowledge in falsework is not deemed to comprise solely engineering. The Code of Practice and Bragg are less likely to have been read or understood or accepted to the same extent (by engineers or others in occupational control). Engineers are not usually in a position of occupational (or economic) authority to be able to influence the process even if aware and committed to the Code of Practice recommendations. The data would point to reliance on the formal structure (such as it is) and contractual means (although the data suggests that these are recognised as limited), but more importantly to the informal organisation.

Where formalisation of the control of falsework has been applied in both building and civil engineering (and formal procedures and checking subsumes the other measures of formalisation) it tends to encourage high quality. In a way 'commonsense' is confirmed in that a good formal system of checking structures prevents poor quality workmanship. Such a finding might be expected since the presence and application of a proper system and performance of regular checks (of faults and remedial actions) would raise the profile of falsework on site and heighten general concern. A conclusion would be to impose or encourage formalisation on a much wider scale (in extreme cases by contractual clauses or client, H.S.E. actions).

On the other hand, the findings show that absence of formalisation in no way precludes the attainment of high quality. It would seem apposite to examine the other determining factors of quality. Differences in quality between civil engineering and building sites were referred to in Chapters 10 and 11 and are detailed in the matrix in Table 1 (civil engineering: 9 'good', 1 'fair', 1 'inadequate', building: 10 'good', 18 'fair', 15 'inadequate'). Such differences point to the differences of occupational control and the effectiveness of occupational control in these two sectors of work. It is the difference in nature and effective functioning of occupational control which provides the best explanation for differences in quality standards and for adopting formalisation. These claims are investigated in the next chapter.

CHAPTER 16

Occupational Order and Quality

Introduction

The model of the occupational order has already been used in order to describe the commonsense understandings shared by practitioners which determine how and by whom occupational control is exercised. Evidence from previous studies such as Phelps Brown (1968) and Birch (1977) and research into the industry in general and falsework in particular performed by the author since 1978, has been presented earlier in this Part 3 to support the description of the different forms of occupational (and economic) forms of control that exist in building and civil engineering.

Occupational authority derives from a legitimated ownership of a corpus of knowledge by virtue of occupational membership. It is assumed by practitioners that the member of the particular occupation in control over a particular operation, has the skill and competence and that he exercises it via routine checking and close supervision throughout the process.

The nature of the body of knowledge termed 'falsework' is covered in detail in Appendix L. On any particular site there exists an amalgam of engineering and trades practice expertise to varying degrees.

In this chapter it will be demonstrated, by further evidence, that the general 'rule' of civil engineering whereby engineers have occupational authority over a group of labourers and a semi-skilled manual workforce who concede authority to the engineer, still applies when dealing with falsework. Falsework is seen to be the preserve of engineers who both have the expertise (engineering knowledge) and exercise that expertise by controlling and supervising the production process. The workforce and supervisory staff such as foremen although possessing trades practice and other skills, still defer to the engineer who has the final decision on design and construction.

Further evidence will also be presented which demonstrates the occupational order which pervades building in its general operations and in particular, falsework construction. In contrast to civil engineering the multitude of tasks are seen as the preserve of that particular occupational specialist. The occupational order comprises autonomous work groups where occupational control is exercised by the most senior member of the group. Members of that occupational group and others concede authority to this senior member. Those engineers who can demonstrate knowledge in and over falsework are given some legitimated authority over the production process. However, the body of knowledge of falsework comprises engineering and trades practice standards and the prevailing occupational order in building is such that the group actually constructing or performing the task, is a self-regulating, autonomous one. The role of the engineer in the falsework and general building process is one of an advisory or service role. Depending upon his legitimated, demonstrated competence, the engineer will be granted some occupational authority over how the falsework is erected. Where the engineer has economic authority, he may choose to exert some occupational control over the process; in general, however, the occupational order in building is so strong and of fundamental necessity that it will operate despite whoever occupies economic control. An engineer, previously engaged in civil engineering and its occupational order, when working in building, and perhaps occupying economic control, will conform to the occupational order of building; that of reliance upon the autonomous self-regulating specialists (trades).

In building, therefore, more dependence is placed upon the competence of the workgroup. This competence comprises the body of knowledge referred to as 'trades practice'. Fundamental assumptions are that at least one member of the workgroup understands and recognises the requirements for stability, can read drawings and set out, fix tightly and plumb etc.. It is frequently recognised by the workgroup that the 'engineer' has some authority, for example in the specialised knowledge of the supplier of proprietary systems.

Of course since reliance is placed upon this assumed level of competence or expertise of the specialist, then the assumption is that they can exercise it, during checks and production as part of the day to day process of production.

		GOOD				FAIR				INADEQUATE			
		Case Number	Competence of Erectors	Formal Checking	Routine Checking	Case Number	Competence of Erectors	Formal Checking	Routine Checking	Case Number	Competence of Erectors	Formal Checking	Routine Checking
CIVIL ENGINEERING	LABOUR ONLY	26	M	L	H					39	M	H	H
		20	H	H	H								
		22	M	H	H								
		29	M	L	L								
		34	L	L	H								
		41	H	H	H								
		45	M	H	H								
		48	H	H	H								
	S/F					53	M	N	L				
	D/L	37	L	N	H								
BUILDING	LABOUR ONLY	17	H	N	L	12	L	L	H	19	L	N	N
						3	H	N	L	16	M	L	L
						30	M	N	H				
						47	M	N	L				
						51	L	N	H				
						5	M	L	H				
						25	M	L	H				
	SUPPLY/FIX	4	H	N	H	11	H	H	L	2	M	N	L
		6	H	N	H	13	M	N	L	7	L	N	N
		8	H	N	H	14	H	N	L	9	M	L	L
		10	H	N	L	32	M	N	N	18	L	L	N
		38	H	H	H	42	M	N	L	21	M	L	L
		40	M	N	L	46	M	H	L	23	M	N	N
						49	M	N	L	27	L	N	L
						52	H	H	L	43	L	N	L
						1	M	H	L	44	M	N	L
										54	H	N	L
	DIRECT	15	M	N	L	33	L	N	L	24	M	N	N
		36	H	L	L	31	H	L	H	35	L	N	N
		28	H	N	L					50	M	N	L

Table 1: Summary of case reference numbers and main variables with respect to quality

It is crucial, therefore, that, having described the nature of the body of knowledge and the workgroup (engineers, joiners, scaffolders etc.) who own it, that the level of competence and nature of skills be determined. Again appendix L gives detailed descriptions, illustrated by data and comments of how this was obtained.

Having described the nature of the occupational control in building and civil engineering the chapter then describes how to measure its effects upon quality by referring to the degrees of routine checking and levels of competence on each site. Table 1, taken from the matrix of variables in the appendix, summarises the important determining variables upon quality. Formal checking has been dealt with previously but appears for comparison purposes later.

Routine checking

A fundamental assumption of occupational control is that control is exercised by regular monitoring, checking and remedying the production process. In civil engineering, therefore, it is expected that engineers will perform routine checks. An assessment was made via interviews and observations of the type and degree of routine checking carried out on the sites. Thus 'Routine Checking' forms one of the organisational variables measured in the research and tabulated in the matrix in the Appendix. The general definition of the measure of routine checking appears below:

Routine Checking: High (H), Low (L), None (N).

'High' means that there is some kind of checking procedure used on site whereby individual members of staff tacitly assume responsibility for checking falsework during erection and/or just before concreting. There were no explicit procedures followed by the individuals who did such checking. Typically individuals undertaking such checks have adequate knowledge and training but consider a highly documented system as unnecessary. Everything is done verbally. Routine checking can co-exist with formal checking. This would mean that some members of staff administer the formal system whilst, in addition, others perform routine checks.

'Low' means that the degree of checking was somewhat more erratic and less thorough than high routine checking. Typically the reasons were lack of experience and knowledge or a heavy workload elsewhere. In this category were placed cases where a difference was found between what staff said their responsibilities were and what they were seen to do.

'None' means that during erection and immediately prior to concreting no single person took responsibility for checking.

Civil Engineering

In the context of civil engineering routine checking was performed by engineers or controlled by engineers. In the case of building more reliance is placed on the competence of the autonomous workforce to perform routine checking. The method of assessment of competence of the workforce is detailed in the appendix and findings are presented below. In the case of the civil engineering occupational order, the engineers are assumed to have the necessary skill to exercise their occupational authority; and this was checked by the research.

The sample organisation charts presented in Chapter 13 exemplify the nature of the occupational control structure which is mirrored in the economic control structure; engineers occupy senior positions in the economic control hierarchy with general foremen and foremen occupying subordinate positions in the economic hierarchy and occupational control structure. Evidence presented below will indicate that the role of the foreman is to assemble the workforce, organise materials and equipment and encourage productivity; the engineer has ultimate control over these economic functions and over how design and construction is performed to his quality standards. Of the 11 civil engineering sites, 10 had graduate engineers in the most senior positions, 9 of whom were also chartered civil engineers.

Before presenting the quantitative data on routine checking, the following evidence is presented to support the general thesis on the type of occupational control exercised in civil engineering, and falsework in particular. The engineer is in total control: ....

> "In civil engineering the agent will stand over you and watch what you're doing."
>
> (General foreman).

> "I am in direct control with the engineering and management side. My function is to make sure that the works are built on time to the contract programme and in the best economical interest to our company so I have the management responsibility and to make sure that the work is done correctly and economically...it is always engineers who design the falsework, we would not allow the works manager to do it...the work is supervised by the works manager who has the experience but the design is always done by a competent engineer."
>
> (Agent/coordinator).

Although the workforce or the general foreman may have skill or knowledge he will not normally be free or willing to exercise discretion:

> "I would not do any change (in design) on my own because he is the design engineer and he tells me what I have to do."
>
> (General foreman).

This contrasts sharply with the practice in building, below, where designs are frequently modified on site.

Although checking is performed as a routine by the first line supervisor (foreman) the engineer, or engineers still perform final checks:

> "The general foreman has 25 years as a scaffolder, we have got great confidence in his ability...he became the supervisor of the sub-contract labour effectively...but in addition the bridge section engineer always goes and checks the falsework."
>
> (Project manager).

and:

> "You have to keep your eyes on them...and go back to the engineer and ask him to have a look as well."
>
> (Works manager).

In the preceding statement the works manager is recognising his lack of economic and occupational authority over a sub-contractor.

> "My duty is to see that the falsework goes up to the drawings...when finished it is my duty to inform the engineer, in turn it is his duty to come and check the falsework."
>
> (General foreman).

The engineer (design engineer) is in effect exercising remote control by producing an engineering drawing; by following a drawing the workforce and supervisors are legitimating his occupational authority. What is evident in civil engineering is that checking forms part of the routine duties of a number of engineers, and several parties will take an active interest.

This routine interest also sometimes applies to the promoter's representative engineer on site. Although his power is formally recognised in the form of his contractual duties and he has some contractual control over payments, he also as an engineer, has occupational authority, he will always be listened to, if not heeded by site personnel. As regards falsework his only contractual duties are those which affect the permanent works and his statutory duties under the Health and Safety at Work Act. Contractual provisions and clauses may be included as discussed in Chapter 15. Their inclusion and implementation is a function of the occupational order. In a normal I.C.E. contract the engineer has the discretion to call for design and calculations. The engineer as the client's representative may further insist that independent design checks and certificates be specifically included in the conditions of contract and instruction to tenderers and be allowed for in the tender sum. He will not normally wish to be involved in the design and construction of temporary works. Frequently the promoter's engineer will avoid making statements which could subsequently be construed as negligent advice but on occasions he will take a positive interest. On such occasions such routine checking by a (promoter's) engineer was taken account of in the assessment of routine checking.

Building

Routine checking is assumed by the occupational order, to take place within the occupational group. Routine checking by the personnel will be a function of interest, knowledge, occupational authority of the engineer and so on. Chapters 13 and 14 have already argued that staffing levels and the exigencies of the economic order are such that it is economically expedient for the main contractor to employ specialists or rely upon self-regulating, self contained workgroups and expect them to control the process from within their group. The economic control structure is such that only minimal control is expected to be needed via day to day site management.

For the external observer or researcher of the organisation of the construction industry, the occupational order in building is difficult to identify. It is not formally recognised (it does not have to be for it to function!). In contrast to civil engineering it is not so clearly evidenced or recognised in the formal economic control structure. In staffing a project and filling the positions in the economic control hierarchy, some assessment of occupational expertise will generally be made. For example a building utilising high quality load bearing brickwork, will be seen to require the requisite experience; a complex geometrical layout or high technical (engineering) content will require the skills of an engineer for more than the usual preliminary setting out and concrete frame operations etc.. Traditionally positions such as agent and foreman were filled by ex-tradesmen, thus recognising and reinforcing their occupational authority over production. Whether such personnel are no longer available or are not seen as necessary today, the positions are becoming filled by other non-trades personnel, the technicians, engineers for example. From the evidence the staffing is based largely upon the availability of staff rather than their particular experience. Providing sub-contractors or work groups can be found the absence of the 'right' staff is seen as undesirable but not problematical.

> "I haven't a clue really...I honestly dreaded coming to this job to start with...but I've muddled through, doing an ordinary foreman's job really. I've taken most of the day to day organisation off the agent's back."
>
> (General foreman).

The fundamental requirement of those in positions of economic control is the ability to 'manage', to organise and coordinate activities, minimise costs, and perhaps exploit any commercial advantages in the administration of the contract, whilst achieving some level of quality (defined by the occupational order).

The traditional assumptions are that the site staff will look after the production and the quantity surveyor will deal with the financial administration. Where the agent is seen as possessing the necessary management skills, financial acumen, education and so on, he will be engaged in a wide range of economic control activities.

The occupants of the positions in the economic control structure originate from a variety of occupations and may not legitimately claim any rights over any production operation. The engineer as agent may claim ownership of certain knowledge of falsework and possession of the necessary trades practice conventions. The degree to which he exercises his occupational authority is limited by occupational and economic orders pertaining at the time. The engineer's fundamental role as an occupation is as a service or advisory role. He performs the basic setting out and surveying and solves technical problems on the drawings and liaises with the design specialists should problems occur. The engineer in a position of economic control such as site manager or agent, still adopts this rationale that other engineers or occupations on site have authority in and over their own occupations.

In contrast to civil engineering, the engineer site manager in building occupies that role by virtue of his managerial ability, expertise and general education rather than his occupational authority.

The traditional job description given by engineers or technically trained, educated personnel in building is:

> "I call myself a builder."
> (Agent).

This brief term, builder, encapsulates all of the tacit understandings and assumptions of the occupational order in building.

On twenty five of the forty three building sites, these 'builders' occupied the positions of economic control, such as agent, project manager, or site manager. Their education ranged from Higher National Certificate in Construction or Civil Engineering, membership of the Institute of Building, graduates in building or civil engineering and chartered membership of the Institution of Civil Engineers. These 'engineers' could therefore exercise occupational authority by virtue of their position in the economic hierarchy. Largely, such control is only exercised in falsework (or the 'engineering' activities) if quality or production standards were seen to be a problem. The assumptions of the occupational order still prevail, in that control is exercised within the workgroup. Interest is also a function of the knowledge possessed by these engineers in falsework (or other activities) which varies considerably. Other engineers on site function in a service role.

On the remaining eighteen building sites the positions of site agent and so on were filled by ex-tradesmen or others (on two sites these 'others' were best described as quantity surveyors). The engineers were seen firmly as providing a service role. On eight sites engineers were not deemed necessary to the production process and on four sites the service role of the engineer was formally recognised by the employment on a temporary basis of an (self-employed) agency engineer. The increasing tendency for some builders to sub-contract also extends to supervision where on one site the site manager was self-employed.

The operation of the occupational order is not only recognised by the site personnel on a building site but also the executive organisation in head office. In contrast to other industries, the civil engineering and building industry has a large membership of practitioners occupying positions in the economic hierarchy at boardroom level. The head office management tacitly recognises the differences between building and civil engineering. On a number of sites the same parent contractor organisation adopted different staffing arrangements and organisation on site depending upon the nature of the work: building or civil engineering. The policies and strategies on economic control (for example the influence or dominance of a quantity surveyor) or occupational control (qualified engineers) and for temporary works and safety vary depending upon the type of work undertaken by a major contractor and the particular occupational order which is presumed to operate.

A high degree of routine checking by supervisory staff in the main contractor's hierarchy will be seen as unnecessary in building. The occupational expertise may not be present in any case (data confirm opinions and fears that general foremen are diminishing in numbers, exacerbated by lack of training policies, and prevalence of sub-contracting). It is deemed uneconomic to impose such (additional) involvement.

For example:

> "Yes the site agent and I checked to the drawings and in addition I asked the carpenter who put it up if it was alright. Basically all the tradesmen are experts in their field so you rely on them, and in any case you cannot do the job for them."
>
> (General foreman).

The above statement is another illustration of the occupational order in building and the added rejoinder also as a recognition of the economic expediency of the occupational order, that "you do not keep a dog and bark yourself". That checking is performed in relation to the drawings is itself a recognition, in part, of the authority of the designer, usually in the form of the geometrical layout and connections and spacing of beams etc.. Workmanship on those conditions referred to in Parts 1 and 2 in for example, bracing, lacing, verticality and so on is still regarded as a matter of trades practice and a function of competence.

The engineer occupies a service role.

> "One (the engineer) is more a specialist, the other (the agent) is more management."
>
> (Site manager).

and: .....

"the engineer does the setting out, makes sure all the steel is on and makes sure everything is on correctly. But to get the job out to programme, the agent, he is the man setting the time to do this and that."

(Sub-contractor foreman).

The site engineer's involvement in falsework ranges from basic setting out, liaison with a supplier to very basic rudimentary checking. On the more traditional building sites where ex-tradesmen are employed in positions of economic control, who also claim occupational authority, the engineer's role in falsework is minimal:

"The engineer comes to site with his drawings in addition to his engineering knowledge but possibly he does not know what is going on, on site...he cannot help you in a problem of placing bricks as per the drawings because he has not done it."

(Agent).

This opinion above of the occupational order and the jaundiced view of the engineer was expressed by an agent, an educated man with 40 years experience controlling the site without an engineer. Another, an ex-tradesman expresses a similar opinion:

"The engineer and me check (the falsework). I go without the drawing because I'm a practical man, not a university man. The engineer goes with the drawings, he needs them to check the reinforcement. I've been working for thirty five years, I can tell if anything is wrong or not."

The role of the engineer is frequently seen in a similar way to that of the promoter's representative, in the position of clerk of works, whose interest lies in the permanent works and who checks the reinforcement only. The role of the structural engineer designer of the permanent works is also a service one. In the dominant forms of building conditions of contract he has no contractual responsibility and is not mentioned in them. Checking is frequently delegated via the architect to the clerk of works. In G.C. Works 1 contracts the S.O. on building works may be an engineer but it is likely that in the vast majority of cases the functioning occupational order of building will be reflected in an architect or similar being in charge of the works. It would be extremely difficult and impractical to incorporate I.C.E. type clauses or 8A clauses in the J.C.T. conditions since the checking and approval of designs would have to be by a third party (an engineer) having no responsibility under the main contract, thus liabilities and responsibilities for the falsework design become further blurred. Such provisions are feasible in G.C. Works contracts if the S.O. or 'the Authority' are engineers. In G.C. Works 1, it is the overall powers of the Authority, and to a certain extent the S.O. that can be implemented, providing those having the power deem it necessary, that is they have the occupational expertise to recognise a problem.

For reasons expressed earlier traditionally on building jobs neither the architect nor the engineer will be involved in temporary works which are regarded as the natural preserve of the contractor. On no occasion did the engineer (or representative of the architect) perform routine checks on building sites in the sample.

Some knowledge of engineering is variously recognised to be an important component of the body of knowledge required to erect falsework. The specialised knowledge of the supplier is a case in point:

> "The people who come down from R.M.D. are engineers."
>
> (Project manager-supply and fix site).

The supplier may provide the design and the equipment and the main contractor and (supply and fix) sub-contractor may have little knowledge or demonstrated competence. Frequently the suppliers' engineer or representative plays more than an advisory, 'trouble-shooting' role but also a checking one.
For example the main contractor may rely upon the supplier to perform checking, or control function:

> "The suppliers' representative, he's the engineer replacing the foreman."
>
> (Site manager on a labour only site).

Supply and fix sub-contractors normally expect, and receive little supervision or checking by the main contractor. They frequently rely upon suppliers' representatives to supplement their own occupational control (if any!) within the workgroup. The suppliers normally accede to their wishes although not contractually obliged to, nor do they accept any responsibility or liability for any checks. The suppliers perceive this function as a necessary part of their liaison duties of customer relations but more importantly a means of preserving their reputation against collapse or minor failures. Where low competence is demonstrated on the part of sub-contractor or main contractor personnel this mere involvement is perceived as necessary by the supplier. For these and other (financial) reasons the suppliers are strong critics of the trend of sub-contracting to less and less capable firms.

The above demonstrates the degree of economic and occupational control exercised in building. The degree of routine checking on the part of the main contractor supervisory personnel is expected to be minimal. The tendency for less tradesmen to be filling the supervisory roles in the main contractor organisation, questionable competence in the occupational workgroup, and innovations by the equipment suppliers, has led to a greater role for the supplier in advising and checking standards. The fundamental assumption still however holds, that the autonomous specialist group controls the process, have the competence and are not prevented from exercising that competence.

In civil engineering,it would appear, that the description and assumptions of the occupational order are being applied to falsework. Occupational control is being applied closely by engineers who claim ownership of the relevant body of knowledge which is first and foremost of an engineering nature. This occupational control assumes that competence in the operative workforce is not essential given the degree of occupational control and the engineering knowledge deemed to be required by the engineers.

The above statements and discussion give an indication of the degree and nature of control exercised by engineers and of how routine checking was assessed. The quantitative findings are tabulated below.

	Routine Checking			
	High	Low	None	Total
Building %	10 23.3	26 60.5	7 16.2	43 100
Civ.Eng. %	9 81.8	2 18.2	0 0	11 100

Table 2: Number of sites with respect to degree of routine checking.

Table 2 shows that all civil engineering sites exercised some degree of routine checking, almost 82% of them a fairly high degree. This contrasts sharply with the building sites, where only 23.3% of them were subjected to a reasonably high degree of routine checking. Sixteen percent of building sites were not subject to any form of routine checking. The incidence of routine checking was marginally higher on those sites where 'engineers' (builders) occupied positions of economic control.

This is what might be expected of the occupational order. In civil engineering the engineers have the occupational authority and expertise and generally apply it by routine checking. The control does not have to rely upon competence in the workforce but obviously it is desirable that it is present. In the case of building it is important to address the level of competence in the workforce since competence is being relied upon by the occupational order where routine checking is assumed not to be necessary.

Competence

In order to define the nature of occupational control in falsework the relevant body of knowledge must first be addressed then the owners of that corpus can be identified. As explained in appendix L, the body of knowledge which comprises 'falsework' is not uniquely defined but is a mixture of engineering and trades practice. In building it is assumed to reside predominantly in the occupational workforce, complemented by the engineering knowledge of the supplier and to a lesser extent the main contractor engineer (who has a limited role). The occupational knowledge is not owned by one occupation but a range of specialists. The situation can be contrasted with civil engineering where the engineer can claim occupational control by virtue of their overall occupational control and power and influence over the construction process.

For control by occupational authority to function effectively, those who claim (legitimated) ownership of the corpus of knowledge must be competent and exercise their skills by routinely checking and supervising the production (erection) process. There are different perceptions of the nature and level of skills and training required to erect or check falsework; these are illustrated by comments included in the appendix. Competence will depend upon occupation, training, knowledge of trades practices and so on. In the case of civil engineering it is usually straightforward to identify those in control (the engineers) and assess their competence based upon knowledge of the Code of Practice, Bragg falsework terminology etc.. In building, however, the identity of the person and workgroup in control varies. The specialists in falsework may be formwork carpenters. The formwork carpenters to a large extent originate from the apprentice carpenters and joiners. From traditional apprenticeships the carpenter learns elementary formwork design, how to read and interpret drawings, how to set out etc.. Scaffolders are now regarded as a craft in terms of the working rule agreements. Those scaffolders who attended in-house or C.I.T.B. certification courses are taught similar skills to those of the carpenter, plus detailed scaffolding, which means that they are able to construct a wide variety of support structures, recognised as beyond the capability of the formwork carpenter.
There is also the range of semi-skilled personnel: the self-taught, non-apprenticed formwork carpenter who turns his hand to falsework, the semi-skilled labourer, or steel erector, who terms himself a 'scaffolder'.

The measure of competence given below determined on each site and presented in the matrix of variables and subsequent tables, had to take account of this range of occupations and their trades practices. The methodology and criteria are described in the appendix. By careful interviewing and observations the researcher had to determine a measure of competence which applied 'across the board' in order that comparisons could be made, just as quality could be compared. In building, where the assumed competence in the workgroup is fundamental to the effective functioning of the occupational order, this determination of competence is clearly crucial.

The appendix indicates the perceptions of the skills, competence and training methods seen as necessary to erect falsework. Frequently these perceptions are minimal judging from the selection of typical comments and evidence of lack of training, formal or otherwise, in falsework/formwork presented in the appendix, and the evidence of the actual skills measured on site. Any assessment has to be based upon interview and observation, calling for experience from the researcher as a practitioner as well as interpreter and conductor of interviews. This thesis maintains that the assessments and measurements made and ratified by the author are valid and would compare with those made by informed practitioners like the 'panel of experts' referred to in Part 2.
The definition of the measurement of competence, as tabulated in the matrix of variables and summary table 1, is summarised below; a fuller discussion is presented in appendix L.

Competence of Erectors High (H), Medium (M), Low (L).

An evaluation of the competence of the erectors, independently of the falsework they actually erected in the study sample, was based upon interviews with them concerning experience, formal certification (where this applied), formal training, knowledge of different proprietary systems, and the ability of a least some members of the operative work group to read and interpret drawings. Assessment of competence was made by engineers in the research team, unaware of the quality scores for the sample falseworks which were determined at the analysis stage.

What is implicit here is that competence is assessed independent of the other (economic) factors which might lead to the potential competence being exercised, or where the workforce were led by the hand through the drawing and setting out to produce a satisfactory structure.

Table 3 presents the data on levels of competence encountered on site.

	Competence of Erectors			
	High	Medium	Low	Total
Building %	14 32.6	20 46.5	9 20.9	43 100
Civ.Eng. %	3 27.3	6 54.5	2 18.2	11 100
Total %	17 31.5	26 48.1	11 20.4	54 100

Table 3: Number of sites with respect to level of competence of erectors.

Overall, highly competent operatives were engaged on only 31.5% of sites, whereas 20.4% of sites engaged operatives of low competence. This figure of approximately 20% of sites with low competence operatives may be an indication of the perception of competence required, a consequence of a competitive labour market and other factors; but a finding, if representative, which is unlikely to improve given the lack of training being performed.

The figures indicate no significant difference in the distribution of relative competence between personnel engaged on building sites and those on civil engineering sites. Given the autonomy and assumed competence of men on building sites, demonstrated by the lack of routine checking and empirical comment, the fact that 20% of building sites employed men of low competence indicates an erosion of the occupational order. The assumption of the occupational order is that competence is present to some degree but clearly on 20% of sites, the workgroup lacks competence; by definition they cannot achieve high quality or indeed construct to a given design or accepted workmanship standards unless closely supervised; this supervision is not generally present. It is suggested here that the potential for quality construction is at risk.

Given the high degree of occupational control on civil engineering sites, evidenced by the degree of routine checking, there would appear to be less of a threat to the successful functioning of the occupational order and less cause for concern about problems in quality. The occupational order in civil engineering does not rely upon competence in an autonomous workforce.

<u>Employment Status</u>

The previous chapter 15 suggested that the nature of the occupational order provided an explanation for the adoption and effectiveness of formalised control. The model of the occupational order and explanation of occupational control also provides an explanation for the degree (type) of subcontracting chosen on site.

Employment directly or as a labour only sub-contractor does not affect the degree or nature of occupational control exerted on civil engineering sites. The engineers have occupational authority over how the falsework is designed and constructed. The problems of controlling the labour productivity, numbers on site, wastage and so on are for the economic control structure to deal with. The role of the supplier is a service one. He may perform a design but it is checked by the contractor's engineers. He may be called out to site to explain errors in design or construction problems but ultimate responsibility and decisions are taken by engineers on site. Seldom would the supplier's representative be called upon to check the structure (in contrast to building sites). The limited contractual responsibility of the supplier is accepted and recognised by the site.

It has been postulated earlier in Chapter 14 that the occupational order of civil engineering will inhibit the trend of supply and fix sub-contracting from being adopted for falsework construction. The data collected show the trend for engineers to be directly employed by main contractors rather than sub-contractors (who largely employ tradesmen/labourers). The practice of supply and fix sub-contracting would, in civil engineering, result in a recognised loss of control by the main contractors' engineers over the workforce and the sub-contracted falsework operations. The sub-contractor has agreed to supply and fix the falsework in working order for an agreed price and this more or less precludes any direct interference by engineers. Should, for example, a major supplier choose to offer a supply and fix service, controlled on site by engineers, the main contractor in civil engineering may be persuaded to adopt it, since engineering control (albeit by another organisation) is still being exercised which will ensure satisfactory quality. The loss of direct occupational control will nevertheless be resisted by the engineering occupational order of the main contractor unless the economic rewards are such that they cannot be refused. Only one (9%) of eleven civil engineering sites adopted supply and fix, for a straightforward culvert roof, compared to twenty five (58%) of forty three building sites. The evidence clearly supports the thesis that supply and fix sub-contracting is understood to disrupt the recognised occupational order in civil engineering.

On the forty three building sites, eight (19%) engaged directly employed falsework erectors, ten (23%) labour only sub-contractors and twenty five (58%) supply and fix sub-contractors. In contrast to civil engineering, supply and fix sub-contracting is recognised as an acceptable, indeed preferable, arrangement. Given the occupational order of building, the employment status is irrelevant.

Falsework is seen as another specialist activity and supply and fix sub-contracting is a rational solution in the economic and technical orders. Since occupational control rests with the occupation group in any case, occupational control is not lost by changing the employment relationship from directly employed to labour only to supply and fix sub-contracting. The relationships become more contractual and economic control exchanged for that regulated by the market.

The apparent dominance of supply and fix sub-contracting in all other construction operations in building, supports the thesis of the occupational order in building; there is nothing in the implicit understandings of the occupational order to inhibit the adoption of supply and fix sub-contracting.

Quality

The general assumptions of the occupational order in building and civil engineering have been demonstrated to apply in falsework. In civil engineering the engineers are in occupational control (and by virtue of this are also in economic control) and are reluctant to relinquish that direct control (by adopting supply and fix) over quality in the production process. The data confirm that the engineers have the competence and apply it by routinely checking. On the other hand, in building reliance is placed upon the autonomous specialist workforce to regulate their activities by internal checking and monitoring of their own performance.

Table 4, summarised from table 1, compares the level of routine checking with the quality obtained on building and civil engineering sites.

	Routine Checking			
Quality	High	Low	None	Total
Good	8	1	0	9
Fair	0	1	0	1
Inadequate	1	0	0	1
Total	9	2	0	11
%	81.8	18.2	0	100

Civil Engineering Sites

	Routine Checking			
Quality	High	Low	None	Total
Good	4	6	0	10
Fair	6	11	1	18
Inadequate	0	9	6	15
Total	10	26	7	43
%	23.3	60.5	16.2	100

Building Sites

Table 4: Level of routine checking and quality of workmanship - civil engineering and building sites.

The high level of routine checking on civil engineering sites reflects and supports the description of occupational control. A high level of routine checking was implemented on 81.8% of civil engineering sites in contrast to only 23.3% of building sites. Sixteen percent of building sites were not subject to any routine checking.

With the exception of one site, high levels of routine checking appear to avoid inadequate quality and high quality cannot be achieved without some routine checking.

Comparing the findings of Chapter 15, where high formal checking also appears to prevent inadequate sites; the absence of formal checking does not preclude the attainment of high quality. In looking at building sites, of the 10 sites in the good category, 8 showed no formal checking though there was evidence of some routine checking on all of them. Civil engineering sites show a higher correlation between formal checking and routine checking since formalisation is regarded as a logical, desirable extension of the routines that are applied. It would appear that routine checking has a more important effect upon the attainment of quality than formal checking. Routine checking, *prima facie* could be regarded as a predictor of quality. This however does not explain the distribution of quality on sites. Ten building sites instigated high routine checking; however this produced high quality only on those four sites where it coincides with high competence. This poses the question of how effective routine checking is in achieving quality on building sites; effective routine checking depends upon the ability of the checkers, and their interpretation of standards. The differences in quality standards on building and civil engineering sites cannot be explained by a simple comparison of routine checking.

Since civil engineering sites exercised a high degree of routine checking by competent engineers it is suggested that the lack of competence in the workforce has little effect on the quality (but means more attention is required). Thus civil engineering sites show a strong correlation between routine checking and quality. On the other hand, building sites rely upon the competence of the workforce; routine checking is to be regarded as a bonus in some cases and in others as having little effect. There is no significant difference in the distribution of relative competence between operatives engaged in building and those engaged on civil engineering sites. As reported in earlier, 20.4% of all sites engaged operatives of low competence and 48.1% engaged only those of medium competence. It is expected therefore that some building sites will have problems of achieving high quality.

Table 5 compares the level of competence with the quality attained on the various building and civil engineering sites.

	Erector Competence			
Quality	High	Low	None	Total
Good	3	4	2	9
Fair	0	1	0	1
Inadequate	0	1	0	1
Total %	3 27.3	6 54.5	2 18.2	11 100

Civil Engineering Sites

	Erector Competence			
Quality	High	Low	None	Total
Good	8	2	0	10
Fair	5	10	3	18
Inadequate	1	8	6	15
Total %	14 32.6	20 46.5	9 20.9	43 100

Building Sites

Table 5: Competence of erectors and quality of workmanship - civil engineering and building sites.

On building sites where the absence of routine checking reflects and supports the nature of the occupational order, there is a strong correlation between quality and competence. Of the ten good quality falseworks, eight (80%) employed highly competent operatives with two sites (20%) employing middling competent men. None of the high quality building falseworks employed men of low competence. By contrast, of the fifteen inadequate building sites, six (40%) employed operatives of low competence and only one (6.7%) with men of high competence.

Looking at civil engineering sites, in contrast to building, only three out of the nine high quality falseworks (33.3%) employed men of high competence (80% in building) and 23% employed men of low competence (none in building). The level of competence has less effect in civil engineering where the basic assumption of the occupational order is that the workforce does not require a great deal of competence except the physical capability to erect the equipment as directed by the engineer.

Nine (81.8%) of eleven civil engineering falseworks were categorised as good quality in contrast to only ten of forty three (23.3%) of building falseworks. The occupational order in civil engineering is therefore demonstrated to be operating reasonably effectively. In building, however, the assumptions of competence in the autonomous workgroup appear to be invalidated on a significant number of sites and the occupational order is not functioning effectively.

Conclusions

This study has addressed the relative quality standards of workmanship on site. These standards have then been compared with a range of organisational variables in order to assess how the management and control of quality can be described. The thesis asserts that the effective functioning of the occupational order is directly related to the attainment of high quality. Formalisation has only a limited effect insofar as the occupational order incorporates it into the control structure. The formal, more 'centralised' procedures recommended in the Code of Practice conflict with the accepted self-regulating work practices of the workgroups on building sites. From the interview data such requirements have barely penetrated the thinking of building site personnel.

The functioning of the occupational order relies upon the assumption and application of competence of those in occupational control. In civil engineering, competent engineers exert control by routine checking and generally prescribing design and construction. In building, routine checking is assumed to take place within the operative workgroup by competent personnel by virtue of their publicly recognised seniority and occupational authority.

Low quality is attained when the occupational order is prevented from functioning. In building the assumption of competence appears invalidated on a significant number of sites. It may be, however, that the level of competence and the resulting level of quality is acceptable to the particular site. This thesis would concur with the viewpoint of falsework designers and those who have formulated or subscribe to the standards set out in the falsework Code of Practice that the quality standards on all or most of the low category sites are 'inadequate'. These sites represent a 'problem' in that the factors of safety or probability of non-failure are less than that anticipated by the Code. These sites do not generally view the quality of falsework as a focus of concern, but as only one of a range of problems to be dealt with. Furthermore, falsework is a temporary means to some permanent end.

The workmanship standards assumed in this thesis to be fundamental are clearly accepted and present in competent personnel and evidenced by 'good' quality on ten building sites. By definition 'low' or 'fair' competence means that the personnel fall short of the fundamental requirements. Sites who employ less competent personnel without supervision, may not perceive quality as a problem by virtue of lack of competence on the part of those in economic or occupational control; or the economic order might constrain them to act in such a manner. Competent personnel demonstrate their body of knowledge of trades practice which concurs with those standards of the Code of Practice. (Chapter 10 has commented upon the realism of the Code of Practice standards and the justification of the quality categories used in the comparisons).

High quality is achieved on sites where there are basic standards of workmanship such as concentric loading, fixity, verticality, adequate base seating, stability etc. plus proper setting out and interpretation of a drawing; on building sites this can be achieved by personnel without any knowledge of the fact that they are complying with a Code of Practice but by virtue of the their competence in their body of knowledge of trades practice.

NOTE:

The reader may be of the opinion that adjustable steel props and proprietary systems are technically so different, requiring totally different trades practices. This thesis argues that quality can and should be compared across all systems of falsework since the choice of system is based upon organisational factors. Nevertheless the analysis presented in this thesis has been repeated for proprietary systems only (the 11 adjustable steel prop sites and 1 tubes and fittings are too small samples). These forty two proprietary systems sites were re-ranked and categorised. The new category of sites is formed by a simple moving of boundaries. The organisational findings on formal and informal organisation remain the same. The conclusions of the main thesis still apply on the effect and implementation of formal and routine checking and the importance of competence.

The reader might regard civil engineering to be so physically, technically, intrinsically and organisationally different to building that building should be treated as a totally separate category. This thesis argues that differences can be described by the occupational order which has developed to satisfy the technical, economic requirements of a particular type of structure. Workmanship standards and competence have to be compared across all sites and compared with different types of control. Again the exercise was performed which re-ranked and re-categorised the forty three building sites only. The conclusions on formal checking and routine checking which were applied to a low extent with little effect still apply, and for the same reasons. The conclusion that quality is strongly correlated to competence is also upheld.

If the level of quality is to be raised then the conclusion of this thesis is that the occupational order has to be strengthened, or the fundamental assumptions of competence and regulation by those in occupational control re-affirmed. It is difficult to adopt and effectively apply formalisation where formal structure does not exist, or where it runs contrary to the assumed way of organising production (by the occupational order). Contractual clauses and provisions for the design of falsework where implemented may have the effect of raising the profile of falsework activity. Their inclusion and eventual implementation is a reflection of those in occupational control. The occupational authority of the engineer is reflected in his employment by the client. Issues on temporary works and falsework are discussed between engineers in the contractor and the client's employ.

In civil engineering the occupational order appears to be operating effectively with the engineer in occupational (and economic) control. It may be hypothesized that the engineers as a body have responded to the criticisms made by Bragg; since 1975 they have also had access to references such as draft Codes of Practice, Bragg Committee reports and so on. Such information is written, by and large, by engineers in engineering terminology which can be understood and interpreted and the philosophy accepted by the engineer(s) who can be identified as being responsible in the event of a problem or accident. To strengthen the occupational control in building and increase the number of better quality sites, requires a higher incidence and application of competence in the specialist workgroup. Alternatively the fundamental nature of the occupational order could be changed, for example, to that resembling civil engineering. It is suggested that the necessary fundamental shift that would be necessary in order that it is publicly recognised that engineers have occupational rights in and over falsework (and other operations) would run counter to the existing economic rationality of the occupational order in building which facilitates the provision of a variety of (unique) products to a variety of promoters. In a great many instances (in particular the many different small projects) there is no need (and it is uneconomic) to employ the services of an engineer, designer, manager etc. to coordinate and manage the construction and design process.

If the distribution and levels of competence are to be accepted, a possible solution is an attempt by the equipment designers to de-skill the erection process. This in turn transfers an element of ownership of the body of knowledge from the workgroup (trades) to the engineer (supplier, manufacturer, engineer). Such ownership rarely results in direct occupational control being exercised by suppliers except in advising on particular design methods (equipment capacities) and specialised knowledge of grid layouts, components and fixing details etc. One (unintended) consequence of the de-skilling process is perhaps to lower still further the perceived standards of competence deemed necessary (on building sites).

CONCLUSIONS

CHAPTER 17

Conclusions

This research set out to explore the hypothesis that workmanship standards in the erection of falsework on site are related to the social organisation involved in its erection. The study thus entailed a comparative analysis of two distinct sets of variables;

i) site organisation and

ii) quality of falsework erection.

The assessment of quality was made by reference to the Falsework Code of Practice as a standard of good practice. The erection tolerances prescribed in the Code are for individually erected telescopic props and 'tubes and fittings' respectively. None are defined, in the Code, for the various proprietary systems which comprised the type of falsework in use on a major proportion of the sites in the study sample. Since most proprietary systems can be regarded as an easily erected and easily braced forms of 'tubes and fittings' arrangement, the tolerances prescribed for the latter were taken as relevant for proprietary systems. From discussions with practitioners it was evident that proprietary systems were certainly regarded as relatively easy to erect and considered inherently more stable and rigid than other individually erected arrangements. These beliefs may have resulted in the relaxation of erection standards on site or omission of components. Thus the idea of systems being 'idiot-proof' may in itself have led to low standards of erection as evidenced in the research.

After measuring and analysing erection standards in terms of their percentage penalty scores, the falsework arrangements on 54 sites were grouped accordingly into three broad categories of relative quality: 'good'(19 sites), 'fair'(19 sites) and 'inadequate'(16 sites). The falseworks labelled as having 'inadequate' quality can be regarded as those where erection standards fell well below those defined in the Code of Practice. The purpose of the research was to categorise falsework in terms of relative quality and not to determine absolute quality in terms of the effect of erection errors in effective functioning and degree of structural safety. Nevertheless such departures from the Code's prescriptions on a significant proportion of falsework arrangements should give cause for concern. The research indicates that either measures need to be taken to ensure reasonable compliance or that further research needs to be conducted to determine whether prescribed standards and tolerances are 'unrealistic' and require relaxation with the lower erection standards incorporated within design considerations. It should not, of course, be overlooked that the group of practitioners who formulated the Code might have been conscious that looser prescribed erection standards might encourage poorer standards to become acceptable and the norm that sites aim for. Whether the falseworks that have been categorised as being of 'inadequate' quality were unacceptable in terms of structural safety is an open question, requiring individual and complex structural analysis.

Having established three broad categories of relative quality achieved in falsework erection, the research was directed towards discovering how organisational variables were related to the achievement of 'good' or 'inadequate' standards of workmanship. Differences in quality standards could not be adequately explained by technical differences in equipment, size, or physical complexity. For example, differences in quality found on civil engineering sites, where nine out of eleven sites were in the 'good' category, and building, where only ten out of forty three were in the same category, point to differences in organisational control. The important variables could be classified in terms of: formal structure, degree of formalisation and the informal structure of occupational control.

The economic control structures on all sites are essentially the same, characterised by a hierarchy of line managers and few functional specialists. Large sites may have the scope for the employment of functional specialists like a planner, but rarely a falsework coordinator who will still perform a line manager role. Reasons for these 'implicitly structured' organisations are based upon the 'low integrated technology' (using the terminology of Pugh *et al* (1977a, 1977b) and upon the features of the product and market characteristics of the construction industry. Differences in quality cannot be explained by formal structure *per se*. It is the personnel who operate that 'weak' (in organisational terms) structure and the methods and assumptions that they adopt that determine the outcome. Pugh and his colleagues pointed out that formalisation, standard procedures for checking, documentation, specific roles and so on were generated and implemented by functional specialists in order to control production. Formalisation of the falsework production process would therefore be predicted to be inhibited by virtue of the lack of functional specialists. Furthermore, formalisation in terms of falsework is devised by a Code of Practice Committee which is external to the organisation and is less likely to be accepted or implemented.

The findings confirm that the Code of Practice recommendations on formalisation have only been adopted to a limited extent. Formal checking procedures were adopted on twenty of the sites, and on only fourteen of these to any degree envisaged by the Code. This formal checking did not necessarily have to be performed or instigated by a specific coordinator on site. A coordinator was appointed on twenty-three sites but only played an active role on eleven of them. The coordinator never performed the full integrating and administrative role recommended by the Code of Practice. The coordinator was always part of the line management hierarchy performing other production control duties. The coordinators frequently expressed difficulties in performing their role whilst maintaining production targets; often they had neither the training and ability nor the authority to perform their role.

Bearing in mind the factors which inhibit the adoption of formalisation on all sites, some still choose to implement it, notably on civil engineering sites where, for example, some formal checking was performed on all but two of the eleven sites. On the other hand on building, twenty nine of forty three sites had no formal checking. Explanations for this difference are provided by examining the nature of the different forms of occupational control prescribed by the occupational order.

Where formal procedures (formal checking, active interest shown by the coordinator etc.) have been implemented on sites they do have some effect on quality (at the very least they have the effect of raising the profile and concern in falsework). Nevertheless 'good' quality can still be produced without any formal checking procedures or specific roles. Quality is achieved by means of another form of organisation structure. This has been characterised as the model of the occupational order.

The 'occupational order' describes the distribution of rights over how an operation is defined and performed, accruing from membership of an occupation and ownership of the appropriate body of knowledge. Within an occupation, authority is based upon seniority, demonstrated competence and experience. Differences in the occupational order established in civil engineering and building projects explain, to a large extent, differences in the application of the falsework code of practice and differences in quality.

In civil engineering it is publicly recognised that engineers have the occupational authority in and over the production process which is deemed to comprise engineering activities. The engineer's position in the occupational control structure is reflected in his position in the economic control structure of the contractor's organisation, and in the appointment of the client's representative. In building the multitude of operations are controlled by the autonomous occupational specialist (traditionally the apprentice-trades). The engineer has a limited service role to play in having occupational control over such tasks as setting out and concrete quality control. The economic control structure whilst recognising the importance of occupational competence, is staffed by a range of occupational specialists.

The evidence from the study demonstrates that the nature and structure of occupational control as described in building and civil engineering operates as the model describes. Engineers on civil engineering sites, have occupational (and economic) control over falsework (and other activities) and exercise that control by routinely checking the activities, which generally results in 'good' quality. The engineers possess and claim legitimated rights of ownership over the body of knowledge of falsework. This engineering body of knowledge has been enhanced by the existence of the Code of Practice, and other documents and courses which are seen necessary and relevant by engineers. The Code and its requirements are written from an engineering perspective, understood and largely accepted by engineers. A centralised form of control with procedures and documentation also concurs with the general way civil engineering and engineers operate. The apparent effects of formal checking upon quality are due to the fact that they are merely reflecting what goes on, in any case, in routine checking.

On building sites the erection of falsework is regarded as being of less engineering importance, even by engineers, and as a task within the competence of a tradesman, who may be a carpenter, scaffolder, formwork carpenter or labourer or a combination of occupations. Routine checking and competence is assumed to be operating within the specialist workgroup and is not generally performed by the main contractor's supervision. Skills of the manual workforce acquire particular significance. The practice of subcontracting is based upon the assumption that the routine checking and competence operates.

The occupational order in civil engineering inhibits the adoption of supply and fix falsework subcontracting. However, should a firm such as a major supplier offer a supply and fix service , controlled on site by their engineers, this would not radically affect the nature of occupational control in civil engineering (or of course building) and the main contractor could adopt it.

Whereas in civil engineering, lack of competence in the manual workforce is 'inconvenient' (since the process is closely controlled and rectified by the engineer), in building it results in poor quality, because the assumption of the occupational order is that competence resides and is applied in the autonomous specialist workgroup. On a significant number of the sites studied this assumption was found to be invalid, with negative effects on the attainment of quality.

This thesis began by hypothesising that organisation plays a crucial determining influence on the attainment of quality. Organisation structures are essentially the same on any building or civil engineering site. Differences in quality cannot be explained by differences in organisation structure *per se*, and to a certain extent the hypothesis is disproved. The effectiveness of formal or informal control relies upon the personnel who operate the structure(s). The main conclusion of the research is that variation as measured in the quality of falsework erection is directly related to variation in the levels of competence of the personnel involved rather than to variation in organisation structure. Quality depends upon the competence of those in occupational control. It could be speculated that the low competence amongst those engaged in producing falsework (supervision and operatives) is due to the failure in selection procedures which are an essential part of managerial responsibilities of those in economic control. While this may be true, the wider socio-economic context (analysis of which is beyond the scope of this thesis, requiring further research and incorporation into the models) in which line management operates must also be responsible. Whilst trained engineers maintain their position on civil engineering sites in occupational and economic control they will produce high quality falsework where they deem it necessary. On building sites it is speculated that the situation will worsen as the potential pool of competent tradesmen decreases owing to the lack of training and retirement of trained personnel. (References such as C.I.T.B. (1988), Briscoe (1989),and the House of Commons (1987) provide data on skill shortages and the lack of training referred to in previous chapters).

Solutions by formal means are of limited effect. Any level of formal checking still requires competence and discretion in the person checking and being checked. The Code of Practice for Falsework may be regarded by some practitioners as an ideal example of Quality Assurance (Q.A.) being applied in practice (Chapter 5). The implementation and success of formalised Q.A. schemes applied to the whole of the design and construction process would, it is postulated, be affected by the nature of the occupational order and the personnel involved. Further research is necessary to establish the effect of client and senior management involvement in such schemes and the effect of differences in contractual arrangements (for example design and build or management-fee, explicitly excluded here) have upon the occupational and economic control structures and the resulting quality.

The standards of workmanship in falsework found on the 54 sites examined here are believed to be representative. Representatives in the industry and interested bodies need to decide whether these standards are satisfactory. It is true that on none of the poorest quality sites did failure occur, but the probability of such failure is greater on these than on the higher quality sites. It may be that serious, dramatic failures (in buildings) will have to occur before interest is focused once again, as in the series of accidents which initiated the Bragg study.

Any recommendations aimed at improving the levels of quality of workmanship in falsework rely upon a problem being recognised. There is therefore a requirement to educate all those involved in producing falsework. It is possible to give recommendations upon how the level of perception of quality of falsework can be raised on building sites, by, for example, booklets, pamphlets with explanatory diagrams showing tolerances and so on, the checklists devised in this study could also be of assistance. Such recommendations may be regarded as typical exhortations made by Bragg and the H.S.E. on falsework and safety and indeed quality in general which appear to have limited effect. Nonetheless the attempt should be made to disseminate in an easily readable form, the main requirements of falsework workmanship and the importance of the structure in terms of economics and safety.

Following on from these general suggestions on education, there appear to be four solutions or recommendations for further work and study:

1) Measures to improve competence in the workforce would have a significant effect upon raising the level of quality. Such measures would not run counter, but strengthen the assumptions made in, and the functioning of, the occupational order. The problems of skill shortages and lack of training must be addressed. These form part of a wider structural, economic and political context. Research is needed upon what type of training is needed and how it could be achieved.

2) The nature of occupational control in building could be changed to that resembling civil engineering where reliance upon competence in the workforce is not so important but control is exercised by someone else (the engineer). This would not be achieved by changes in the formal structure, since its operation depends upon the informal organisation, but by changes in the general occupational order in building. A fundamental shift in the nature of the occupational order would have to take place and in the rationale upon which its existence is based. A form of supply and fix subcontracting where, for example, a supplier designs and supervises falsework is one means of changing the nature of occupational control. This would call for changes in the suppliers' marketing strategies.

3) Formal controls which have the quasi-legal backing of a British Standard Code of Practice are essentially voluntary, and their adoption is largely inhibited unless deemed necessary by the occupational order; there is therefore no guarantee of their implementation. These controls could be made mandatory by contractual or statutory means. Bragg too suggested such measures which have been resisted (as discussed in Chapter 3 and Wilshere (1982, 1983b)). If it is accepted that the standards of workmanship in the Code of Practice are realistic and should be adhered to, then perhaps statutory means of control (by for example the H.S.E.) or contractual ones (by stronger client involvement, for example in the public sector) should be investigated again.

4) The situation regarding competence and quality could be accepted and research could be devoted into evaluating the consequences, in terms of structural failures, (and the resulting economic loss and safety complications) and then changing the design assumptions and equipment capacities (the design and equipment would still need to be erected to some, lower standard by sites who may view the requirements as over conservative.) The equipment may be developed further to cater for fewer skills (with a possible consequence of further erosion). It should be remembered, however, that the skills necessary (in what are termed 'high' competence operatives) are not that great - ability to set out, read drawings, erect plumb, fix tightly etc. and it is difficult to conceive of any system to counter absence of such skills.

Further research is advocated into other European countries bearing in mind the requirement for technical harmonisation. It would be of interest to know what falsework codes are in existence; and any differences in types of formal or informal controls that are exercised in falsework production on site. In particular, other European countries adopt different policies on training (the institutional and structural differences in countries need to be explored) and research is needed to assess the effects upon levels of competence and resulting quality, given the controls. From 1992 contractors will have to compete with other European firms who may have better trained operatives or more effective forms of control.

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ORGANISATION AND QUALITY OF FALSEWORK CONSTRUCTION

A socio-economic study of the organisational structure of the Construction Industry with respect to the falsework production process and the quality of workmanship attained

Volume II of II

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APPENDIX A

Glossary of Terms

Glossary of Terms

BASE PLATE:

A metal plate with a spigot for distributing load from a standard, raker or other load bearing member. An adjustable base plate incorporates a screw-jack.

BAY LENGTH:

The distance between the centres of two adjacent standards measured horizontally.

BEARER:

A horizontal or sloping beam of steel, aluminium or timber normally continuous over several supports, for example, carrying the decking for a suspended concrete slab.

BIRDCAGE:

A three dimensional grid of scaffolding. The grid resembles a birdcage except for the inner part which also contains scaffolding.

BLINDING:

A layer of lean concrete usually 50mm to 100mm thick, put down in soil such as clay to seal the ground and provide a clean bed for construction work.

BRACE:

A tube or similar placed diagonally with respect to the vertical or horizontal members of a scaffold and fixed to them to afford stability.

BRACING:

A diagonal system of scaffolding members that connect frames of scaffolding laterally. The bracing greatly reduces the possible rotations of the connections and therefore makes the scaffolding frame a continuous structure. Bracing also provides overall stability against horizontal forces.

CAMBER:

The intentional curvature of a beam or formwork, either formed initially to compensate for subsequent deflection under load, or produced as a permanent effect for aesthetic reasons.

CENTERING:

The support for deck or floor formwork. Particularly applicable to arches and other curved soffits.

COUPLER:

A component used to joint scaffold tube. Check couplers or safety couplers are couplers added to a joint under load to give security to the coupler(s) carrying the load.

DECKING:

Sheeting (plywood, steel, aluminium) or waffle moulds to the soffit formwork.

DROP HEAD:

A device fitted to a tubular prop or standard to permit removal of beams and soffit formwork without disturbing the prop.

FACTOR OF SAFETY:

Ratio of ultimate load to the maximum working load.

FALSEWORK:

Any temporary structure used to support a permanent structure while it is not self-supporting.

FLOOR CENTRE:

A beam of adjustable length, usually a metal lattice or sheet metal box beam, used to support decking or secondary beams to a floor slab.

FLYING FORM:

A large table form designed to be extracted and re-erected without dismantling by moving with a crane.

FORKHEAD:

A U-shaped housing used to support the primary beams, joists, bearers or runners. An adjustable forkhead incorporates a screw-jack.

FORMWORK and FORMS:

The section of temporary works used to give the required shape and support to poured concrete. It consists primarily of sheathing material (eg. wood, plywood, metal sheet or plastic sheet) in direct contact with the concrete and joists or bearers that directly support the sheathing. Part of the sheathing may be permanently left in place.

FOOT-TIE:

A member close to the ground, stabilising two or more standards.

FRAME:

The principal panel unit of a prefabricated falsework structure formed from welded, bolted or clamped tubular or rolled sections.

JOIST:

See bearer.

LACING:

Essentially horizontal members that connect together and reduce the unsupported length of columns.

LEDGER:

See lacing above (normally term applies to access scaffolding).

LIFT:

In terms of strict falsework design, lift is the height of the structure. In terms of formwork it is the height of concrete cast in one pour. In terms of scaffolding, it is the height between levels of lacing, which determines the length used in calculating the strut length. For the purposes of this thesis and the conventional terminology on site this latter is the definition used.

PERMIT TO LOAD:

A certificate issued to indicate that the falsework may safely be put to its designed used.

PRIMARY BEARER
(runner,beam,joist etc): A member which spans between standards or props and supports the secondary bearer.

PROP:

Any vertical or inclined compressive support, but usually proprietary adjustable (telescopic) steel strut.

PROPRIETARY DECKING:

A system of beams integral to the support system, which may also include decking and sheathing material or units. For the purposes of this thesis, proprietary decking applies only to the temporary primary and secondary beams which are integral to the support structure, and not the decking material or equipment. Any permanent decking material, eg. profile steel sheeting is naturally excluded from the definition of falsework.

PROPRIETARY SYSTEMS:

A system of individual tubular members of framed units which connect together via clips, wedges or bolts to form the support scaffolding structure. Traditional or proprietary decking equipment may be placed on top of these proprietary systems.

RAKER:

Inclined strut or prop.

RUNNER: See bearer.

SCAFFOLDING:

A temporarily provided structure that provides access, on or from which persons work, or that is used to support material, plant or equipment. The definition conventionally applied on site includes falsework support structures as well as access.

SHORING:

See falsework generally. More often a structure of timber or more usually tubes and fittings (or a combination) used to stabilise. support an existing local bearing wall or facade to a building. Proprietary systems are generally unsuitable since they cannot withstand tension.

Raking - inclined to ground.

Flying - horizontal thrust member (between building walls).

Dead - falsework supporting concrete or more usually existing structures (eg. needles in underpinning).

SHUTTERING: See formwork.

SOFFIT:

The exposed under-surface of any concrete element.

SOLE PLATE:

A timber, concrete or metal spreader used to distribute the load from a standard or base plate to the ground.

STANDARD:

A vertical or near vertical tube (prop).

STRUT:

A member in compression.

TABLE FORM:

Combined soffit and support falsework, used in modular multi-storey construction.

TIE:

A scaffolding member that is attached to a rigid structure to create or improve the stability of the scaffolding. Some proprietary systems use the terminology 'shoring tie' to denote those prefabricated lacing members which are part of a heavy duty support system.

WEDGE:

A piece of strong timber or metal that tapers in its length and is used to adjust elevation or line or to tighten falsework. Folding wedges comprise a pair of wedges laid one above the other so that their outer faces are parallel.

APPENDIX B

Drawings 1 and 2, summary of errors and penalty scores on each site in each condition

SUMMARY OF ERRORS LISTED ON CHECKLISTS OF BEAM AND SLAB TYPE FALSEWORK CONSTRUCTIONS.

PROPRIETARY SYSTEMS / TRADITIONAL DECKING (25 SITES)

TYPE OF SYSTEMS / CASE STUDY No	2	6	8	9	12A	15	16	17	20	22	24	25A	26	29	31	34	36A	37	39A	41	45	47A	48	49	53
SAMPLE SIZE	63	64	64	52	47	56	44	60	50	54	68	48	54	50	54	52	14	46	16	49	54	32	50	28	24
FALSEWORK HEIGHT (in metres)	2.5	3.8	4.3	4.3	2.7	3.0	6.0	4.3	9.75	4.9	2.15	3.5	6.0	3.2	3.5	2.9 to 4.7	4.25	10.5 [illegible]	2.5	7.0	2.63	3.25	5.0	2.7	3.25
POUR No. (No of from Total)	3/50+	15/30+	1/50+	2/50+	1/20	30/40	93/100	1/20	4/4	1/2	1/1	1/1	1/3	1/2	12/20	1/2	3/50+	1/2	2/2	10/10	3/10+	1/1	1/3	1/2	1/2
TYPE OF EQUIPMENT	X	Z	Y	X	X	Y	Z	X Z	Z	Z	X	Z	Y	Y	Y	Z	Y	AL	Z	Z	Z	Z	Z	X	X
HEAD CONDITION																									
1 Eccentricity	10/63	6/64	✓	40/52	✓	✓	✓	✓	✓	✓	5/68	24/48	✓	✓	6/54	26/52	✓	–	✓	✓	✓	✓	✓	✓	✓
2 Joints in Beams not Central ≥ 15mm	4	✓	✓	✓	✓	✓	90% ≥15mm	✓	✓	✓	7/43	✓	2/25	2	1	12/15	✓	–	–	✓	✓	✓	✓	✓	✓
3 Clips/Wedges frequency of missing or loose	+5/63	32/64	–	AI	✓	✓	AI	✓	✓	✓	AI	✓	✓	✓	10%	✓	✓	–	50%	✓	✓	AI	✓	8	–
4 Jack extension beyond limit	✓	✓	✓	✓	✓	✓	AI	✓	✓	✓	✓	✓	✓	✓	25/54	✓	✓	–	All > 300	✓	✓	All > 400	✓	1/28	✓
5 Light or Heavy duty head jacks	✓	✓	–	–	–	–	–	–	✓	✓	✓	–	–	✓	–	–	✓	–	✓	–	✓	–	–	–	–
6 Connections (including pins)	✓	✓	✓	✓	✓	✓	–	✓	✓	✓	✓	✓	✓	Pgs ✓	–	✓	✓	–	✓	✓	✓	✓	✓	✓	✓
7 Conditions of fork heads, Jacks etc	✓	old	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	F	✓	✓	✓	✓	✓	F	✓	✓	✓	✓	✓	✓
8 Timber not secured on props	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
BASE CONDITION																									
1 Assessment of adequacy of packing for provision of horizontal + vertical restraint	✓	✓	✓	✓	50 70 % I	✓	AI	AI	✓	✓	23/68	3/48	10/54	✓	✓	7/32	✓	I	✓	✓	13/54	✓	30% I	✓	6/24
2 Light or Heavy duty base jacks	–	–	–	–	✓	–	–	–	✓	✓	✓	–	✓	–	–	✓	✓	✓	–	–	–	–	✓	–	✓
3 Excessive jack extension (> 300)	✓	–	–	✓	✓	✓	All > 300	–	✓	✓	✓	1	✓	✓	All > 400	✓	–	✓	✓	✓	✓	–	✓	✓	✓
4 Connections (including pins)	✓	✓	–	✓	✓	✓	✓	–	✓	✓	✓	✓	✓	✓	–	✓	✓	✓	✓	✓	✓	–	✓	✓	✓
5 Conditions of materials	✓	F old	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	F	✓	F	F	✓	✓	✓	✓	✓
VERTICAL MEMBERS																									
Lift Height excessive	N	N	N	N	Y	N	N	N	N	N	Y	N	N	N	N	N	N	N	Y	N	N	N	N	Y	N
(a) No in any line	–	–	–	–	60%	–	–	–	–	–	All	–	–	–	–	–	–	–	All	–	–	–	–	All	–
(b) Total No	–	–	–	–	60%	–	–	–	–	–	All	–	–	–	–	–	–	–	All	–	–	–	–	All on lift	–
2 No of Lacing missing (L/T)	✓	✓	–	✓	✓	✓	80% missing	✓	✓	✓	1	5	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	33%	✓
3 Light or Heavy Duty	–	–	–	–	–	–	–	–	–	✓	–	–	–	–	–	✓	✓	–	–	✓	–	–	–	–	–
4 Verticality																									
30'–60' (Measured in Longitudinal and transverse directions)	17/9	1/0	3/4	1/5	3/2	2/1	3/8	10/7	0/0	0/0	6/9	14/15	4/3	6/6	2/2	1/1	–	4/3	3/0	2/4	5/3	3/1	3/2	1/2	2/5
60'–90'	10/0	–	–	0/1	1/1	–	0/4	1/1	–	–	17/25	0/2	–	2/0	1/1	–	–	–	–	–	–	–	–	–	–
90'–120'	2/0	–	–	–	–	–	–	–	–	–	4/8	–	–	–	–	–	–	–	–	–	–	–	–	–	–
> 120	–	–	–	–	–	–	–	–	–	–	2/3	–	–	–	–	–	–	–	–	–	–	–	–	–	–
5 Trend – Longitudinal	80%	–	–	–	–	–	–	70%	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
– Transverse	57%	–	–	–	–	–	85%	70%	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
6 Connections	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	14/116	4/85	✓	5/100	✓	2/128	✓	✓	2/44	✓	✓	✓	✓	✓	✓
7 Incorrect pins on props.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
BRACING																									
1 Correct Type	✓	✓	N/A	✓	✓	✓	None	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	I	T/F ✓	✓	✓	✓	✓	✓
2 Nos missing																									
Longitudinal direction	3/19	–	–	24/24	✓	8/58	–	✓	✓	✓	4/16	8/14	✓	2/12	6/9	✓	✓	50%	✓	✓	✓	9/16	✓	8/8	✓
Transverse direction	5/8	–	–	2/26	✓	14/36	–	✓	✓	1/40	✓	✓	✓	1/16	10/34	✓	✓	50%	✓	✓	50%	–	✓	16/32	8/40
3 Nodes > 150 mm.	All > 200	✓	–	All > 400	60% > 150	✓	–	–	✓	–	All > 300	✓	✓	5	✓	–	–	–	All > 400	6/80	✓	✓	✓	✓	7
4 Tightness of connections	✓	✓	–	✓	✓	✓	–		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
5 Conditions of materials	✓	old	–	✓	✓	✓	–	✓	✓	✓	✓	✓	✓	✓	✓	✓	F	F	✓	✓	✓	✓	✓	✓	✓
TYING-IN																									
1 Check for Lateral stability	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2 Check bracing for node stability	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3 Tightness of connections	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
ACCESS and SAFETY																									
1. Access to check, adjust falsework	G	G	G	G	G	G	I	G	G	G	G	G	F	F	G	G	G	I	G	I	I	I	G	G	G
2. Access to concrete his formwork beam sides	G	F	G	G	G	G	I	G	G	G	F	F	G	I	G	I	G	G	G	G	F	G	G	G	F
3 General site tidiness	T	U	F	T	F	T	U	T	T	T	T	T	F	T	F	T	T	F	F	F	F	U	T	G	F
DRAWINGS																									
1 Availability of	Y	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	N	Y*	Y	Y	N
2 Conformity to.	N	G	–	N	N	G	–	G	G	G	I	I	G	F	–	G*	F	F	N*	F	–	F	G	N	–
3 Quality of	G	F	–	F	G	F	–	F	G	G	I	F	G	G	–	G	I	G	F	I	–	I	G	G	–
Remarks			Triframe				Tower system.				Top Lift lowered in both directions.			*Bracing inadequate on drawing			Standard centres and direction of timber runners altered – single instead of double runners.	All Tying-in / Bracing left to Contractor.				*No working drawing available site sketches only.			

PROPRIETARY SYSTEMS / PROPRIETARY DECKING (17 SITES)

TYPE OF SYSTEMS / CASE STUDY No	1A	3	4	5	10A	11	13A	14A	30	33	38	40	42	43	46	51	52
SAMPLE SIZE	26	50	60	56	36	54	40	45	56	64	50	42	42	56	54	38	38
FALSEWORK HEIGHT (in metres)	3.0	4.2	2.65	2.7	2.6	5.8	3.6	3.3	5.8	3.3	8.1	3.6	3.25	3.15	2.5	2.7	3.25
POUR No. (No of from Total)	43/50	2/13	3/[illegible]	25/50	40/50	1/30+	4/20	1/30	80/100	20/30	1/15	11/40	45/50	1/6	13/40	1/1	1/50
TYPE OF EQUIPMENT	X	X	Z	Z	Y	Z	Y/Z	Z	Z	Z	Z	X	X	Y	X	Z	Z
HEAD CONDITION																	
1 Eccentricity	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2 Joints in Beams not Central ≥ 15mm	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3 Clips/Wedges frequency of missing or loose	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
4 Jack extension beyond limit	✓	✓	✓	✓	✓	✓	✓	✓	✓	> 500	✓	✓	✓	All > 430	–	✓	> 380
5 Light or Heavy duty head jacks	✓	✓	✓	✓	–	–	✓	–	✓	✓	–	✓	✓	✓	✓	✓	✓
6 Connections (including pins)	✓	✓	✓	✓	50%	✓	[illegible]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
7 Conditions of fork heads, Jacks etc	✓	✓	✓	✓	✓	✓	F	✓	✓	F	✓	–	✓	✓	✓	F	✓
8 Timber not secured on props	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
BASE CONDITION																	
1 Assessment of adequacy of packing for provision of horizontal + vertical restraint	✓	✓	✓	✓	✓	✓	✓	✓	I	✓	7/50	✓	5/42	7/56	AI	✓	✓
2 Light or Heavy duty base jacks	–	–	✓	✓	–	✓	–	–	–	–	–	–	–	–	✓	–	–
3 Excessive jack extension (> 300)	✓	✓	✓	All > 500	✓	✓	–	✓	All 340 to 530	✓	✓	✓	–	> 450	✓	✓	> 800 ✓
4 Connections (including pins)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	–	✓	✓	✓	✓	✓
5 Conditions of materials	✓	✓	F old	F old	✓	✓	F	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
VERTICAL MEMBERS																	
Lift Height excessive	Y	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N
(a) No in any line	AI	–	–	–	–	–	–	–	–	–	–	2	50%	–	–	–	–
(b) Total No	AI	–	–	–	–	–	–	–	–	–	–	2	50%	–	–	–	–
2 No of Lacing missing (L/T)	L No	✓	✓	✓		✓	✓	✓	6/398	✓	✓	✓	33/[illegible]	✓	4/84	4	4
3 Light or Heavy Duty	–	–	✓	✓	–	–	–	–	–	–	–	–	–	–	–	✓	–
4 Verticality																	
30'–60'	2/5	6/1	3/0	7/4	0/0	8/2	0/1	2/3	0/0	1/2	9/8	1/2	3/4	4/5	9/7	6/3	1/1
60'–90'	0/1	1/12	–	–	–	–	–	1/0	9/5	0/0	–	–	10/3	–	0/2	0/4	–
90'–120'	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0/1	–	–
> 120	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
5 Trend – Longitudinal	–	–	–	–	–	–	–	–	–	–	80%	–	–	–	–	–	–
– Transverse	–	–	–	–	–	–	–	–	–	–	62%	–	–	–	–	–	–
6 Connections	✓	✓	✓	✓	✓	✓	✓	✓	15/146	11/400	4	✓	✓	✓	3/50	✓	✓
7 Incorrect pins on props.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
BRACING																	
1 Correct Type	✓	✓	✓	✓	✓	✓	None	✓	✓	✓	✓	✓	✓	None	✓	None	✓
2 Nos missing																	
Longitudinal direction	13/18	15/30	✓	24/60	✓	12/27	–	22/30	24/42	26/50	✓	✓	✓	–	✓	–	18/42
Transverse direction	12/12	6/54	✓	48/64	✓	12/30	–	22/28	7/69	All	✓	✓	✓	–	✓	–	10/38
3 Nodes > 150 mm.	AI	✓	✓	✓	✓	> 150 > 250 All	–	All > 150	12	–	2	> 110 > 500	10/30	–	30%	–	8/72
4 Tightness of connections	✓	✓	✓	✓	✓	✓	–	✓	✓	11/400	✓	✓	✓	–	✓	–	✓
5 Conditions of materials	✓	✓	old	old	✓	✓	–	✓	F	✓	✓	✓	✓	–	✓	–	✓
TYING-IN																	
1 Check for Lateral stability	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2 Check bracing for node stability	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3 Tightness of connections	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
ACCESS and SAFETY																	
1. Access to check, adjust falsework	G	F	I	F	G	G	G	G	G	F	G	G	G	G	I	G	G
2. Access to concrete his formwork beam sides	AI	F	G	G	G	G	G	G	G	I	G	G	G	F	I	I	G
3 General site tidiness	U	U	F	U	T	T	F	T	F	T	T	T	U	T	I	U	G
DRAWINGS																	
1 Availability of	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2 Conformity to.	N	F	G	N	F	F	N	N	F	F	G	G	N	N	I	N	N
3 Quality of	F	F	F	F	G	I	I	G	G	I	G	G	I	F	G	G	I
Remarks								2 m. Lift height shown on drawing							Bracing shown on drawing but missing.		

ADJUSTABLE PROPS / TRADITIONAL DECKINGS (18 SITES) and TUBES/FITTINGS / TRAD DECKS (3 Sites)

TYPE OF SYSTEMS / CASE STUDY No	1B	7	10B	12B	13B	14B	18	19	21	23	27	28	35	39B	44	47B	50	54	25B	32	36B	NOTES
																						'B' Denotes Secondary falsework
SAMPLE SIZE	21	37	21	18	35	18	54	41	50	56	56	21	12	9	41	37	50	52	16	56	36	Figures denote No of Verticals in the sample.
FALSEWORK HEIGHT (in metres)	3.0	2.7	2.6	2.75	3.58	3.1	3.13	2.58	4.07	2.25	3.0	3.4 to 4.06	2.5	2.5	2.57	3.25	2.45	3.28	4.7	2.4 to 5.0	4.25	Height measured from the Base plate to Soffit formwork
POUR No. (No of from Total)	45/50	4/30	40/50	1/20	4/20	1/30	6/30+	1/1	1/8	4/12	12/50	1/1	3/3	2/2	1/7	1/1	1/1	20/30	1/1	25/30	15/30	1/20 means first pour of possible 20 pours.
TYPE OF EQUIPMENT	Z	A	Y	X	A	Z	A	X	A	A	A	A	X	A	A	A	A	A	T/F	T/F	T/F	X Y Z etc denote certain proprietary systems A denotes props and T/F - Tubes & fittings
HEAD CONDITION																						
1 Eccentricity	✓	8/37	✓	✓	✓	5/18		28/41	1/50	9/56	3/56	✓	AI	3/19	7/41	4/37	6/50	10/52	8/16	6/50	✓	30/63 means 30 out of 63 Verticals assessed errors.
2 Joints in Beams not Central ≥ 15mm	✓	✓	✓	✓	–	✓	✓	✓	2/9	1	2	–	✓	✓	–	–	✓	–	✓	AI	✓	
3 Clips/Wedges frequency of missing or loose	–	–	–	–	–	–	–	–	–	–	✓	–	–	–	–	–	–	–	✓	9/56	✓	
4 Jack extension beyond limit	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✓	8/56	✓	
5 Light or Heavy duty head jacks	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✓	✓	✓	
6 Connections (including pins)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✓	✓	✓	
7 Conditions of fork heads, Jacks etc	✓	–	✓	✓	✓	50% bent	F	✓	5 No bent	F	✓	✓	F	F	F	✓	F	✓	F	F	F	
8 Timber not secured on props	AI	10/37	✓	AI	✓	AI	✓	4	12	✓	5	✓	✓	AI	AI	AI	8	10	–	–	–	
BASE CONDITION																						
1 Assessment of adequacy of packing for provision of horizontal + vertical restraint	3/21	4/37	✓	I	✓	30% I	✓	18/41	✓	7/56	1/56	3/12	✓	AI	4/37	✓	✓	✓	✓	9/56	✓	
2 Light or Heavy duty base jacks	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
3 Excessive jack extension (> 300)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	All 340 to 530 means that all Standards had extensions between 340 to 520 mm.
4 Connections (including pins)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✓	✓	✓	
5 Conditions of materials	✓	F	F	✓	F old	50% I	F	✓	✓	F	15 bent	3 bent	I	F	F	F	✓	✓	✓	✓	F	
VERTICAL MEMBERS																						
Lift Height excessive	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	N	N	N	
(a) No in any line	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
(b) Total No	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
2 No of Lacing missing (L/T)	All	2/5	–	–	←	All missing	→	20% missing	90% missing	–	1	✓	–	–	✓	38	3	✓	✓	✓	–	
3 Light or Heavy Duty	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
4 Verticality																						
30'–60'	8/5	6/8	2/6	2/1	10/16	7/2	7/13	13/7	11/7	15/2	4/12	4/5	2/3	3/0	9/8	10/5	5/3	9/12	0/5	3/6	0/3	17/9 means 17 in longitudinal direction and 9 in transverse direction
60'–90'	2/5	4/6	4/1	5/6	6/5	3/3	8/8	5/12	5/12	15/13	22/19	4/1	0/2	–	3/3	9/10	9/13	1/10	5/2	–	1/0	
90'–120'	1/2	3/2	2/2	1/1	4/1	1/0	1/0	3/6	3/4	5/6	4/6	–	1/1	–	0/1	2/0	1/1	–	–	–	–	
> 120	–	2/3	–	–	1	1/0	4/0	2/1	1/1	3/8	5/4	–	–	–	–	1/0	3/1	–	–	–	–	
5 Trend – Longitudinal	–	65%	–	50%	–	50%	–	–	60%	–	80%	–	100%	–	15%	–	70%	–	–	–	–	
– Transverse	90%	62%	–	50%	–	50%	–	–	60%	–	80%	–	90%	–	66%	–	55%	–	–	–	–	
6 Connections	✓	F	✓	✓	✓	✓	–	30% I	✓	✓	43/37	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
7 Incorrect pins on props.	2/21	9/37	✓	✓	9/35	✓	✓	1/44	7/50	–	1	–	11/12	–	–	–	–	–	–	–	–	
BRACING																						
1 Correct Type	None	–	–	–	None	None	✓	–	None	→	→	→	→	→	→	→	T/F ✓	None	N A	✓	None	
2 Nos missing																						
Longitudinal direction	–	–	–	–	–	–	10/12	–	–	–	–	–	–	–	–	–	✓	–	–	✓	–	
Transverse direction	–	–	–	–	–	–	7/9	–	–	–	–	–	–	–	–	–	14/14	–	–	I	–	
3 Nodes > 150 mm.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	AI	–	
4 Tightness of connections	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✓	–	–	✓	–	
5 Conditions of materials	–	–	–	–	–	–	✓	–	–	–	–	–	–	–	–	–	✓	–	–	✓	–	
TYING-IN																						
1 Check for Lateral stability	None	–	–	–	←	None	→	I	None	–	None →	→	→	→	→	→	→	→	✓	✓	✓	
2 Check bracing for node stability	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	50% okay	✓	
3 Tightness of connections	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	✓	✓	✓	
ACCESS and SAFETY																						
1. Access to check, adjust falsework	G	I	G	G	G	G	G	G	I	G	G	G	G	G	G	I	G	G	G	G	G	
2. Access to concrete his formwork beam sides	AI	I	G	G	G	G	G	G	G	G	I	F	G	I	F	G	G	G	F	G	G	
3 General site tidiness	U	U	T	F	F	T	T	U	U	T	U	T	T	F	U	U	F	G	T	T	T	
DRAWINGS																						
1 Availability of	N	N	Y	N	N	Y	Y	Y	N	Y	N	Y	N	Y	Y	Y*	Y	N	N*	N	N	
2 Conformity to.	–	–	F	–	–	N	N	N	–	N	–	G	–	N	F	F	G	–	–	–	–	
3 Quality of	–	–	G	–	–	G	F	I	–	G	–	G	–	F	F	I	G	–	–	–	–	
Remarks						No Bracing shown on the drawing.				Lacing / Bracing shown on RMD drawing but not installed on site		Supplier drawing does not specify bracing			*No working drawings available, site sketches only				Site made a good job of T/F			

KEY

- – N/A
- ✓ OK
- AI. All Inadequate
- I Inadequate
- T. Tidy
- U. Untidy
- G. Good
- F. Fair
- Y. Yes
- N. No

GENERAL NOTES

1. This drawing should be read in conjunction with Drawing No 2.
2. This drawing is an attempt to summarise information on checklists

Research Project. The Management of Falsework Construction (1985-87)

Drg No. 1

TITLE:- Types of Errors encountered on 54 Main sites and 9 Secondary sites.

ANALYSIS OF QUALITY OF WORKMANSHIP ON FALSEWORKS

PROPRIETARY SYSTEMS / TRADITIONAL DECKING (25 SITES)

TYPE OF SYSTEMS																									
CASE STUDY No. —	2	6	8	9	12A	15	16	17	20	22	24	25A	26	29	31	34	36A	37	39A	41	45	47A	48	49	53
SAMPLE SIZE	63	64	64	52	47	56	44	60	50	54	68	48	54	50	54	52	14	46	16	49	54	32	50	28	24
FALSEWORK HEIGHT (in metres)	2.5	3.5	4.3	4.3	2.7	3.0	6.0	4.3	9.75	4.9	2.5	3.5	8.0	3.2	3.5	2.9 to 4.7	4.25	10.5 to 17.7	2.5	7.0	2.63	3.25	5.0	2.7	3.25
HEAD CONDITION																									
Eccentricity > 25mm (-100)	-50	-10	0	-80	0	0	0	0	0	0	-20	-50	0	0	-11	-50	0	N/A	0	0	0	0	0	0	0
Fixity (-100)	-80	-50	0	-100	-50	0	-100	-30	0	0	-100	0	-16	0	-10	0	0	N/A	-50	0	0	-100	0	-28	0
BASE CONDITION																									
Adequacy of Seating (-100)	0	0	0	0	-75	0	-100	-50	0	0	-34	-6	-19	0	0	0	0	-2	0	-14	-24	0	-30	0	-25
JACK EXTENSION																									
Head Condition (-100)	0	0	0	0	0	0	-100	0	0	0	0	0	N/A	0	-52	0	0	-13	-100	0	0	-100	0	0	N/A
Base Condition (-100)	0	N/A	N/A	0	0	0	-100	N/A	0	0	0	0	N/A	0	-52	0	N/A	0	0	0	0	0	0	0	0
VERTICAL MEMBERS																									
Effective height (-50)	0	0	0	0	-50	0	0	0	0	0	-50	0	0	0	0	0	0	0	-50	0	0	0	0	-60	0
Lacing Missing (-50)	0	0	0	0	0	0	-40	0	0	0	0	-5	0	0	0	0	0	0	0	0	0	0	0	-17	0
Verticality (-100)	-60	0	-11	-14	-15	-5	-30	0	0	0	-76	-65	-13	-28	-11	-4	0	-13	-19	-12	-15	-13	-10	-11	-30
Inadequate pins on props (-50)	N/A	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	N/A
BRACING																									
Longitudinal Direction (-100)	-100	0	N/A	-100	0	-14	-100	0	0	0	-10	-67	0	-16	-66	0	0	-20	0	0	-56	0	0	-100	0
Transverse Direction (-100)	-30	0	N/A	-6	0	-39	-100	0	0	-3	0	0	0	-6	-30	0	0	-20	0	0	-50	0	0	-50	-20
Nodes > 150mm. (-100)	-100	0	0	-100	-60	0	N/A	0	0	0	0	-100	0	0	0	0	0	0	-100	0	0	0	0	0	-30
For props only: Bottom Lace (-50)	N/A	N/A	N/A	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	N/A
For props only: Angle (-50)	N/A	N/A	N/A	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	N/A
TYING IN																									
Present and Adequate (-100)	N/A	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	N/A
MARKS	420/1000	80/900	11/700	402/1000	260/1000	56/1000	670/900	80/900	0/1000	3/1000	390/1000	183/1000	48/800	50/1000	232/1000	54/1000	0/900	66/800	319/1000	34/1000	88/1000	266/1000	40/1000	256/1000	105/900
PERCENTAGE	42%	7%	2%	40%	26%	6%	74%	9%	0%	0%	39%	18%	6%	5%	23%	5%	0%	9%	32%	3%	9%	27%	4%	26%	12%
RANKING (1)	56	17	6	53	37	15	63	18	1	1	52	27	15	12	32	12	1	18	45	9	18	40	10	37	24
CONDITIONS of MATERIAL																									
Good (0) Old/Fair (-30) Poor (-60) V Old/Poor (-100)	0	-60	0	0	0	0	0	0	0	0	0	-30	0	0	0	0	-70	0	-30	0	0	0	0	0	0
MARKS	420/1100	120/1000	11/800	402/1100	260/1100	56/1100	670/1000	80/1000	0/1100	3/1100	390/1100	213/1100	48/900	50/1100	232/1100	54/1100	70/1000	66/900	349/1100	34/1100	88/1100	269/1100	40/1100	256/1100	105/1000
PERCENTAGE	38%	12%	1%	37%	24%	5%	67%	8%	0%	0%	35%	19%	5%	5%	21%	5%	7%	8%	32%	3%	8%	24%	4%	23%	11%
RANKING (2)	53	23	3	52	37	10	62	16	7	1	50	29	10	10	30	10	15	16	48	4	16	37	8	34	22
ACESS and SAFETY																									
Adequacy to check (-33) Adequacy to concrete (-33) Site Tidiness (-33)	0	-50	-10	0	-10	0	-100	0	-20	0	-20	-20	-30	-50	-20	-33	0	-40	-10	-40	-50	-66	0	0	-20
TOTAL MARKS	420/1200	170/1100	21/900	402/1200	270/1200	56/1200	770/1100	80/1100	20/1200	3/1200	410/1200	233/1200	78/1000	109/1200	252/1200	87/1200	70/1100	106/1000	359/1200	74/1200	138/1200	335/1200	40/1200	256/1200	125/1100
TOTAL PERCENTAGE	35%	15%	2%	34%	23%	5%	70%	7%	2%	0%	34%	19%	8%	8%	21%	7%	6%	11%	30%	6%	12%	28%	3%	21%	10%
RANKING WITHIN SYSTEMS (4)	24	15	2	22	19	5	25	8	2	1	22	16	10	10	17	8	6	13	21	6	14	20	4	17	12
OVERALL RANKING (3)	53	25	2	50	36	8	61	11	2	1	50	28	13	13	31	11	9	20	47	9	21	43	4	31	19
SUPPLIER OF EQUIPMENT	X	Z	Y	X	X	Y	Z	Z	Z	Z	X	Z	Y	Y	Y	Z	Z	AL	Z	Z	Z	Z	Z	X	X
DRAWINGS Availability of ..	Y	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	N	Y	Y	Y	Y
Conformity to ...	N	G	–	N	N	G	–	G	G	G	I	I	G	F	–	G	F	F	N	F	–	F	G	N	N
Quality of	G	F	–	F	G	F	–	F	G	G	I	F	G	G	–	G	I	G	F	I	–	I	G	G	G
Presence of Falsework Coordinator	N	N	L	L	N	N	L	N	H	H	N	H	N	H	N		N	N	H	H	H	N	H	N	N
PERMIT TO LOAD	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	Y	Y	Y	N	Y	N	N
TYPE OF ERECTORS	J	J	S/J	S/J	J	J	S/J	S	S	S	S	S	L	J	S	J	S	J	J	S	S	S	S	J	J
COMPETENCE OF ERECTORS	M	H	H	M	L	M	M	H	H	M	M	M	M	M	H	L	H	L	M	H'	M	M	H	M	M
FORMAL CHECKING	N	N	N	L	L	N	L	N	H	H	N	L	L	L	L	L	L	N	H	H	H	N	H	N	N
ROUTINE CHECKING	L	H	H	L	H	L	L	L	H	H	N	H	H	L	H	H	L	H	H	H	H	L	H	L	L
No. of ENGINEERS on SITE	3	1	7	3	2	1	13	6	6	3	0	6	6	4	2	2	1	5	5	6	9	0	11	4	2
BUILDING or CIVIL ENGINEERING	B	B	B	B	B	B	B	B	C	C	B	B	C	C	B	C	B	C	C	C	C	B	C	B	C

PROPRIETARY SYSTEMS / PROPRIETARY DECKING (17 SITES)

TYPE OF SYSTEMS																	
CASE STUDY No. —	1A	3	4	5	10A	11	13A	14A	30	33	38	40	42	43	46	51	52
SAMPLE SIZE	28	50	60	56	36	54	40	45	56	64	50	42	42	56	54	38	38
FALSEWORK HEIGHT (in metres)	3.0	4.2	2.65	2.7	2.6	5.8	3.6	3.3	5.8	3.3	8.1	3.6	3.25	3.15	2.5	2.7	3.25
HEAD CONDITION																	
Eccentricity > 25mm (-100)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fixity (-100)	0	0	0	0	0	0	-43	0	0	0	0	0	0	0	0	0	0
BASE CONDITION																	
Adequacy of Seating (-100)	0	0	0	0	0	0	0	0	-20	0	-14	0	0	-14	-100	0	0
JACK EXTENSION																	
Head Condition (-100)	0	0	0	0	0	0	0	0	0	-100	0	0	0	-100	0	0	0
Base Condition (-100)	0	N/A	0	-100	0	0	0	0	-100	0	0	0	N/A	-14	0	0	0
VERTICAL MEMBERS																	
Effective height (-50)	-50	0	0	0	0	0	0	0	0	0	0	0	-25	0	0	0	0
Lacing Missing (-50)	0	0	0	0	0	-16	0	0	-2	0	0	0	-20	0	-6	-5	-5
Verticality (-100)	-27	-40	-5	-20	0	-13	0	-13	-25	-5	-54	-7	-50	18	-36	-35	-5
Inadequate pins on props (-50)	N/A	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	N/A
BRACING																	
Longitudinal Direction (-100)	-72	-50	0	-40	0	-45	-100	-73	-87	-50	0	0	-10	-100	0	-100	-42
Transverse Direction (-100)	-100	-11	0	-75	0	-40	-100	-79	-10	-100	0	0	-10	-100	0	-100	-35
Nodes > 150mm. (-100)	-30	0	0	0	0	-100	N/A	0	-38	0	-4	-30	-33	N/A	-50	N/A	-11
For props only: Bottom Lace (-50)	N/A	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	N/A
For props only: Angle (-50)	N/A	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	N/A
TYING IN																	
Present and Adequate (-100)	N/A	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	N/A
MARKS	279/1000	101/900	8/1000	235/1000	18/1000	199/1000	243/900	165/1000	252/1000	255/1000	52/1000	37/1000	148/900	346/900	190/1000	240/900	98/1000
PERCENTAGE	28%	11%	1%	24%	2%	20%	27%	17%	25%	26%	5%	4%	16%	38%	19%	27%	10%
RANKING (1)	44	22	8	34	6	29	40	26	36	37	12	10	25	51	28	40	21
CONDITIONS of MATERIAL																	
Good (0) Old/Fair (-30) Poor (-60) V Old/Poor (-100)	0	0	-30	-30	-30	0	-30	0	0	-20	0	0	0	0	0	-40	0
MARKS	279/1100	101/1000	35/1100	265/1100	46/1100	88/800	273/1000	165/1100	252/1100	275/1100	52/1100	37/1100	148/1000	346/1000	190/1100	280/1000	98/1100
PERCENTAGE	25%	10%	3%	24%	4%	18%	27%	15%	23%	25%	5%	3%	15%	35%	17%	28%	9%
RANKING (2)	41	20	4	37	8	28	43	25	34	41	10	4	25	50	27	45	19
ACESS and SAFETY																	
Adequacy to check (-33) Adequacy to concrete (-33) Site Tidiness (-33)	-66	-70	-60	-40	0	0	-10	0	-20	-40	0	0	-33	-10	-100	-65	0
TOTAL MARKS	345/1200	171/1200	96/1200	305/1200	46/1200	198/1200	293/1100	165/1200	272/1200	315/1200	52/1200	37/1200	81/1100	366/1100	290/1200	345/1100	96/1200
TOTAL PERCENTAGE	29%	14%	8%	25%	4%	17%	26%	14%	23%	26%	4%	3%	16%	32%	24%	31%	8%
RANKING WITHIN SYSTEMS (4)	15	6	4	12	2	9	13	6	10	13	2	1	8	17	11	16	4
OVERALL RANKING (3)	46	23	13	39	6	27	40	23	36	40	6	4	26	49	38	48	13
SUPPLIER OF EQUIPMENT	X	X	Z	Z	Y	Z	Y/Z	Z	Z	Z	Z	X	X	Y	X	Z	Z
DRAWINGS Availability of ..	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Conformity to ...	N	F	G	N	F	F	N	N	F	F	G	G	N	N	I	N	N
Quality of	F	F	F	F	G	I	I	F	G	I	G	G	I	F	G	G	I
Presence of Falsework Coordinator	H	N	N	L	N	H	N	N	N	N	H	N	N	N	H'	N	H
PERMIT TO LOAD	Y	N	N	N	N	N	N	N?	N	N	Y	N	N	N	Y	N	Y
TYPE OF ERECTORS	J	J	J	J	J	S	J	S	S	J	S	L	J	J	L'	L	S
COMPETENCE OF ERECTORS	M	H	H	M	H	H	M	H	M	L	H	M	M	L	M	L	H
FORMAL CHECKING	H	N	N	L	N	H	N	N	N	N	H	N	N	N	H	N	H
ROUTINE CHECKING	L	L	H	H	L	L	L	L	H	L	H	L	L	L	L	H	L
No. of ENGINEERS on SITE	2	1	1	2	2	6	3	3	5	1	1	3	0	1	8	2	6
BUILDING or CIVIL ENGINEERING	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B

ADJUSTABLE PROPS / TRADITIONAL DECKINGS (18 SITES)

TYPE OF SYSTEMS																		
CASE STUDY No. —	7	18	19	21	23	27	28	35	44	50	54	1B	10B	12B	13B	14B	39B	47B
SAMPLE SIZE	37	54	41	50	56	58	21	12	41	50	52	21	21	18	35	18	19	37
FALSEWORK HEIGHT (in metres)	2.7	3.13	2.58	4.07	2.25	3.0	3.4 to 4.06	2.5	2.57	2.45	3.28	3.0	2.6	2.75	3.59	3.1	2.6	3.25
HEAD CONDITION																		
Eccentricity > 25mm (-100)	-20	-30	-70	0	-16	-5	0	-100	-17	-12	-20	0	0	0	0	-28	-16	-16
Fixity (-100)	-50	0	-10	-24	0	-10	0	0	-100	-100	-20	-100	0	-50	-100	-100	-100	-100
BASE CONDITION																		
Adequacy of Seating (-100)	-15	0	-44	0	-13	0	0	-40	-100	0	0	0	0	-75	0	-50	0	-11
JACK EXTENSION																		
Head Condition (-100)	N/A	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	N/A
Base Condition (-100)	N/A	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	N/A
VERTICAL MEMBERS																		
Effective height (-50)	N/A	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	N/A
Lacing Missing (-50)	-70	-50	-20	-85	-50	0	0	-75	0	-10	0	0	-50	N/A	-50	-50	0	-56
Verticality (-100)	-30	-10	-30	-18	-40	-34	0	-42	-2	-12	0	-14	-10	-11	-14	-11	0	-51
Inadequate pins on props (-50)	-25	0	-2	-14	0	0	0	-42	0	0	0	-10	0	0	-25	0	0	0
BRACING																		
Longitudinal Direction (-100)	-100	-83	N/A	-100	-100	-100	N/A	-100	N/A	0	-100	N/A	N/A	N/A	N/A	-100	N/A	-100
Transverse Direction (-100)	-100	-77	N/A	-100	-100	-100	N/A	-100	N/A	-100	-100	N/A	N/A	N/A	N/A	-100	N/A	-100
Nodes > 150mm. (-100)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
For props only: Bottom Lace (-50)	N/A	-50	N/A	N/A	N/A	N/A	N/A	N/A	N/A	-50	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
For props only: Angle (-50)	N/A	-50	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TYING IN																		
Present and Adequate (-100)	N/A	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	N/A
MARKS	410/750	350/850	176/550	341/750	319/750	249/750	0/850	499/750	219/550	284/850	240/750	124/550	60/550	136/500	189/550	439/700	116/550	434/750
PERCENTAGE	55%	41%	32%	45%	43%	33%	0%	67%	40%	33%	32%	23%	11%	27%	34%	59%	21%	58%
RANKING (1)	59	55	45	58	57	48	1	62	53	48	45	32	21	40	50	61	30	60
CONDITIONS of MATERIAL																		
Good (0) Old/Fair (-30) Poor (-60) V Old/Poor (-100)	-60	-30	0	-10	-50	-30	-20	-70	-60	0	-10	-30	-30	0	-60	-50	-30	-60
MARKS	470/850	380/950	176/650	351/850	369/850	279/850	20/650	569/850	279/650	284/950	250/850	154/650	90/650	136/600	249/650	489/850	146/650	494/850
PERCENTAGE	55%	40%	27%	41%	43%	33%	3%	67%	43%	30%	29%	24%	14%	23%	38%	58%	22%	58%
RANKING (2)	59	55	43	56	57	49	4	62	57	47	46	37	24	34	53	60	31	60
ACESS and SAFETY																		
Adequacy to check (-33) Adequacy to concrete (-33) Site Tidiness (-33)	-70	0	-33	-70	-10	-60	-50	0	-45	-15	0	0	0	-10	-10	0	-10	-66
TOTAL MARKS	540/950	380/1050	209/750	421/960	379/950	339/950	70/750	569/950	324/750	299/1050	250/950	154/760	90/750	148/700	259/750	489/950	156/750	560/950
TOTAL PERCENTAGE	57%	36%	28%	44%	40%	36%	9%	60%	43%	28%	26%	20%	12%	21%	34%	51%	21%	59%
RANKING WITHIN SYSTEMS (4)	10	5	3	9	7	5	1	11	8	3	2	2	1	3	5	6	3	7
OVERALL RANKING (3)	60	54	43	58	56	54	17	62	57	43	40	29	21	31	50	59	31	61
SUPPLIER OF EQUIPMENT	A	A	X	A	A	A	A	X	A	A	A	X	Y	X	A	Z	A	A
DRAWINGS Availability of ..	N	Y	Y	N	Y	N	Y	N	Y	Y	N	N	Y	N	N	Y	Y	Y
Conformity to ...	–	N	N	–	N	–	G	–	F	G	–	–	F	–	–	N	N	G
Quality of	–	F	I	–	G	–	G	–	F	G	–	–	G	–	–	G	F	G
Presence of Falsework Coordinator	N	L	N	L	N	N	N	N	N	N	N	H	N	N	N	N	H	N
PERMIT TO LOAD	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	Y	N
TYPE OF ERECTORS	J	J	J	J	J	J	J	J	J	J	J	J	S	J	J	S	J	S
COMPETENCE OF ERECTORS	L	L	L	M	M	L	H	L	M	M	H	M	H	L	M	H	M	M
FORMAL CHECKING	N	L	N	L	N	N	N	N	N	N	N	H	N	L	N	N	H	N
ROUTINE CHECKING	N	N	N	L	N	L	L	N	L	L	L	L	L	H	L	L	H	L
No. of ENGINEERS on SITE	1	2	0	3	0	8	1	0	0	0	3	2	2	2	3	3	5	0
BUILDING or CIVIL ENGINEERING	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	C	B

TUBES/FITTINGS/TRAD DECKS (3 sites)

TYPE OF SYSTEMS				NOTES
CASE STUDY No. —	32	25B	36B	B Denotes secondary Falsework
SAMPLE SIZE	56	16	36	Figures denotes No of verticals in the sample
FALSEWORK HEIGHT (in metres)	2.4 to 5.0	4.7	4.25	Height measured from the Base plate to Soffit formwork
HEAD CONDITION				
Eccentricity > 25mm (-100)	-45	-50	0	
Fixity (-100)	-16	0	0	
BASE CONDITION				
Adequacy of Seating (-100)	-50	0	0	
JACK EXTENSION				
Head Condition (-100)	-14	0	0	No jacks with Adjustable props
Base Condition (-100)	0	N/A	0	
VERTICAL MEMBERS				
Effective height (-50)	0	0	0	
Lacing Missing (-50)	0	0	0	For props both effective height and lacing missing considered for (-100) total score
Verticality (-100)	-16	-75	-11	
Inadequate pins on props (-50)	N/A	N/A	N/A	
BRACING				
Longitudinal Direction (-100)	-90	N/A	N/A	Bracing required in accordance with the Code BS: 5975: 1982.
Transverse Direction (-100)	0	N/A	N/A	
Nodes > 150mm. (-100)	-100	N/A	N/A	
For props only: Bottom Lace (-50)	0	N/A	N/A	
For props only: Angle (-50)	0	N/A	N/A	
TYING IN				
Present and Adequate (-100)	+90	N/A	N/A	Plus marks if Tying in is adequate
MARKS	241/1000	125/600	11/700	
PERCENTAGE	24%	21%	2%	
RANKING (1)	34	30	6	For Five conditions
CONDITIONS of MATERIAL				
Good (0) Old/Fair (-30) Poor (-60) V Old/Poor (-100)	0	-30	-70	
MARKS	241/1100	150/700	81/800	
PERCENTAGE	22%	22%	10%	
RANKING (2)	31	34	20	Ranking 1. + Conditions of materials
ACESS and SAFETY				
Adequacy to check (-33) Adequacy to concrete (-33) Site Tidiness (-33)	0	-20	0	
TOTAL MARKS	241/1200	175/800	81/900	
TOTAL PERCENTAGE	20%	22%	9%	
RANKING WITHIN SYSTEMS (4)	2	3	1	
OVERALL RANKING (3)	29	35	17	Ranking 2 + Access and Safety
SUPPLIER OF EQUIPMENT	T/F	T/F	T/F	
DRAWINGS Availability of ..	N	N	N	Y-YES N-NO
Conformity to ...	–	–	–	G-Good F-Fair N-No I-Inadequate
Quality of	–	–	–	" " " "
Presence of Falsework Coordinator	N	H	N	H-High L-Low N-None or No Coordinator
PERMIT TO LOAD	N	N	N	Y-Yes N-No
TYPE OF ERECTORS	S	S	S	L-Labourer J-Joiner S-Scaffold S/J-Scaffolder/Joiner
COMPETENCE OF ERECTORS	M	M	H	L-Low M-Medium H-High
FORMAL CHECKING	N	L	L	H-High L-Low N-None
ROUTINE CHECKING	N	H	L	" " "
No. of ENGINEERS on SITE	13	6	1	
BUILDING or CIVIL ENGINEERING	B	B	B	B-Building C-Civil Engineering

NOTES

1. Figures in brackets like (-100) for each error of head condition means maximum possible negative penalty score that could be registered.
2. The drawing should be read in conjunction with Drawing No 1.
3. Percentages shown for each error on this drawing denotes a summary of information from the checklists and other notes on samples.

Notes on individual sites (left to right):

- NO BASE JACKS
- TIE FRAME. NO BASE JACKS BRACING PART OF THE FRAME
- NO JACKS
- TRIGGER BRACING
- TRIGGER BRACING
- JACK EXTENSION 360 mm at HEAD 320 mm at BASE BOTH BRACED
- TRIGGER BRACE NO BRACE JACKS
- ALUMINIUM PRIMARIES BOLTED TO U-HEADS BRACING NOT CONTINUOUS TO GROUND
- NO HEAD JACKS - EFFECTIVE HEIGHT INCREASED
- NO BASE JACKS
- TRIGGER BRACING
- EXPERIENCED SCAFFOLDERS ON SITE
- 15 PINS IMPROPERLY INSERTED AT THE HEAD CONDITION.
- 2 m LIFT HEIGHT TO DRAWING
- 6/398 LACING MISSING
- TRIGGER BRACING
- NO JACKS AT BASE EFFECTIVE HEIGHT INCREASED
- NO BRACING REQUIRED DUE TO CIRCULAR SHAPE OF BUILDING AND TIMBER BUTTED AGAINST WALL.
- ALTHOUGH FLOOR HEIGHT IS LESS THAN 2.75 m LACING AND BRACING WERE MISSED OUT w.r.t DRAWING
- BRACING NOT REQUIRED ALL LACING BUTTED AGAINST WALLS
- STAYS BRACING REQUIRED FOR LATERAL STABILITY.
- NO BRACING BUT LACING BUTTED AGAINST THE WALL.
- BRACING SHOWN ON DRAWING
- NO BRACING REQUIRED DUE TO SMALLNESS OF AREA
- NO BRACING REQUIRED DUE TO SMALLNESS OF AREA EXPERIENCED SCAFFOLDER ON SITE.
- NO BRACING REQUIRED DUE TO ISOLATED POSITIONS OF PROPS
- NO BRACING REQUIRED PROPS AROUND COLUMNS
- BRACING NOT REQUIRED DUE TO SMALLNESS OF AREA
- LAYOUT CHANGED FOR PROPS BUT NO BRACING SHOWED FOR PROPS ON ORIGINAL LAYOUT
- TIED TO ADJACENT BAY WITH BRACING AT EVERY LEVEL.
- NO HEAD OR BASE JACKS BECAUSE TUBES WERE CUT TO RIGHT LENGTH
- NO BRACING BUT ADEQUATE TYING IN PRESENT

Research Project. Drg No 2

THE MANAGEMENT OF FALSEWORK CONSTRUCTION. (1985 - 1987)

TITLE:- SUMMARY OF DATA COLLECTED FROM 54 MAIN SITES AND 8 SECONDARY SITES.

APPENDIX C

Typical Checklists

CHECK LIST NO. 1

PROPRIETARY SYSTEM - TRADITIONAL DECKING (TIMBER/ALUMINIUM BEAMS)

SAMPLE SIZE:-
SUPPLIERS:-

HEAD CONDITION

General Comments

1. Eccentricity >25 mm

2. Joints in Beam not centred >15 mm

3. Clips/wedges - frequency of missing or loose

4. Jack extension beyond limit (>300 mm)

BASE CONDITION

1. Assessment of adequacy of seating for provision of horizontal and vertical restraint

2. Excessive jack extension (>300 mm)

VERTICAL MEMBERS

1. Lift height excessive:-
   (a) No. in any line
   (b) Total No.

2. No. of lacing missing

3. Verticality
   Longitudinal Direction
   Transverse Direction

BRACING

1. Correct type

2. Nos. missing -
   Longitudinal Direction
   Transverse Direction

3. Nodes >150 mm

TYING IN

1. Check for lateral stability

2. Check bracing for node stability

3. Tightness of Connections

CONDITIONS OF MATERIALS

ACCESS AND SAFETY

1. Access to check, adjust Fwk

2. Access to Concrete, fix Formwork to beam sides

3. General site tidiness

CONFORMITY TO DRAWINGS

1. Availability of

2. Conformity to

3. Quality of

CHECK LIST NO.2

PROPRIETARY SYSTEM - PROPRIETARY DECKING

SAMPLE SIZE:-
SUPPLIERS:-

General Comments

HEAD CONDITION

1. Jack extension beyond limit (>300 mm) and if not braced

2. Connections (including pins)

BASE CONDITION

1. Assessment of adequacy of seating for provision of horizontal and vertical restraint

2. Excessive jack extension (>300 mm)

VERTICAL MEMBERS

1. Lift height excessive:-
   (a) No. in any line
   (b) Total No.

2. No. of lacing missing

3. Verticality
   Longitudinal Direction
   Transverse Direction

BRACING

1. Correct type

2. Nos. missing -
   Longitudinal Direction
   Transverse Direction

3. Nodes >150 mm

TYING IN

1. Check for lateral stability

2. Check bracing for node stability

3. Tightness of Connections

CONDITIONS OF MATERIALS

ACCESS AND SAFETY

1. Access to check, adjust Fwk

2. Access to Concrete, fix Formwork to beam sides

3. General site tidiness

CONFORMITY TO DRAWINGS

1. Availability of

2. Conformity to

3. Quality of

CHECK LIST NO.3

ADJUSTABLE PROPS AND TRADITIONAL DECKING (TIMBER/ALUMINIUM BEAMS)

SAMPLE SIZE:-
SUPPLIERS:-

	General Comments
HEAD CONDITION	
1. Eccentricity >25 mm	
2. Joints in Beam not centred > 15 mm	
3. Timbers or aluminium beams not secured on props	
BASE CONDITION	
1. Assessment of adequacy of seating for provision of horizontal and vertical restraint	
VERTICAL MEMBERS	
1. No. of lacing missing	
2. Incorrect pins	
3. Verticality Longitudinal Direction Transverse Direction	
BRACING	
1. Correct type	
TYING IN	
1. Check for lateral stability	
CONDITIONS OF MATERIALS	
ACCESS AND SAFETY	
1. Access to check, adjust Fwk	
2. Access to Concrete, fix Formwork to beam sides	
3. General site tidiness	
CONFORMITY TO DRAWINGS	
1. Availability of	
2. Conformity to	
3. Quality of	

CHECK LIST NO.4

TUBES AND FITTINGS - TRADITIONAL DECKING
(TIMBER/ALUMINIUM BEAMS)

SAMPLE SIZE:-
SUPPLIERS:-

HEAD CONDITION — General Comments

1. Eccentricity >25 mm

2. Joints in Beam not centred >15 mm

3. Clips/wedges - frequency of missing or loose

4. Jack extension beyond limit (>300 mm) and if not braced

BASE CONDITION

1. Assessment of adequacy of seating for provision of horizontal and vertical restraint

VERTICAL MEMBERS

1. Lift height excessive:-
   (a) No. in any line
   (b) Total No.

2. No. of lacing missing

3. Verticality
   Longitudinal Direction
   Transverse Direction

BRACING

1. Correct type

2. Nos. missing -
   Longitudinal Direction
   Transverse Direction

3. Nodes >150 mm

TYING IN

1. Check for lateral stability

2. Check bracing for node stability

3. Tightness of Connections

CONDITIONS OF MATERIALS

ACCESS AND SAFETY

1. Access to check, adjust Fwk

2. Access to Concrete, fix Formwork to beam sides

3. General site tidiness

CONFORMITY TO DRAWINGS

1. Availability of

2. Conformity to

3. Quality of

CHECK LIST NO.1

PROPRIETARY SYSTEM - TRADITIONAL DECKING (TIMBER/ALUMINIUM BEAMS)

SAMPLE SIZE:- (No. of stds)	POUR NO:- (No. wrt total)
FLOOR HEIGHT:- (in metres)	SUPPLIER:- (X,Y,Z, Props or T/F)
HEAD CONDITION	**Typical comments**
1. Eccentricity >25 mm	Report magnitude and frequency > 50 mm. Report adverse condition.
2. Joints in Beam not centred > 15 mm	Report total No. of joints in sample area and the numbers with faults.
3. Clips/wedges - frequency of missing or loose	Comment upon absence of nailing if applicable. Comment of wedges undersize on sloping formwork. Comment on materials of wedges.
4. Jack extension beyond limit (>300 mm) and if not braced	How much different to design. (Refer to manufacturers' requirements). Any bracing?
5. Light or Heavy Duty head jacks	Any specific area and reason.
6. Connections (including pins)	Nos. found loose and any relevant point.
7. Conditions of forkheads, jacks etc.	General comment - bent, rust, corroded, poor welds, etc. Good, fair, poor.
BASE CONDITION	
1. Assessment of adequacy of seating for provision of horizontal and vertical restraint	Combine conditions of formation, soleplate base seating, poor weld, distorted, bent base plates - any of these inadequacies renders the whole base condition inadequate.
2. Light or Heavy Duty base jacks	Any specific area.
3. Excessive jack extension (>300 mm)	Report w,r,t, drawing, braced or not. Manufacturers' requirement?
4. Connections (including pins)	Good, fair, poor.
5. Conditions of materials	Same as above.
VERTICAL MEMBERS	
1. Lift height excessive:-	Any reason.
(a) No. in any line	Decrease in load capacity if effective length increased.
(b) Total no.	
2. No. of lacing missing	Any effect on node stability. Replaced by additional bracing.
3. Light or Heavy Duty	Any specific area.
4. Verticality	Nos. in two directions
Longitudinal Direction	30'-60', 60'-90', 90'-120', >120'
Transverse Direction	30'-60', 60'-90', 90'-120', >120'
5. Conditions of Materials	Good, fair, poor - same as above
6. Connections	Good, fair, poor
BRACING	
1. Correct type	Not correct type. If not correct type then conclude that it is effectively omitted.

2. Nos. missing – Longitudinal Direction Transverse Direction	Comment on Distribution in both directions. Bracing may be acceptable if fixed in different bays.
3. Nodes >150 mm	Nos. beyond 150 mm and reasons.
4. Tightness of Connections	Nos. found loose
5. Condition of Materials	Good, fair, poor.

TYING IN

1. Check for lateral stability	Ensure load bearing couplers and adequate fixity
2. Check bracing for node stability	Fixed at all lacing levels? Bracing rule of up to 4 verticals From column to be applied.
3. Tightness of Connections	Check Nos. found loose.

ACCESS AND SAFETY

1. Access to check, adjust Fwk	General comments and reasons for any comments made.
2. Access to Concrete, fix Formwork to beam sides	-ditto-
3. General site tidiness	-ditto-

CONFORMITY TO DRAWINGS

Report on availability of drawings, quality of drawings, tender or working drawings, number and types of changes made on site compared to the drawing, reasons for changes, communication with the Design Office regarding changes etc.

CHECK LIST NO. 2

PROPRIETARY SYSTEM - PROPRIETARY DECKING

SAMPLE SIZE:- (No. of stds) FLOOR HEIGHT:- (in metres)	POUR NO:- (No. wrt total) SUPPLIER:- (X,Y,Z or others)
HEAD CONDITION	**Typical Comments**
1. Jack extension beyond limit (>300 mm) and if not braced	How much different to design. (Refer to manufacturers' requirements). Any bracing?
2. Light or Heavy Duty	Any specific area and reason.
3. Connections (including pins)	Nos. found loose and any relevant point.
4. Conditions of forkheads, jacks etc.	General comment - bent, rust, corroded, poor welds, etc. Good, fair or poor.
BASE CONDITION	
1. Assessment of adequacy of seating for provision of horizontal and vertical restraint	Combined conditions of formation, soleplate base seating, poor weld, distorted, bent base plates - any of these inadequacies renders the whole base condition inadequate.
2. Light or Heavy Duty base jacks	Any specific area.
3. Excessive jack extension (>300 mm)	Report w.r.t. drawing, braced or not. Manufacturers' requirement?
4. Connections (including pins)	Good, fair, poor.
5. Conditions of materials	Same as above.
VERTICAL MEMBERS	
1. Lift height excessive:-	Any reason.
(a) No. in any line	Decrease in load capacity if effective length increased.
(b) Total No.	
2. No. of lacing missing	Any effect on node stability. Replaced by additional bracing.
3. Light or Heavy Duty	
4. Verticality	Nos. in two directions
Longitudinal Direction	30'-60', 60'-90', 90'-120', >120'
Transverse Direction	30'-60', 60'-90', 90'-120', >120'
5. Conditions of Materials	Good, fair, poor - same as above
6. Connections	Good, fair, poor
BRACING	
1. Correct type	Not correct type. If not correct type then conclude that it is effectively omitted.
2. Nos. missing - Longitudinal Direction, Transverse Direction	Comment on Distribution in both directions. Bracing may be acceptable if fixed in different bays.
3. Nodes >150 mm	Nos. beyond 150 mm and reasons.
4. Tightness of Connections	Nos. found loose
5. Condition of Materials	Good, fair, poor.
TYING IN	
1. Check for lateral stability	Ensure load bearing couplers and adequate fixity

2.	Check bracing for node stability	Fixed at all lacing levels? Bracing rule of up to 4 verticals from column to be applied.
3.	Tightness of Connections	Check Nos. found loose.

ACCESS AND SAFETY

1.	Access to check, adjust Fwk	General comments and reasons for any comments made.
2.	Access to Concrete, fix Formwork to beam sides	-ditto-
3.	General site tidiness	-ditto-

CONFORMITY TO DRAWINGS

Report on availability of drawings, quality of drawings, tender or working drawings, number and types of changes made on site compared to the drawing, reasons for changes, communication with the Design Office regarding changes etc.

CHECK LIST NO. 3

ADJUSTABLE PROPS AND TRADITIONAL DECKING (TIMBER/ALUMINIUM BEAMS)

SAMPLE SIZE:- (No. of props)	POUR NO:- (No. wrt total)
FLOOR HEIGHT:- (in metres)	SUPPLIER:- (X,Y,Z or others)
HEAD CONDITION	**Typical Comments**
1. Eccentricity >25 mm	Report magnitude and frequency > 50 mm. Report adverse condition.
2. Joints in Beam not centred >15 mm	Report total No. of joints in sample area and the numbers with faults.
3. Timbers or aluminium beams not secured on props	Minimum 2 nails required for timber and 1 clip for Al-beams.
4. Conditions of forkheads, jacks etc.	General comment - bent, rust, corroded, poor welds, etc. Good, fair, poor.
BASE CONDITION	
1. Assessment of adequacy of seating for provision of horizontal and vertical restraint	Combine conditions of formation, soleplate base seating, poor weld, distorted, bent base plates - any of these inadequacies renders the whole base condition inadequate.
2. Conditions of materials	Same as above.
VERTICAL MEMBERS	
1. No. of lacing missing	Any effect on node stability. Replaced by additional bracing.
2. Incorrect pins	No. and type of incorrect pins.
3. Verticality	Nos. in two directions
Longitudinal Direction	30'-60', 60'-90', 90'-120', >120'
Transverse Direction	30'-60', 60'-90', 90'-120', >120'
4. Connections	Good, fair, poor.
BRACING	
1. Correct type	Not correct type. If not correct type then conclude that it is effectively omitted.
2. Nos. missing - Longitudinal Direction Transverse Direction	Comment on Distribution in both directions. Bracing may be acceptable if fitted in different bays.
3. Tightness of Connections	Nos. found loose
4. Condition of Materials	Good, fair, poor.
TYING IN	
1. Check for lateral stability	Ensure load bearing couplers and adequate fixity
2. Tightness of Connections	Check Nos. found loose.
ACCESS AND SAFETY	
1. Access to check, adjust Fwk	General comments and reasons for any comments made.
2. Access to Concrete, fix Formwork to beam sides	- ditto -
3. General site tidiness	- ditto -

CONFORMITY TO DRAWINGS

Report on availability of drawings, quality of drawings, tender or working drawings, number and types of changes made on site compared to the drawing, reasons for changes, communication with the Design Office regarding changes etc.

CHECK LIST NO. 4

TUBES AND FITTINGS - TRADITIONAL DECKING (TIMBER/ALUMINIUM BEAMS)

SAMPLE SIZE:- (No. of stds)
FLOOR HEIGHT:- (in metres)

POUR NO:- (No. wrt total)
SUPPLIER:- (X,Y,Z or others)

HEAD CONDITION	Typical Comments
1. Eccentricity >25 mm	Report magnitude and frequency > 50 mm. Report adverse condition.
2. Joints in Beam not centred >15 mm	Report total No. of joints in sample area and the numbers with faults.
3. Clips/wedges - frequency of missing or loose	Comment upon absence of nailing if applicable. Comment of wedges undersize on sloping formwork. Comment on materials of wedges.
4. Jack extension beyond limit (>300 mm) and if not braced	How much different to design. (Refer to manufacturers' requirements). Any bracing?
5. Connections (including pins)	Nos. found loose and any relevant point.
6. Conditions of forkheads, jacks etc.	General comment - bent, rust, corroded, poor welds, etc. Good, fair, poor.

BASE CONDITION	
1. Assessment of adequacy of seating for provision of horizontal and vertical restraint	Combine conditions of formation, soleplate base seating, poor weld, distorted, bent base plates - any of these inadequacies renders the whole base condition inadequate.
2. Connections (including pins)	Good, fair, poor.
3. Conditions of materials	Same as above.

VERTICAL MEMBERS	
1. Lift height excessive:-	Any reason.
(a) No. in any line	Decrease in load capacity if effective length increased.
(b) Total No.	
2. No. of lacing missing	Any effect on node stability. Replaced by additional bracing.
3. Verticality	Nos. in two directions
Longitudinal Direction	30'-60', 60'-90', 90'-120', >120'
Transverse Direction	30'-60', 60'-90', 90'-120', >120'
4. Conditions of Materials	Good, fair, poor - same as above
5. Connections	Good, fair, poor.

BRACING	
1. Correct type	Not correct type. If not correct type then conclude that it is effectively omitted.
2. Nos. missing - Longitudinal Direction, Transverse Direction	Comment on Distribution in both directions. Bracing may be acceptable if fixed in different bays.
3. Nodes >150 mm	Nos. beyond 150 mm and reasons.
4. Tightness of Connections	Nos. found loose
5. Condition of Materials	Good, fair, poor.

TYING IN

1. Check for lateral stability	Ensure load bearing couplers and adequate fixity
2. Check bracing for node stability	Fixed at all lacing levels? Bracing rule of up to 4 verticals from column to be applied.
3. Tightness of Connections	Check Nos. found loose.

ACCESS AND SAFETY

1. Access to check, adjust Fwk	General comments and reasons for any comments made.
2. Access to Concrete, fix Formwork to beam sides	- ditto -
3. General site tidiness	- ditto -

CONFORMITY TO DRAWINGS

Report on availability of drawings, quality of drawings, tender or working drawings, number and types of changes made on site compared to the drawing, reasons for changes, communication with the Design Office regarding changes etc.

APPENDIX D

Sample of completed checklists

CHECK LIST

Case Study No. Sample Size

Falsework Technology :

HEAD CONDITION	Good	Fair	Inadeq.
1) Eccentricity - Beams not centrally located. Beyond BS requirements of 25mm			
2) Clips/Wedges missed out for beams smaller than forkheads			
3) Joints in beam not located centrally on forkheads (more than 15mm)			
4) Jack extension beyond limit and no bracing wrt drawing			
5) Timber beam seatings on propheads not secured No. of props beyond BS requirements			
6) Load bearing wedges not wide enough (on sloping falsework)			
7) Wedges of inadequate material (on sloping soffits)			
8) Conditions of Forkheads/Bearing plates of propheads/ adjustable steel props			
9) Undersize timber - Primary and Secondary runners			
10) Light instead of heavy duty propheads (eg Hybrid system)			
11) Incorrect pins on certain prophead assemblies			

BASE CONDITION	Good	Fair	Inadeq
1) Light instead of heavy duty jacks			
2) Conditions of foundations/sole plates			
3) Base plate seating inadequate			
4) Incorrect pins used on adjustable jacks (Load bearing pins) of certain types			
5) Excessive jack extensions - no bracing wrt drawings			
6) Base plate conditions			

VERTICAL MEMBERS	Good	Fair	Inadeq.
1) Lift height excessive (wrt drawings)			
2) Lacing missing (Eg in one or both directions)			
3) Incorrect pins on adjustable steel props. (Eg replaced by mild steel, nails or high tensile reinforcing bars)			
4) Condition of materials			
5) Excessive inclination (Eg exceeding 1½$^{\circ}$ 1 BS requirements)			
6) Light duty instead of heavy duty vertical standards as specified on drawings			
7) Fixings at all node points (for tightness) Nos. found loose			

	Good	Fair	Inadeq.
BRACING			
1) Correct type of bracings) (Eg light/heavy duty inadequate strength and length of the tubes)			
2) Distance from node points eg > 150mm (Special notes on various distances from the node points)			
3) Position, proportion and distribution to the drawings (In one or both directions)			
4) Conditions of materials (Eg bent, corroded, etc)			
TYING-IN			
1) Conformity with the drawings or replacing bracing for lateral stability			
2) Check bracing for node stability			

	Good	Fair	Inadeq.
GENERAL CONDITIONS OF MATERIALS			
ACCESS AND SAFETY			
CONFORMITY OF ERECTION WITH FORMALISED DESIGN			

GENERAL CONDITIONS OF MATERIALS

Genral information based upon information gathered from previous conditions.

Three conditions possible:-

(1) No serious comments

(2) Rusty, bent etc., but no structural problems.

(3) Rusty, bent etc., but may cause local structural problems.

ACCESS AND SAFETY (w.r.t. no. of actions taken)

(1) Is safe access provided to reach all parts for works, i.e. ladders and adequate access scaffold?

(2) Are all walkways level & free from obstruction?

(3) Are there adequate guard rails and toe boards?

(4) Are all access materials in good condition and free from obvious defects?

(5) Are all ladders secured at the top and bottom?

(6) Are there sufficient boards at all working platforms in use?

(7) Are the ladders properly positioned for access?

(8) Ladder rise must be at least 1.07m above the place of landing. If not, is there adequate hand-hold at the place of landing?

(9) Is the site tidy and are materials stored in safe position?

(10) Is somebody responsible for the inspections and are they carried out and recorded?

CONFORMITY OF ERECTION WITH FORMALISED DESIGN

Make notes of nos and type of changes made with respect to the drawings.

CHECK LIST - CASE STUDY 22

(1) Falsework : Proprietary systems. GKN Kwikform, Kwikstage Shorring. Technology

(2) Sample Size: 54 no. standards.

(3) Head Condition:

3.1 Eccentricity:

Mabey MK1 Soldiers centrally located in shorring 'U'-head.
None 25mm

3.2 Clips/Wedges:

Not Applicable.

3.3 Joints 15mm
Mabey MK 1 Primary's connected end-to-end using 4 no M16 bolts.
Joints on 'U'-head - D11 to D17 (Drawing no. 22820-5-13B)

(mm)	(mm)	(mm)
D11 - 900	D14 - 10	D17 - 15
D12 - 15	D15 - 5	
D13 - 20	D16 - 20	

3.4 Jack Extensions - all unbraced jack extensions within specified 400mm.

3.5 Timber beam seatings - Not Applicable

3.6 Load bearing wedges on sloping Falsework - wide enough on all U-heads.

3.7 Load bearing wedges of hard and softwood. The majority would appear to be softwood.

3.8 Condition of Forkheads:
- Jack Threads in good condition.
- no visible cracking of welds in U-heads.

3.9 to 3.11 Not Applicable

Note: According to the Section Manager a number of the U-heads required straightening on delivery. Jack threads required greasing. He believed that some of the Kwikstage shoring had come directly from his previous job.

(4) Base Condition

4.1 All Heavy Duty Jacks.

4.2 Foundations:
on the existing carriageway the timber sleepers were bedded on

25mm sand/cement mixture. Elsewhere the subgrade was rolled anc compacted. 100mm of type 1 fill was then placed and compacted. The timber sleepers were bedded on 75mm of E-mix concrete and sand was placed between the sleepers.

4.3 Base Plate Seating:
all plates placed centrally on sleepers. On row A the base plates were seated on hardwood blocks on top of the sleepers placed side by side, (See Plate 1.)

4.4 Pins - Not Applicable

4.5 Excessive Jack Extensions:
Maximum allowable extention unbraced is 450mm (Drg No 22820-5-05-A)
No extension 450mm.

4.6 Base Plates:
all in good condition, all flat, no damage, no cracks of welds. No damage to threads.

(5) Vertical Members

5.1 Lift Height:
Max specified lift = 1.981m (Drg No 22820-5-05-A)
Max Actual lift = 1.50mm

5.2 Lacing:
none missing; all in accordance with drawing.

5.3 Pins:
Not Applicable

5.4 Condition of Materials:
None bent or kinked in sample. A sample of 200no. lngs was examined and no cracked welds discovered.

5.5

Inclination	0.0°	0.5°	0.5°	
Number	98	10	0	Σ = 108 = 2 × 54

B.S. requirement for proprietary systems is 0.6°. This was exceeded by no standards in this sample.

5.6 All Heavy Duty Vertical Standards.

5.7 Node Fixings
5 no out of 200 shoring tie to standard connections were found to be loose.

Note: One standard (ref D17 - see Drg No 22820-5-13-B) was found to be missing with the lacing continuous between rows C and E. This was because the timber sleepers for that particular row fell short of the standards design position by 200mm standard

D17 was the last in row D.

(6) Bracing

6.1 Bracings-correct type with respect to the drawings. Trigger bracing and adjustable jack braces at base and head positions.

6.2 Distance from node positions:
Not Applicable.

6.3 Position, proprtion and distribution compared to the drawings:
Longitudinal - as specified, 4 bays, 11 std's in section.
Lateral - as specified in every row between A - B and F - G.
Exceptions - 1 no.brace missing at head position A - B13. No base bracing along centre line rows A - B10 to A - B17 but jack extensions 450mm allowable.

(7) Tying In

None specified. None Used.

(8) General Conditions

No serious comments. Rust in patches and paint work flaking.

(9) Access and Safety

9.1 Access adequate - ladders to north and south spans plus east end abutment.

9.2 Walkway level but free passage hampered by primary's extending across walkway. One of which left only 250mm clearance to guard rail.

9.3 Guard rails and toe boards all in place.

9.4 Materials in general good condition.

9.5 Scaffold boards at all working platforms covering full width.

9.6 Ladders secured top but no bottom.

9.7 Ladder position properly. Access tower erected on south span side of bridge.

9.8 Ladder rise at landing adequate.

9.9 Site generally tidy with Form and Falsework stacked away from bridgework. Joiners currently stripping Formwork were causing considerable untidyness.

9.10 Section Manager records inspections - see copies. Safety Officer visits weekly. No resident officer appointed.

CHECK LIST - CASE STUDY 24

(1) Falsework Techniques : a) In-situ beam Formwork supported by RMD mini-slims on Forkheads, supported in turn by a proprietory scaffold system.
b) Slab support with adjustable floor centres.
c) Overhang to existing wall plus tying in using tubes/fittings system.

(2) Sample Size: 68 no standards.

(3) Head Condition:

3.1 Eccentricity - 5 no out of a possible 68 minislims (130) mm wide) not centrally in Forkheads (165 mm wide).

3.2 No wedges used.

3.3 Joints - The 1.2m long slims were jointed and bolted end to end (with 2 no diagonally positioned bolts) over each Forkhead the two rows adjacent to the longest existing wall had several joints centrally located, in the order of 15 to 45mm off. 17 no out of possible 43 joints.

3.4 The jack extension was minimal but there was some 750 mm clear distance from the bottom of the U-head to the top line of lacing, where the top of the standard had not been braced.

3.5 Where make up piece's of 9 x 3 were used as the primary instead of the 1.2 m mini-slims then the secondarys were secured using one nail on each end of the secondary.

3.6 NA

3.7 NA

3.8 Forkhead Condition - old and rusty but the side bolt's on these RMD patented stripping Forkheads were all new.

3.9 Contractors own 6 x 3 timber used as secondarys as detailed on the Formwork suppliers drawing.

3.10 Heavy duty propheads used throughout.

3.11 No upper pins

(4) Base Condition

4.1 RMD Adjustable base MK2 used with 150 square base plate and a 430mm length outer collar - as detailed on the suppliers drawing.

4.2 Foundations - all but the outer row founded on the floor slab which had a very rough finish, sufficient to reduce the bearing on 6 no base plates. the outer row was seated on a simply supported sleepers and block arrangement due to the change in level behind the cast in-situ retaining wall.

4.3 Base Plates seated on this sleeper arrangement were centrally located and secured by means of two nails through the plate.

4.4 All pins corect on adjustable jacks, although on the outer two rows pins were in use.

4.5 No foot bracing. Where diagonals had been used there was still up to 600mm clear distance from the lower level of the lacers to the floor slab.

4.6 Base Plates rusty, 2 no had bent corners but generally flat.

(5) Vertical Members

5.1 Lift height: Actual 2.5 mm base plate to bottom of Forkhead then 0.75 up to underside of slab.

Drawing merely indicates a 1.981 standard to be used.

5.2 Plan arrangement indicates a 970mm gap in the row nearest the wall - this was laced using tubes and fittings at the lower level only. The erectors had also managed to fit another bay into this row of Falsework. The lacer was missing from the outermost rows - see sketch.
The lacing was very uneven in level - see photo.

5.3 NA

5.4 Materials condition - fairly good

5.5

Inclination	0°	0.5°	1.0°	1.5°	2.0°	2.5°	3.0°
Numbers	55	16	46	12	5	0	2

Total = 68 x 2 direction = 136
BS Requirement for proprietary systems is 0.6° - this is exceeded by 48% of the standards.

5.6 Vertical standards as specified on the drawing.

5.7 Node fixing: 14 no out of 116 checked were found loose, ie 12%

(6) Bracing

6.1 Type of bracing unspecified on the drawing. Actual - RMD 1950mm HD Brace.

6.2 Distances from node. 4 no braces measured at both ends. Distances (450,400), (400,320), (170,550), (150,550). Typical.

6.3 Bracing distribution generally erratic with little reference to the suppliers drawing.

6.4 Materials condition - good.

(7) <u>Tying In</u>

No tying in except at soffit level where the 6 x 3 secondary timbers were clamped around the column heads.

<u>Floor Centres</u>

Drawing details 35no RMD 42's @ 450mm centres. 27 no were actually used @ approx 600mm, hence the spare centres observed on site (16no counted).

(8) General Condition of Materials: good no serious comments.

(9) <u>Access and Safety</u>

9.1 One ladder to reach deck slab - adequate.

9.2 All walkways levle and free.

9.3 No toe boards longer length of walkway has no guard rail - this was erected later on the request of the Site manager.

9.4 Access materials in good condition.

9.5 Ladder secured at top.

9.6 There were either one or two boards on a working platform, but not three.

9.7 Ladder adequately positioned.

9.8 Ladder rise 1.07m.

9.9 Site Tidy.

9.10 Site Manager - No records.

CHECK LIST - CASE STUDY 28

(1) Falsework Technology : Adjustable steel props with timber runners on Forkheads supporting RMD adjustable floor centres tube and fitting lacing.

(2) Sample: 21 no props

(3) Head Condition

3.1 Eccentricity: 9 x 3 (225 x 75) runners on 80 mm wide Forkhead, 140 deep. All runners centrally located on props by Forkhead.

3.2 Wedges - none needed

3.3 Joints: 2 no in sample, both centrally located.

3.4 NA

3.5 Seatings secured: timber beams in Forkheads but no nails through

3.6 and 3.7 NA

3.8 Condition of Forkheads: all fair; plates flat.

3.9 Timber size; 9 x 3 primary runners used. Size unspecified on the drawings.

3.10 Prophead; 140 deep x 80 int. width. Size unclear on the drawing.

3.11 NA

(4) Base Condition

4.1 NA

4.2 Foundations: 15 no founded on unswept in-situ first floor and ground floor (through stair well) slab. Other 6 no seated on 9 x 3 timber forming a joint between props placed vertically end to end up the stair well.

4.3, 4.4 and 4.5 NA

4.6 Base Plate Condition; 3 no had bent corners; rusty but structurally sound.

(5) Vertical Members

5.1 Lift Height: Actual - main room, 3.00m as per drawing.
- stair well, 7.71m (measures 7.90m on the drawing but they did not show a section through the stairwell)

5.2 Lacing: All in as per the drawing but no dimensions as to its position up the prop height given - better to be laced around mid height as suggest in brochure.

5.3 Pins - all correct

5.4 Condition of Props: well used but sound.

5.5

Inclination	0.0°	0.5°	1.0°	1.5°	2.0°
Numbers	17	14	8	1	2

Total = 21 x 2 direction = 42 measurements BS requirement for props is 1.5° exceeded by 5% but these were both the short props used on the 1.22m lift as shown in the sketch.

5.6 Props: No 2 size - 1.68m outer tube.

5.7 Node fixing: all tubes and fittings and all secure.

(6) Bracing

None Sepecified

(7) Tying-in

None specified on the Falsework suppliers drawing. As shown in plate 7.7 the erector had endeavoured to extend the scaffold tubes lacing to fit the exact size of the room. This involved cutting short lengths of tubing and butting them up to the concrete face with timber piece's to prevent fouling of the face wall.

(8) General Conditions of Materials

Rusty but no structural proplems.

(9) Access and Safety

9.1 Safe access adequate.

9.2 All walkways level and free.

9.3 3 no sides at lower working platform all with guard rails, only one has toe board. 3 no sides at upper slab level only two of which have guard rails.

9.4 Materials good.

9.5)
9.8) Two ladder. First and more permanent tied at top and extends well above landing. Second up to slab pour level is a light aluminium job and is tied to the slab steel so it was untied as concrete approach. No extension on this ladder.

9.6 Sufficient boards

9.7 Ladder properly positioned.

9.9 Site very tidy, well swept due to client's requirement as site part of Nuclear Power Station

9.10 Site Agent, no records obtained.

CHECK LIST - CASE STUDY 27

(1) Falsework : Adjustable steel props with timber runners
Technology and mid-height lacers using proprietary ledgers.

(2) Sample Size: 56 no. adjustable props.

(3) Head Condition:

3.1 Eccentricity: 3 no 25mm

3.2 No forkheads therefore no wedges.

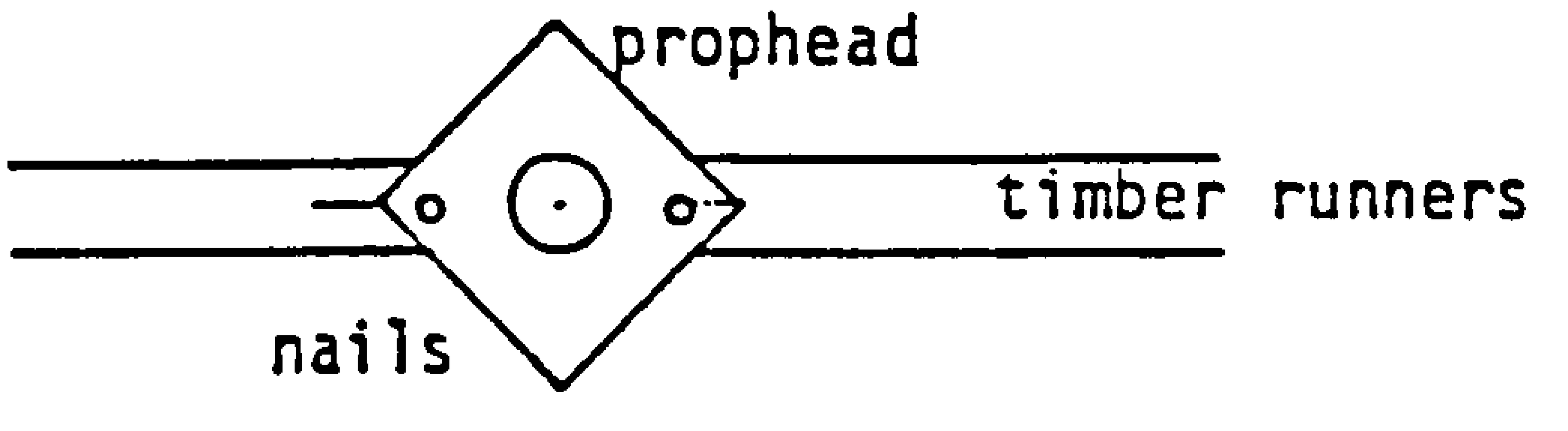
3.3 Joints:
Most primary's overlapping. 12 no. such laps in section studied. 4 no. end to end joints, all centrally located.

3.4 N.A

3.5 Seatings secured: nails through prophead as follows:

Nails	0	1	2	3	4
Number	0	24	27	5	0

Of the 56 no. props studied and the 32 no. which had two or more nails to secure the timber seating, 23 no. were considered to be completely right, i.e.



3.6 and 3.7 N.A.

3.8 Condition of bearing plates: Old, rusty but structurally sound. All plates flat except one badly bent one

3.9 Timber Sizes: Primary's 6 x 3
Secondary's 4 x 3
One very bad piece of 6 x 3 used

3.10 and 3.11 N.A.

(4) Base Condition:

4.1 N.A.

4.2 Condition of Foundations:
Float finished floor slab but unswept and patches of standing water. Large area of concrete clipping around the columns on which props were founded. Generally foundings good.

4.3 Plate seating:
Generally good, one prop not fully extended such that the base plate was free to wobble and not bearing fully on the slab - see plate. 6.9

4.4 and 4.5 N.A.

4.6 Base Plate Conditions:
14 no. Bent plus one very bent.

(5) Verticle Members:

5.1 Lift Height: No.1 size props;actual height 3.21m

5.2 Lacing: One lacer missing adjacent to the column.

5.3 Pins: Short piece of HT reinforcement bar used in one prop. All others correct, ie. pins on chains or a curved 12mm rod used - see plate - otherwise known in SGB's brochure as a spigot pin.

5.4 Condition of Props: Generally old but solid. Researcher dismantled one prop to reveal a very rusty inner, deteriorating with depth but still structurally sound.

5.5

Inclination	0.0°	0.5°	1.0°	1.5°	2.0°	2.5°
Number	31	19	42	10	6	4

Total = 56 x 2 directions = 112 measurement. B.S. requirement for props is 1.5° which was exceeded by 9% of the standards.

5.6 N.A.

5.7 Node Fixings: (4 no per prop) 43no. out of 217 counted were found loose ie. 20%.

(6) Bracing:

None.

(7) Tying In:

At deck level, secondary's packed/wedged around column heads.

(8) General Condition Of The Materials:

Rusty, bent but no structural problems.

(9) Access and Safety:

9.1 Adequate Access.

9.2 Walkways littered with timbers and prop's.

9.3 Adequate rails and boards.

9.4 Contains own GKN Kwikstage in good condition.

9.5 One ladder found in use, tied half way up its length to a lacer tieing across together and resting on a secondary at the top. Others okay.

9.6, 9.7 and 9.8 All good/correct.

9.9 Site untidy, Materials not stored safely. Some lower floor slab left in semi-stripped state very dangerous.

9.10 Companys own scaffolding inspector - see records obtained.

APPENDIX E

Sample of checklist comments by practitioners

General Note (for designers/checkers participating in filling in this form)

(1) % of standards or props indicated with each fault is a rough guidance towards determining the effect that particular fault may have on the structure. It is felt at this stage that low percentage may have little or no effect compared to higher percentages which may lead to a possible collapse.

(2) The faults noted on the check list are by no means a complete set of faults. If the participants know of this please add to the check list with relevant comments.

(3) If the participants do not agree with the way any fault is presented he or she is free to make any changes or add to satisfy his or her requirements.

(4) It is hoped that a check list can be produced to be used on beam/slab constructions in multi-storey buildings and simpler bridge structures. More complicated structures will require special check lists to suit those particular structures.

(5) An example of 50 verticals may be a combination of props (for awkward areas) and proprietary standards or a complete birdcage of tubes and fittings only.

In this case the respondent appends the following note and refers to it later in checklist comments:

Note!

1) Marks given are based on commercial implications & judgement.
2) Customer accepts the risks involved
3) If commercial implications are not relevant then marks will reduce.
4) This form has been completed by a designer from Hire & Sales Division of a Scaffolding company – i.e. Customer is responsible for the safe & proper use of equipment.

, F. NATHWANI - BRISTOL - Proprietary system equipment only.
(Prof. Designer)

CHECK LIST REFERRING TO BS.5975 REQUIREMENTS

SAMPLE SIZE 50 PROPS.STANDARDS OR ~~TUBES/FITTINGS~~.

HEAD CONDITION

Item		Range	Good	Fair	Inadeq.	M.
1) Eccentricity - Beams not centrally located. Beyond BS requirements of 25mm						
	< 5mm	0 - 2%	✓			8
	5mm - 13mm.	2 - 5%		✓		6
	> 13mm	5 - 10%			✓	4
		over 10%			✓	
2) Clips/Wedges missed out for beams smaller than forkheads						
		0 - 2%	✓			8
		2 - 5%		✓		6
		5 - 10%			✓	5
		more than 10%			✓	4
3) Joints in beam not located centrally on forkheads (more than 15mm)						
	up to 15mm	0 - 2%	✓			9
	15m - 25m	2 - 5%		✓		7
		5 - 10%			✓	5
		more than 10%			✓	4
4) Jack extension beyond limit and no bracing wrt drawing (With regards to extent length and loadings - say worst case was longitudinal or transverse or both.)						
		0 - 20%	✓			6
		20 - 40%		✓		4
		above 40%			✓	2
Check designs against data available - if within loading limits. Check leg load against data on graph.						
5) Timber beam seatings on propheads not secured. No. of props beyond BS requirements.						
		0 - 2%	✓			8
		2 - 5%	✓			6
		5 - 10%		✓		5
		10 - 30%			✓	4
		over 30%			✓	3
6) Load bearing wedges not wide enough (on sloping falsework)						
		0 - 2%		✓		6
		2 - 5%		✓		5
		5 - 10%			✓	4
		over 10%			✓	2

..AD CONDITION (Contd)

		Good	Fair	...naged	Mar...
7) Wedges of inadequate material (on sloping soffits)					
Subject to design check regarding Bending induced at F/Head level	0 - 5%	✓			6
	5 - 10%		✓		5
	10 - 20%			✓	3
	above 20%			✓	2
8) Conditions of Forkheads/Bearing plates of propheads/ Adjustable steel props	0 - 10%		✓		5
(Eg plates distorted, corroded, poor welds,	10 - 20%			✓	3
Jack threads corroded etc.)	over 20%			✓	2
If only distorted give more marks if degree of distortion is such that load bearing capacity is acceptable. For other conditions marks as noted					
9) Undersize timber - Primary and Secondary runners	0 - 5%		✓		5
Would ask for additional support	5 - 10%			✓	3
	10 - 20%			✓	2
	over 20%			✓	1
10) Light instead of heavy duty propheads					
If design load < failure load of prop head	0 - 2%		✓		8
(Eg Hybrid system)	2 - 5%			✓	6
If design load < 66% of failure load	5 - 10%			✓	4
	over 10%			✓	2
11) Incorrect pins on certain prophead assemblies					6
Design check re. shear would be req^d.	0 - 5%		✓		
	5 - 10%		✓		5
	over 10%			✓	4

BASE CONDITION

Item	Range	Good	Fair	Inadeq.	Marks
1. Light instead of heavy duty jacks if design load < failure load < 60%	→ 0 - 2%		✓		8
	→ 2 - 5%			✓	6
If design load > 60% failure load of jack	5 - 10%			✓	4
	over 10%			✓	2
2) Conditions of foundations/sole plates (Eg Bad ground conditions	0 - 5%		✓		7
Inadequate size and type of sole plates)	5 - 10%		✓		5
	10 - 20%			✓	3
	over 20%			✓	2
3) Base plate seating inadequate (Eg eccentricity or	0 - 5%		✓		7
inadequate connection to sole plate)	5 - 10%		✓		6
	10 - 20%			✓	4
	over 20%			✓	3
4) Incorrect pins (load bearing) used on adjustable jacks (Load bearing pins) of certain types Design chart req^d. for shear value.	→ 0 - 5%		✓		8
	5 - 10%		✓		6
	10 - 20%			✓	4
	over 20%			✓	2
5) Excessive jack extensions - no bracing wrt drawings (With due regard to extension length	0 - 20%	✓			
and loadings on jack data sheets	20 - 40%		✓		
Report on both longitudinal and	above 40%			✓	
transverse sections) Same as 4 in head condition.					
6) Base plate conditions (Eg degree of bent, corroded, poor welds	0 - 5%		✓		5
Jack threads corroded etc)	5 - 10%			✓	3
	10 - 20%			✓	2
Clarification req^n ie if only bent. give slightly more marks. For ditto conditions marks as noted	over 20%			✓	1

VERTICAL MEMBERS

		Good	Fair	Inadeq.	Marks (out of)
1) Lift height excessive (wrt drawings)					
(Eg lift height altered for access	0 - 5%		✓		7
requirement - site modification)	5 - 10%		✓		6
Design check would be required	10 - 20%			✓	4
and if necessary additional tube	over 20%			✓	3
struts / braces to be fixed					
2) Lacing missing					
(Eg in one or both directions)	0 - 10%		✓		5
Remedial work must be	10 - 20%			✓	4
done re. lacing to be prim	20 - 30%			✓	2
	over 30%			✓	1
3) Incorrect pins *(loadbearing)* on adjustable steel props.					
(Eg Replaced by mild steel, nails	0 - 5%		✓		8
or high tensile reinforcing	5 - 10%			✓	6
bars)	10 - 20%			✓	4
Design check reqd. for these values	over 20%			✓	2
4) Condition of materials					
(Eg bent *degree of bend*, kinked, inadequate *Δ < 15mm/m.*	0 - 5%		✓		8
welding of lugs etc.) *Δ upto 5mm*	5 - 10%			✓	7
Δ - degree of 'bent' to be *25mm*	10 - 20%			✓	4
checked. *> 25mm.*	over 20%			✓	1
5) Excessive inclination					
(Eg exceeding 1½° - BS requirements)	0 - 10%		✓		6
> 1½ % and	10 - 20%			✓	1
	20 - 40%			✓	1
ecc. > 25mm.	over 40%			✓	1
6) Light duty instead of heavy duty					
vertical standards as specified on	0 - 10%			✓	5
drawings *if design load < failure.*	10 - 20%			✓	4
If design load 66% fail	20 - 30%			✓	2
> 66%.	over 30%			✓	1

8 Marks for Bent only. Reduce marks for inadequate welding

7) Fixings at all node points (for tightness) Nos. found loose

	Good	Fair	Inadeq.	Marks
0 - 5		✓		
5 - 10			✓	
10 - 20			✓	
Over 20			✓	

BRACINGS

		Good	Fair	Inadequate	Marks
1) Correct type of bracings (Eg light/heavy duty Inadequate strength and length of the tubes) *Subject to design test*	0 - 10%		✓		7
	10 - 20%		✓		5
	20 - 30%			✓	2
	over 30%			✓	1
2) Distance from node points eg > 150mm (Special notes on various distances from the node points)	0 - 10%	✓			8
	10 - 20%		✓		7
	20 - 30%			✓	4
	over 30%			✓	2
3) Position, proportion and distribution to the drawings (In one or both directions)	0 - 20%	✓			7
Removal work must be done i.e. braces re-positioned or extra braces put in	20 - 40%		✓		4
	over 40%			✓	1
4) Condition of materials (Eg bent, corroded, etc)	0 - 5%	✓			9
	5 - 10%		✓		7
	10 - 20%			✓	6
	over 20%			✓	3

** Marks given for best condition only. Ranged marks for corroded condition*

Note! 1) Marks given are based on commercial implications & judgement.

2) If commercial implications are not relevant then marks will reduce

TYING-IN		Good	Fair	Inadeq.	Marks
1) Conformity with the drawings or replacing bracing for lateral stability					
(No. and type of tying	0 - 25%		✓		
description required eg for	25 - 50%			✓	
50 standards 8 wall ties are	50 - 75%			✓	
considered or 8 column ties are	75 - 100%			✓	
considered)					
Designers prefer bracing to tying in – tying in is the problem – Depend on drawing					
2) Check bracing for node stability (if tying-in is introduced at every level and every row. Positions, proportions and distribution)		✓			
If not and missing by -	0 - 20%		✓		
	20 - 40%			✓	
	over 40%			✓	

Note - Describe the reasons for choice of tying-in ie site or Design Office decision.

GENERAL CONDITIONS OF MATERIALS	Good	Fair	Inadeq.	Marks [illegible]
General information based upon information gathered from previous conditions.				
Three conditions possible:-				
(1) No serious comments	✓			9
(2) Rusty, bent etc., but no structural problems.		✓		6
(3) Rusty, bent etc., but may cause local structural problems.			✓	3–1
ACCESS AND SAFETY (w.r.t. no. of actions taken)				
(1) Is safe access provided to reach all parts for works, i.e. ladders and adequate access scaffold?				
(2) Are all walkways level & free from obstruction?				
(3) Are there adequate guard rails and toe boards?				
(4) Are all access materials in good condition and free from obvious defects?				
(5) Are all ladders secured at the top and bottom?				
(6) Are there sufficient boards at all working platforms in use?				
(7) Are the ladders properly positioned for access?				
(8) Does the ladder rise at least 1.07m above the place of landing. If not, is there adequate hand-hold at the place of landing?				
(9) Is the site tidy and are materials stored in safe position?				
(10) Who is responsible for the inspection, are they carried out and recorded?				

CONFORMITY OF ERECTION WITH FORMALISED DESIGN

When making assessment under this column the checkers are taking into account the number of changes made on sites irrespective of structural implication, good or otherwise. Checkers to assess whether the communication between the designer and site via drawing has been adequate.

Recommended assessment :-

			Marks out of ten
1	Change/alteration	Good	9
2	Changes	Fair	7
3	Changes	Fair	5
	More than 3 changes	Inadequate	3 or less

Note : Each case study to describe the alterations made and reasons for these alterations.

Good	Fair	Inadeq.	Marks out of ten

CHECK LIST REFERRING TO BS.5975 REQUIREMENTS. 3/1/86 [illegible]

SAMPLE SIZE 50 PROPS.STANDARDS ~~OR TUBES/FITTINGS~~.

HEAD CONDITION		Good	Fair	Inadeq.	Marks of ten
1) Eccentricity - Beams not centrally located. Beyond BS requirements of 25mm					
	0 - 2%		✓		
	2 - 5%		✓		
	5 - 10%			✓	
2) Clips/Wedges missed out for beams smaller than forkheads					
	0 - 2%		✓		
	2 - 5%		✓		
	5 - 10%			✓	
	more than 10%				
3) Joints in beam not located centrally on forkheads (more than 15mm)					
	0 - 2%	✓			
	2 - 5%			✓	
	5 - 10%			✓	
	more than 10%				
4) Jack extension beyond limit and no bracing wrt drawing					
With regards to extent length	0 - 20%			✓	
and loadings - say worst case was	20 - 40%			✓	
longitudinal or transverse or both. (Heights of building may change)	above 40%			✓	
5) Timber beam seatings on propheads not secured					
No. of props beyond BS requirements.	0 - 2%	✓			
	2 - 5%	✓			
	5 - 10%		✓		
	10 - ~~30%~~ 20%		✓		
	over ~~30%~~ 20%			✓	
6) Load bearing wedges not wide enough (on sloping falsework)					
(Dependant on loading, wedges need not necessarily be of full width). (Bearing stress to be considered).	0 - 2%			✓	
	2 - 5%			✓	
	5 - 10%			✓	
	over 10%				

HEAD CONDITION (Contd)

		Good	Fair	Inadeq.	Marks of te
7) Wedges of inadequate material (on sloping soffits) (Note as N° 6.)	0 - 5%			✓	
	5 - 10%			✓	
	10 - 20%			✓	
	above 20%				
8) Conditions of Forkheads/Bearing plates of propheads/ Adjustable steel props	0 - 10%		✓		
Eg plates distorted, corroded, poor welds,	10 - 20%			✓	
Jack threads corroded etc.	over 20%			✓	
9) Undersize timber - Primary and Secondary runners	0 - 5%			✓ (0 - 20%)	
	5 - 10%				
	10 - 20%				
	over 20%				
10) Light instead of heavy duty propheads	0 - 2%		✓		
Eg Hybrid system	2 - 5%		✓		
	5 - 10%			✓	
	over 10%				
11) Incorrect ~~and missing~~ pins	0 - 5%			✓ (0 - 10%)	
	5 - 10%				
	over 10%				

BASE CONDITION		Good	Fair	Inadeq.	Marks of t
1) Light instead of heavy duty jacks					
	0 - 2%				
	2 - 5%			✓	
	5 - 10%				
	over 10%				
2) Conditions of foundations/sole plates					
Eg Bad ground conditions	0 - 5%		✓		
Inadequate size and type of sole plates	5 - 10%		✓		
	10 - 20%			✓	
	over 20%			✓	
3) Base plate seating inadequate					
Eg eccentricity or	0 - 5%				
inadequate connection to sole plate	5 - 10%			✓	
	10 - 20%				
(Own experience - one prop inadequacy meant that a stretch of falsework pulled out.)	over 20%				
4) Incorrect pins used on adjustable jacks (Load bearing pins)					
	0 - 5%				
	5 - 10%			✓	
	10 - 20%				
	over 20%				
5) Excessive jack extensions - no bracing wrt drawings					
With due regard to extension length	0 - 20%				
and loadings on jack data sheets	20 - 40%			✓	
Report on both longitudinal and	above 40%				
transverse sections					
6) ~~[illegible]~~ Base plate conditions					
Eg Bent, corroded, poor welds	0 - 5%		✓		
Jack threads corroded etc	5 - 10%		✓		
	10 - 20%			✓	
	over 20%				

VERTICAL MEMBERS		Good	Fair	Inadeq.	Marks out of ten
1) Lift height excessive (wrt drawings) Eg lift height altered for access requirement – site modification	0 - 5%		✓		
	5 - 10%			✓	
	10 - 20%			✓	
	over 20%			✓	
2) Lacing missing Eg in one or both directions. Dependant on loading Condition. (Props need not necessarily be laced, except maybe for stability during erection)	0 - 10%			)	if lacing is Req'd
	10 - 20%			)	
	20 - 30%			) ✓	
	over 30%				
3) Incorrect pins on adjustable steel props. Eg Replaced ~~by mild steel~~ nail. * (or high tensile reinforcing bars load bearing pins)	0 - 5%			)	
	5 - 10%			) ✓	
	10 - 20%			)	
	over 20%				
4) Condition of materials Eg bent, kinked, inadequate welding of lugs etc.	0 - 5%		✓		
	5 - 10%			✓	
	10 - 20%			✓	
	over 20%			✓	
5) Excessive inclination Eg exceeding $1\frac{1}{2}^{\circ}$ - BS requirements	0 - 10%		✓		
	10 - 20%			✓	
	20 - 40%			✓	
	over 40%			✓	
6) Light duty instead of heavy duty specified on drawings	0 - 10%		✓		
	10 - 20%			✓	
	20 - 30%			✓	
	over 30%			✓	
(7) Fixings at all node points (for tightness)	No. found loose				
	0-5		✓		
	5-10			✓	
	10-20			✓	
	over 20.			✓	

BRACING		Good	Fair	Inadeq.	Marks (of t(
1) Correct type of bracings					
Eg light/heavy duty	0 - 10%				Assuming loads in braces are to max allowable
Inadequate strength	10 - 20%			✓	
and length of the tubes	20 - 30%				
(Dependant on load in brace light duty may be adequate.)	over 30%				
2) Distance from node points eg > 150mm					
Special notes on various	0 - 10%		✓		
distances from the node points	10 - 20%			✓	
	20 - 30%			✓	
	over 30%			✓	
3) Position, proportion and distribution to the drawings					
In one or both directions	0 - 20%		✓		
could be critical if legs are unevenly loaded.	20 - 40%			✓	
Position may not be important (within reason).	over 40%			✓	
4) ~~Bracing omitted - replaced by Tying-in?~~ Is it adequate?					
~~(a) If not replaced by Tying-in mark inadequate or 0/10~~	~~(b) Is there a different grading grading system of tying-in?~~				
5) Condition of materials					
	0 - 5%		✓		
Eg bent, corroded, etc	5 - 10%			✓	
	10 - 20%			✓	
	over 20%				

TYING-IN		Good	Fair	Inadeq.	Marks of t
1) Conformity with the drawings or replacing bracing for lateral stability					
No. and type of tying	0 - 25%				
description required eg for	25 - 50%			✓	
50 standards 8 wall ties are	50 - 75%				
considered or 8 column ties are considered	75 - 100%				
2) Check bracing for node stability (if tying-in is introduced) at every level and every row. Positions, proportions and distribution)					
If not and missing by -	0 - 20%		✓		
	20 - 40%			✓	
	over 40%			✓	

Note - Describe the reasons for choice of tying-in ie site or Design Office decision.

GENERAL CONDITIONS OF MATERIALS	Good	Fair	Inadeq.	Marks out of ten
General information based upon information gathered from previous conditions.				
Three conditions possible:-				
(1) No serious comments	✓			
(2) Rusty, bent etc., but no structural problems.		✓		
(3) Rusty, bent etc., but may cause local structural problems.			✓	
ACCESS AND SAFETY (w.r.t. no. of actions taken)				
(1) Is safe access provided to reach all parts for works, i.e. ladders and adequate access scaffold?		✓		
(2) Are all walkways level & free from obstruction?		✓		
(3) Are there adequate guard rails and toe boards?				
(4) Are all access materials in good condition and free from obvious defects?				
(5) Are all ladders secured at the top and bottom?	0-2	3-5	>5	
(6) Are there sufficient boards at all working platforms in use?				
(7) Are the ladders properly positioned for access?				
(8) Does the ladder rise at least 1.07m above the place of landing. If not, is there adequate hand-hold at the place of landing?				
(9) Is the site tidy and are materials stored in safe position?				
(10) Who is responsible for the inspection, are they carried out and recorded?				

CONFORMITY OF ERECTION WITH FORMALISED DESIGN

When making assessment under this column the checkers are taking into account the number of changes made on sites irrespective of structural implication, good or otherwise. Checkers to assess whether the communication between the designer and site via drawing has been adequate.

Recommended assessment :-

			Marks out of ten
1	Change/alteration	~~Good~~ FAIR	9
2	Changes	Fair	7
3	Changes	Fair	5
	More than 3 changes	Inadequate	3 or less

Note : Each case study to describe the alterations made and reasons for these alterations.

Good	Fair	Inadeq.	Marks out of ten

CHECK LIST REFERRING TO BS.5975 REQUIREMENTS.
SAMPLE SIZE 50 PROPS, STANDARDS OR ~~TUBES/FITTINGS.~~ Kerr & Carter – City/Kimbolton

HEAD CONDITION

		Good	Fair	Inadeq.	Marks out of ten
1) Eccentricity - Beams not centrally located. Beyond BS requirements of 25mm					
A If the standard are fully loaded	0 - 2%	A			
" "	2 - 5%	A			
B " " lightly	5 - 10%		A		
	More than 10% 25%	B		A	
2) Clips/Wedges missed out for beams smaller than forkheads					
	0 - 2%	✓			
	2 - 5%	✓			
	5 - 10%	✓	✓		
	more than 10% 25%			✓	
	>25%				
3) Joints in beam not located centrally on forkheads (more than 15mm)					
	0 - 2%	✓			
50	2 - 5%	✓			
	5 - 10%		✓		
	more than 10%			✓	
4) Jack extension beyond limit and no bracing wrt drawing (With regards to extent length and loadings - say worst case was longitudinal or transverse or both.)					
	0 - 20%			✓	
	20 - 40%			✓	
	above 40%			✓	
~~WITH BRACING~~ WITHOUT.					
5) Timber beam seatings on propheads not secured. No. of props beyond BS requirements.					
	0 - 2%	✓			
	2 - 5%	✓			
	5 - 10%		✓		
	10 - 30%			✓	
	over 30%			✓	
6) Load bearing wedges not wide enough (on sloping falsework)					
	0 - 2%	AB F			
	2 - 5%		A		
A Fully Loaded	5 - 10%	B		A	
B Lightly Loaded	over 10%			B A	

HEAD CONDITION (Contd)

		Good	Fair	Inadeq.	Marks of ter
7) Wedges of inadequate material (on sloping soffits)	0 - 5%	A B			
	5 - 10%	B		A	
	10 - 20%		B	A	
	above 20%			A B	
8) Conditions of Forkheads/Bearing plates of propheads/ Adjustable steel props	0 - 10%	✓ [illegible]			
(Eg plates distorted, corroded, poor welds,	10 - 20%			✓	
Jack threads corroded etc.)	over 20%			✓	
9) Undersize timber - Primary and Secondary runners	0 - 5%			✓	
	5 - 10%				
	10 - 20%			✓	
	over 20%			✓ ✓	
10) Light instead of heavy duty propheads	0 - 2%			✓	
(Eg Hybrid system)	2 - 5%			✓	
	5 - 10%			✓	
	over 10%			✓	
11) Incorrect pins on certain prophead assemblies	0 - 5%			✓	
	5 - 10%			✓	
	over 10%			✓	

BASE CONDITION

Item	Range	Good	Fair	Inadeq.	Marks of t
1) Light instead of heavy duty jacks					
	0 - 2%				
	2 - 5%				
	5 - 10%				
	over 10%				
2) Conditions of foundations/sole plates					
(Eg Bad ground conditions	0 - 5%				
Inadequate size and type of sole plates)	5 - 10%				
	10 - 20%				
	over 20%				
3) Base plate seating inadequate					
(Eg eccentricity or	0 - 5%				
inadequate connection to sole plate)	5 - 10%				
	10 - 20%				
	over 20%				
4) Incorrect pins used on adjustable jacks (Load bearing pins) of certain types	0 - 5%				
	5 - 10%				
	10 - 20%				
	over 20%				
5) Excessive jack extensions - no bracing wrt drawings					
(With due regard to extension length	0 - 20%				
and loadings on jack data sheets	20 - 40%				
Report on both longitudinal and	above 40%				
transverse sections)					
6) Base plate conditions					
(Eg Bent, corroded, poor welds	0 - 5%				
Jack threads corroded etc)	5 - 10%				
	10 - 20%				
	over 20%				

VERTICAL MEMBERS

		Good	Fair	Inadeq.	Marks of t
1) Lift height excessive (wrt drawings) (Eg lift height altered for access requirement - site modification)	0 - 5%			✓	
	5 - 10%			✓	
	10 - 20%			✓	
	over 20%			✓	
2) Lacing missing (Eg in one or both directions) B	0 - 10%	B		A	
	10 - 20%			AB	
	20 - 30%			A B	
	over 30%			A B	
3) Incorrect pins on adjustable steel props. (Eg Replaced by mild steel, nails or high tensile reinforcing bars)	0 - 5%			✓	
	5 - 10%			✓	
	10 - 20%			✓	
	over 20%			✓	
4) Condition of materials (Eg bent, kinked, inadequate welding of lugs etc.)	0 - 5%		✓		
	5 - 10%			✓	
	10 - 20%			✓	
	over 20%				
5) Excessive inclination (Eg exceeding $1\frac{1}{2}^{o}$ - BS requirements)	0 - 10%				
	10 - 20%				
	20 - 40%				
	over 40%			✓	
6) Light duty instead of heavy duty vertical standards as specified on drawings	0 - 10%			✓	
	10 - 20%				
	20 - 30%				
	over 30%				
7) Fixings at all node points (for tightness) — Nos. found loose; A Heavy, B Light	0 - 5	B		A	
	5 - 10			A B	
	10 - 20			A B	
	Over 20			A B	

BRACING

		Good	Fair	Inadeq.	Marks of t
1) Correct type of bracings (Eg light/heavy duty Inadequate strength and length of the tubes) A B	0 - 10%		B	A	
	10 - 20%		B	A	
	20 - 30%			A B	
	over 30%			A B	
2) Distance from node points eg > 150mm (Special notes on various distances from the node points)	0 - 10%	✓			
	10 - 20%			✓	
	20 - 30%			✓	
	over 30%				
3) Position, proportion and distribution to the drawings (In one or both directions) A (B) C	0 – 20%	A C		B	
	20 - 40%			A B C	
	over 40%			A B C	
4) Condition of materials (Eg bent, corroded, etc)	0 - 5%	✓			
	5 - 10%			✓	
	10 - 20 %			✓	
	over 20%			✓	

TYING-IN		Good	Fair	Inadeq.	Marks ou of ten
1) Conformity with the drawings or replacing bracing for lateral stability					
(No. and type of tying	0 - 25%			✓	
description required eg for	25 - 50%			✓	
50 standards 8 wall ties are	50 - 75%			✓	
considered or 8 column ties are	75 - 100%			✓	
considered)					
2) Check bracing for node stability (if tying-in is introduced at every level and every row. Positions, propertions and distribution)					
If not and missing by →	0 - 20%			✓	
	20 - 40%			✓	
	over 40%			✓	
Note - Describe the reasons for choice of tying-in ie site or Design Office decision.					

GENERAL CONDITIONS OF MATERIALS	Good	Fair	Inadeq.	Marks out of ten
General information based upon information gathered from previous conditions.				
Three conditions possible:-				
(1) No serious comments	✓			
(2) Rusty, bent etc., but no structural problems.		✓		
(3) Rusty, bent etc., but may cause local structural problems.			✓	
ACCESS AND SAFETY (w.r.t. no. of actions taken)				
(1) Is safe access provided to reach all parts for works, i.e. ladders and adequate access scaffold?				
(2) Are all walkways level & free from obstruction?				
(3) Are there adequate guard rails and toe boards?				
(4) Are all access materials in good condition and free from obvious defects?				
(5) Are all ladders secured at the top and bottom?				
(6) Are there sufficient boards at all working platforms in use?				
(7) Are the ladders properly positioned for access?				
(8) Does the ladder rise at least 1.07m above the place of landing. If not, is there adequate hand-hold at the place of landing?				
(9) Is the site tidy and are materials stored in safe position?				
(10) Who is responsible for the inspection, are they carried out and recorded?	✓5-	10	X5	✓

50%

CONFORMITY OF ERECTION WITH FORMALISED DESIGN

When making assessment under this column the checkers are taking into account the number of changes made on sites irrespective of structural implication, good or otherwise. Checkers to assess whether the communication between the designer and site via drawing has been adequate.

Recommended assessment :- over 6s

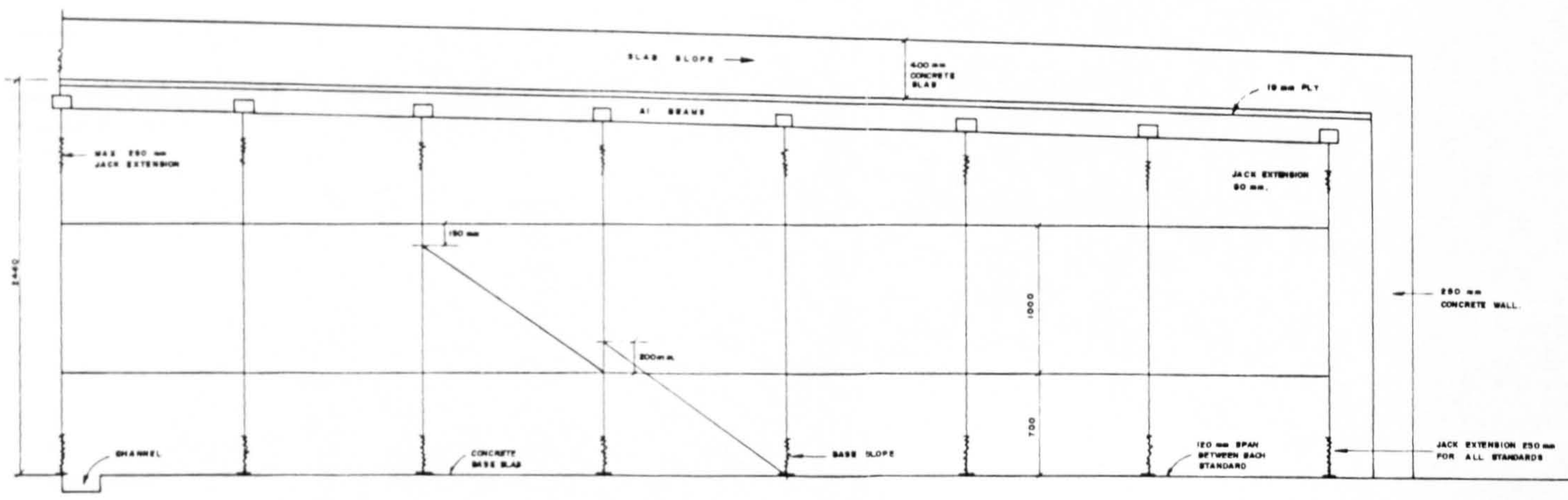
			Marks out of ten
1	Change/alteration	Good	9
2	Changes	Fair	7
3	Changes	Fair	5
	More than 3 changes	Inadequate	3 or less

Note : Each case study to describe the alterations made and reasons for these alterations.

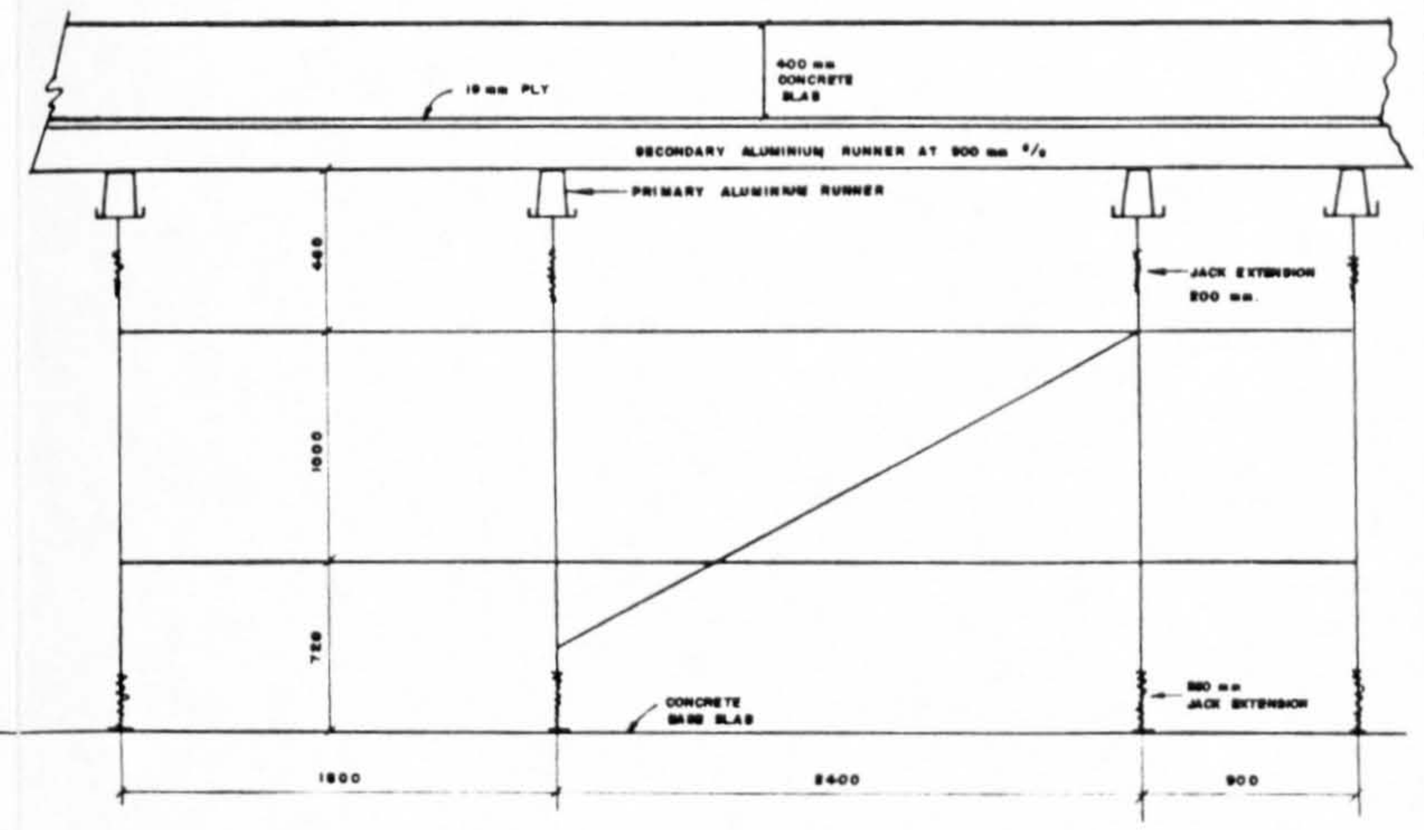
Good	Fair	Inadeq.	Marks out of ten
4	4-8	>8	

APPENDIX F

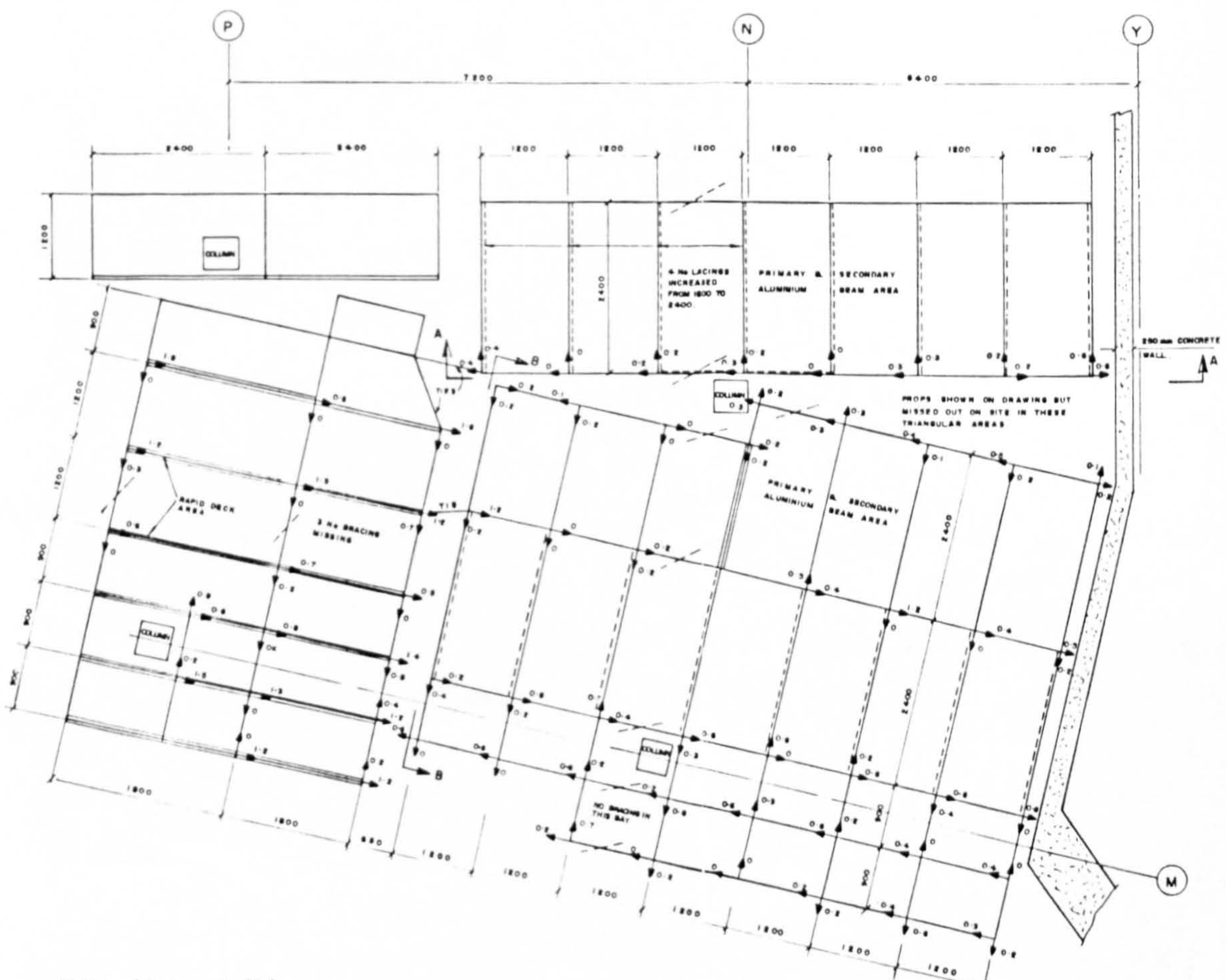
Sample of drawings of quality checks made on site



SECTION A - A (Scale 1 : 25)



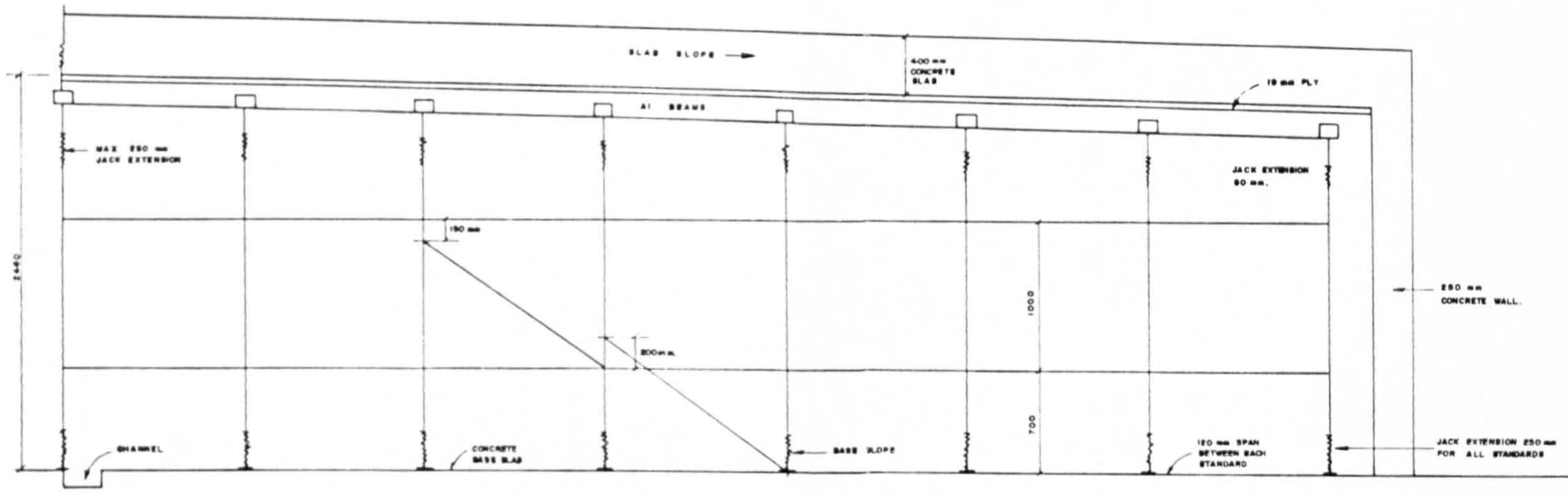
SECTION B - B (Scale 1 : 25)



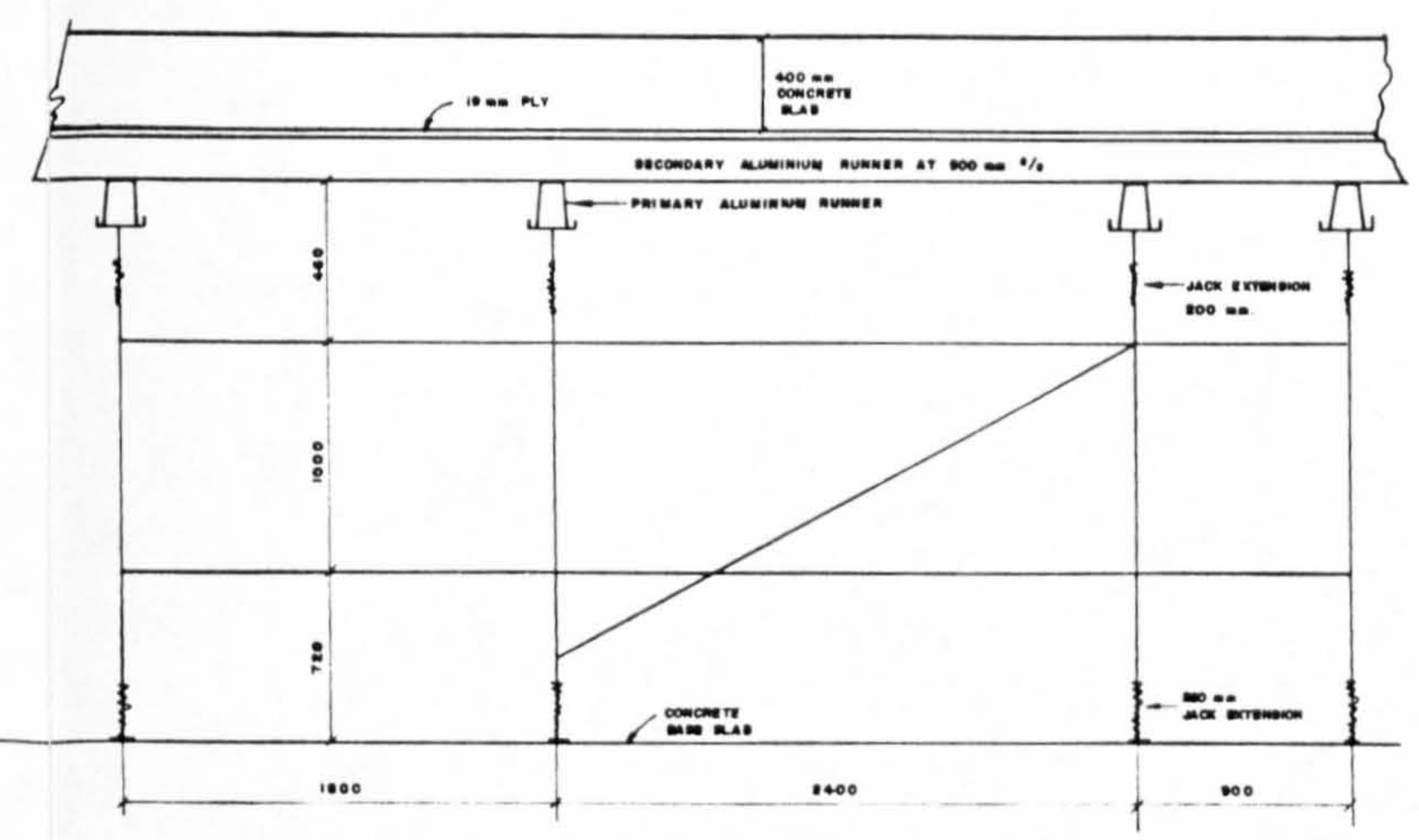
PLAN (Scale 1 : 50)

GENERAL NOTES

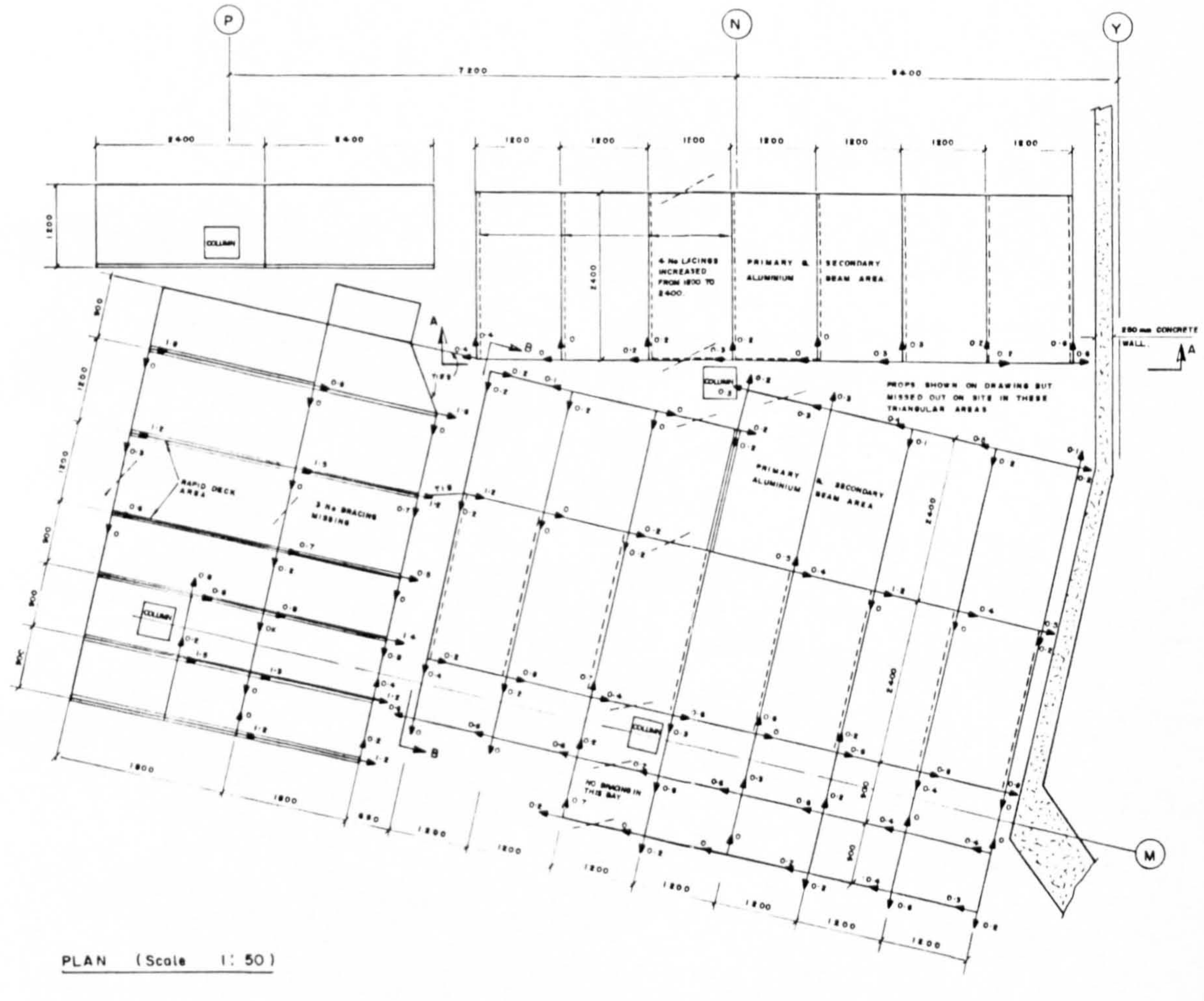
1 SIZE OF SAMPLE — 63 PROPRIETARY STANDARDS
2 DESCRIPTION OF STRUCTURE — MULTISTOREY OFFICE BUILDING.
3 DESCRIPTION OF SYSTEM A COMBINATION OF RAPID DECK AND ALUMINIUM PRIMARY & SECONDARY RUNNERS ON PROPRIETARY BIRDCAGE.
4 METHOD OF POUR — PUMPING
SIZE OF POUR APPROXIMATELY 60 cu. m.
5 REFER TO RMD. DRG. No. 85/31674/4A.
6 ALTHOUGH RAPID DECK SECTION COULD HAVE BEEN INCLUDED IN THE SAMPLE AI. BEAM AREA WAS CHOSEN ON THE BASIS THAT IT HAD SOME PROBLEMATIC SECTIONS.
7. LABOUR ONLY CONTRACTOR WAS RESPONSIBLE FOR ERECTING THE FALSEWORK.
8 BOTH THE ROOF AND THE BASEMENT SLAB HAD SLIGHT SLOPES.
9. PHOTOGRAPHS TAKEN SHOWS THAT IN ABOUT THREE AREAS THE JOINTS IN THE AI. BEAMS DID NOT MATERIALISE IN THE AND THE JOINTS WERE SUPPORTED ON WOODEN BLOCKS WHICH WERE IN TURN SUPPORTED ON SO AND TRAN
IT SEEMED THAT NOBODY IN THE MC. ORGANISATION TOOK ANY NOTICE OF THIS.
10. MAXM. LEG LOAD = 38·02 KN.
MAXM SWL. = 40 KN.



SECTION A – A (Scale 1 : 25)



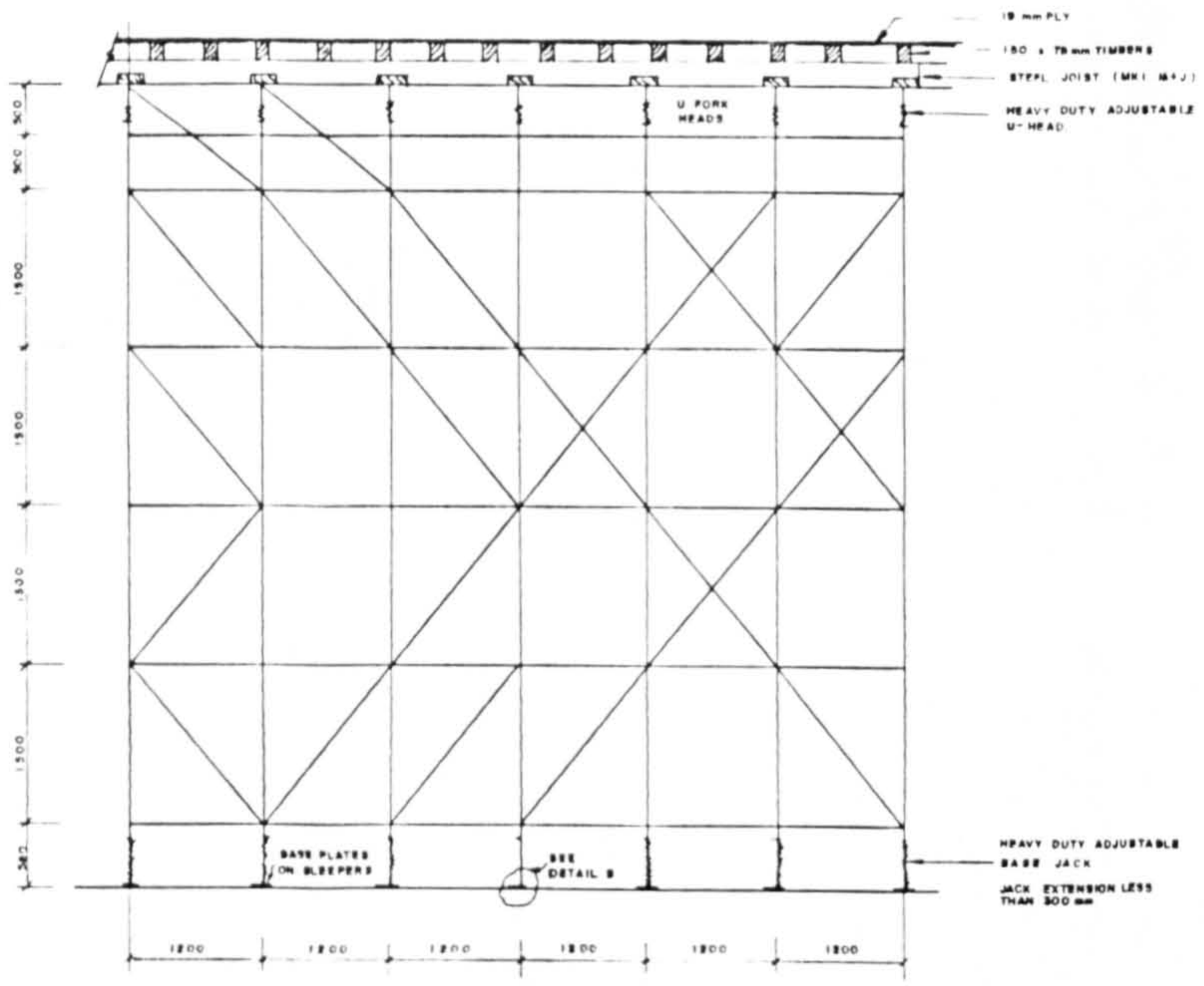
SECTION B - B (Scale 1 : 25)



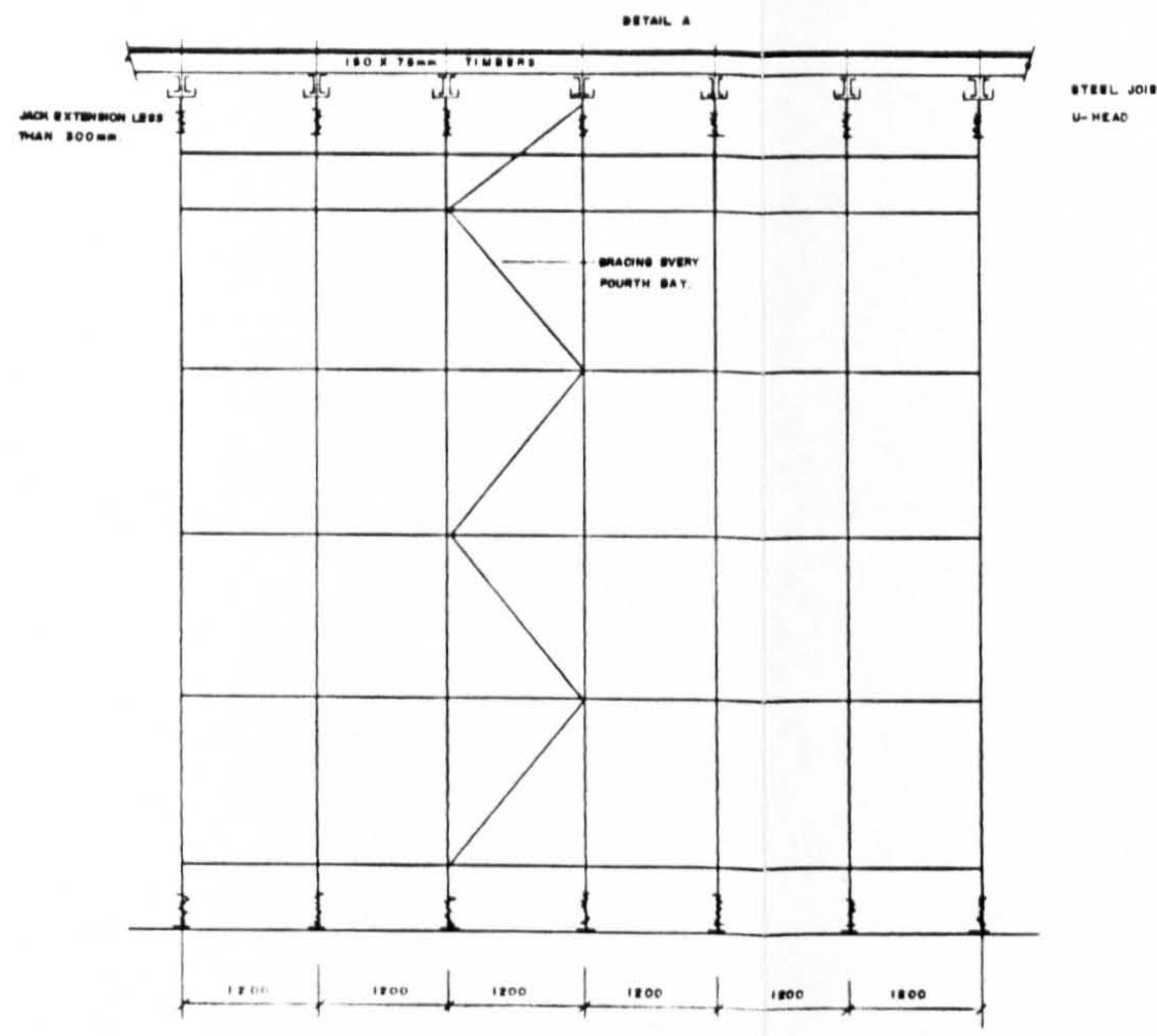
PLAN (Scale 1 : 50)

GENERAL NOTES

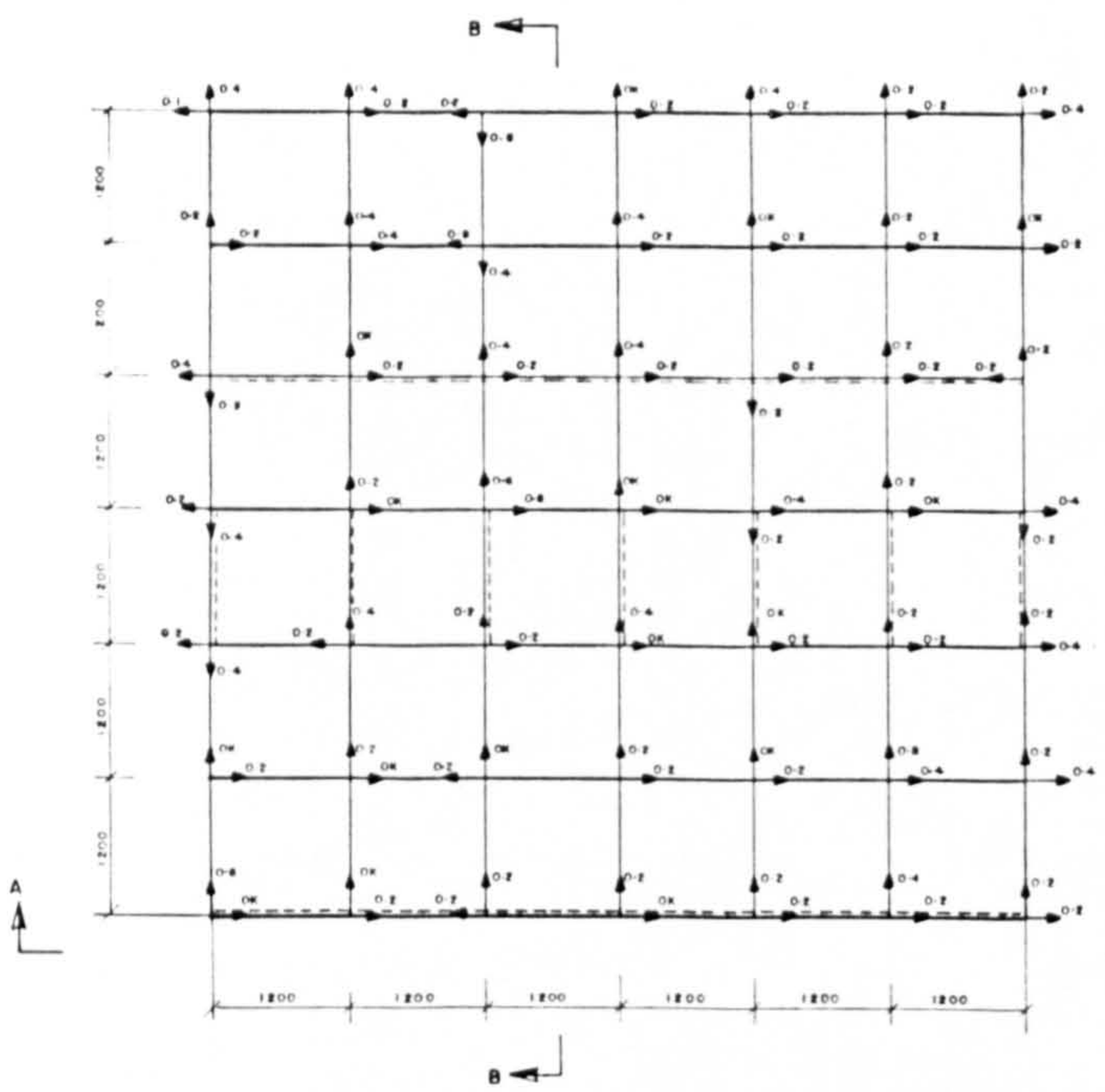
1. SIZE OF SAMPLE – 63 PROPRIETARY STANDARDS
2. DESCRIPTION OF STRUCTURE – MULTISTOREY OFFICE BUILDING.
3. DESCRIPTION OF SYSTEM A COMBINATION OF RAPID DECK AND ALUMINIUM PRIMARY & SECONDARY RUNNERS ON PROPRIETARY BIRDCAGE.
4. METHOD OF POUR – PUMPING
   SIZE OF POUR APPROXIMATELY 60 cu. m.
5. REFER TO RMD. DRG. No. 85/31674/4A.
6. ALTHOUGH RAPID DECK SECTION COULD HAVE BEEN INCLUDED IN THE SAMPLE AI. BEAM AREA WAS CHOSEN ON THE BASIS THAT IT HAD SOME PROBLEMATIC SECTIONS.
7. LABOUR ONLY CONTRACTOR WAS RESPONSIBLE FOR ERECTING THE FALSEWORK.
8. BOTH THE ROOF AND THE BASEMENT SLAB HAD SLIGHT SLOPES.
9. PHOTOGRAPHS TAKEN SHOWS THAT IN ABOUT THREE AREAS THE JOINTS IN THE AI. BEAMS DID NOT MATERIALISE IN THE AND THE JOINTS WERE SUPPORTED ON WOODEN BLOCKS WHICH WERE IN TURN SUPPORTED ON 90 AND TRAN
   IT SEEMED THAT NOBODY IN THE MC. ORGANISATION TOOK ANY NOTICE OF THIS.
10. MAXM. LEG LOAD = 38·02 KN.
    MAXM SWL. = 40 KN.



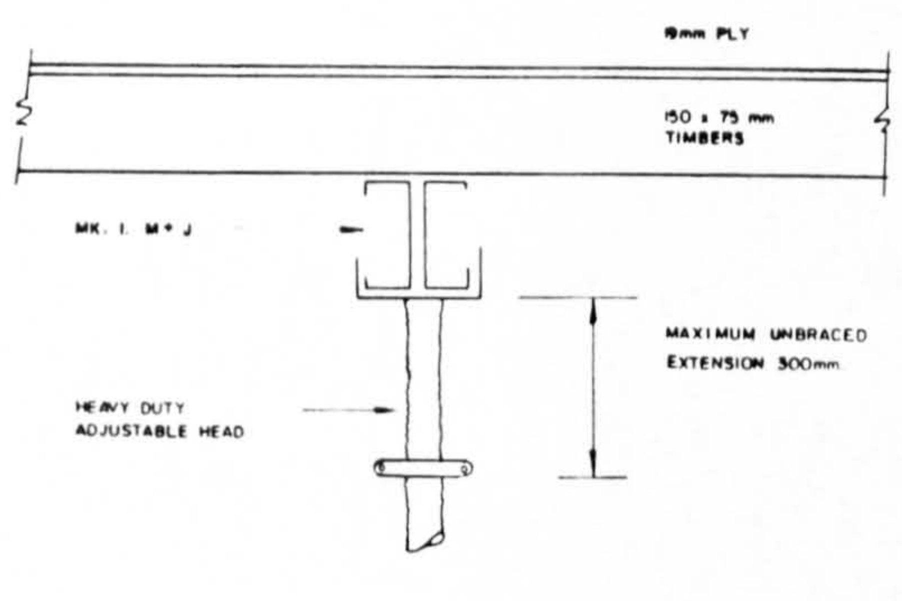
SECTION A–A (Scale 1: 50)



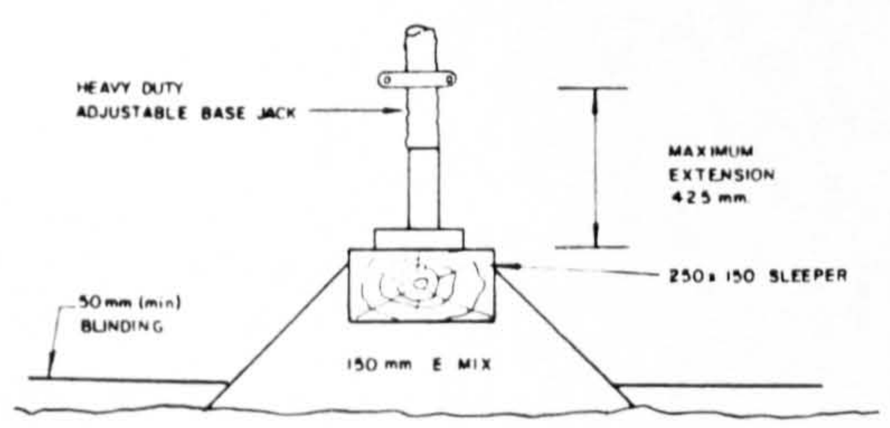
SECTION B–B (Scale 1: 50)



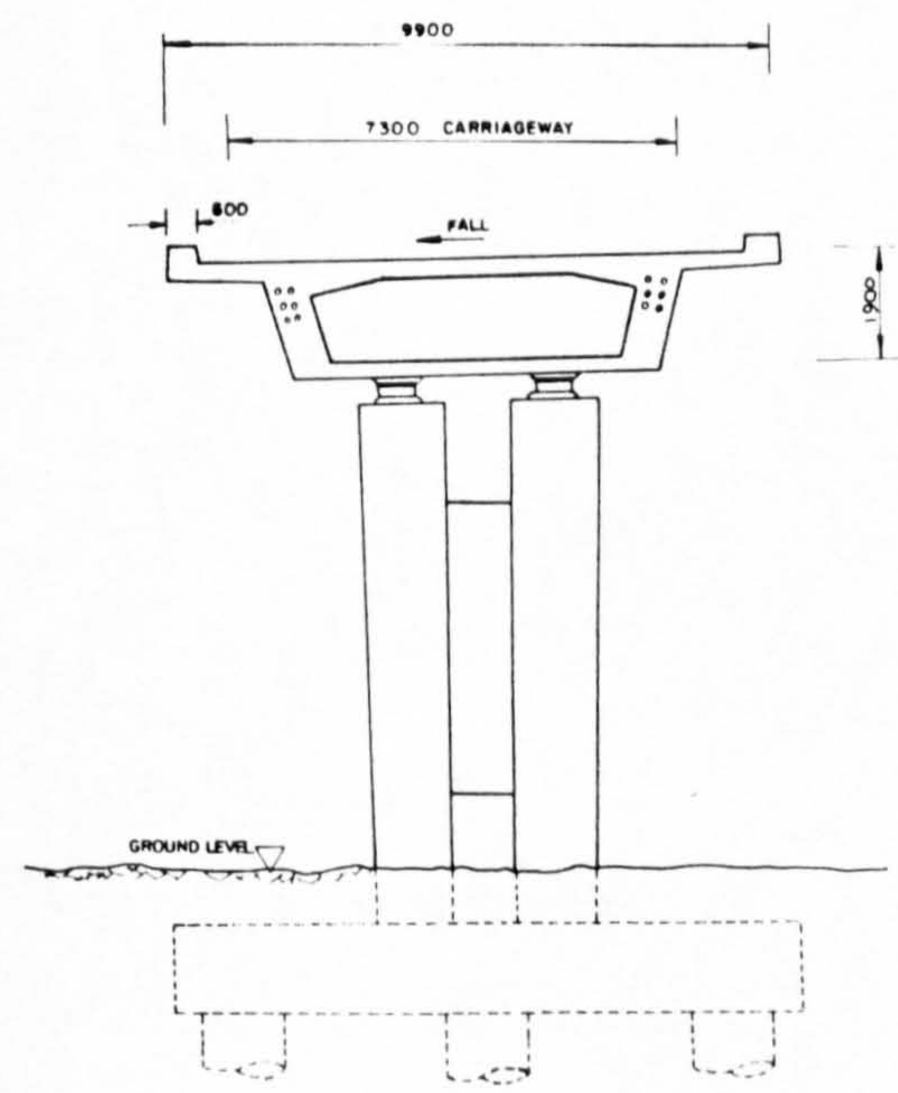
PLAN (Scale 1: 50)



DETAIL A. (Scale 1: 10)



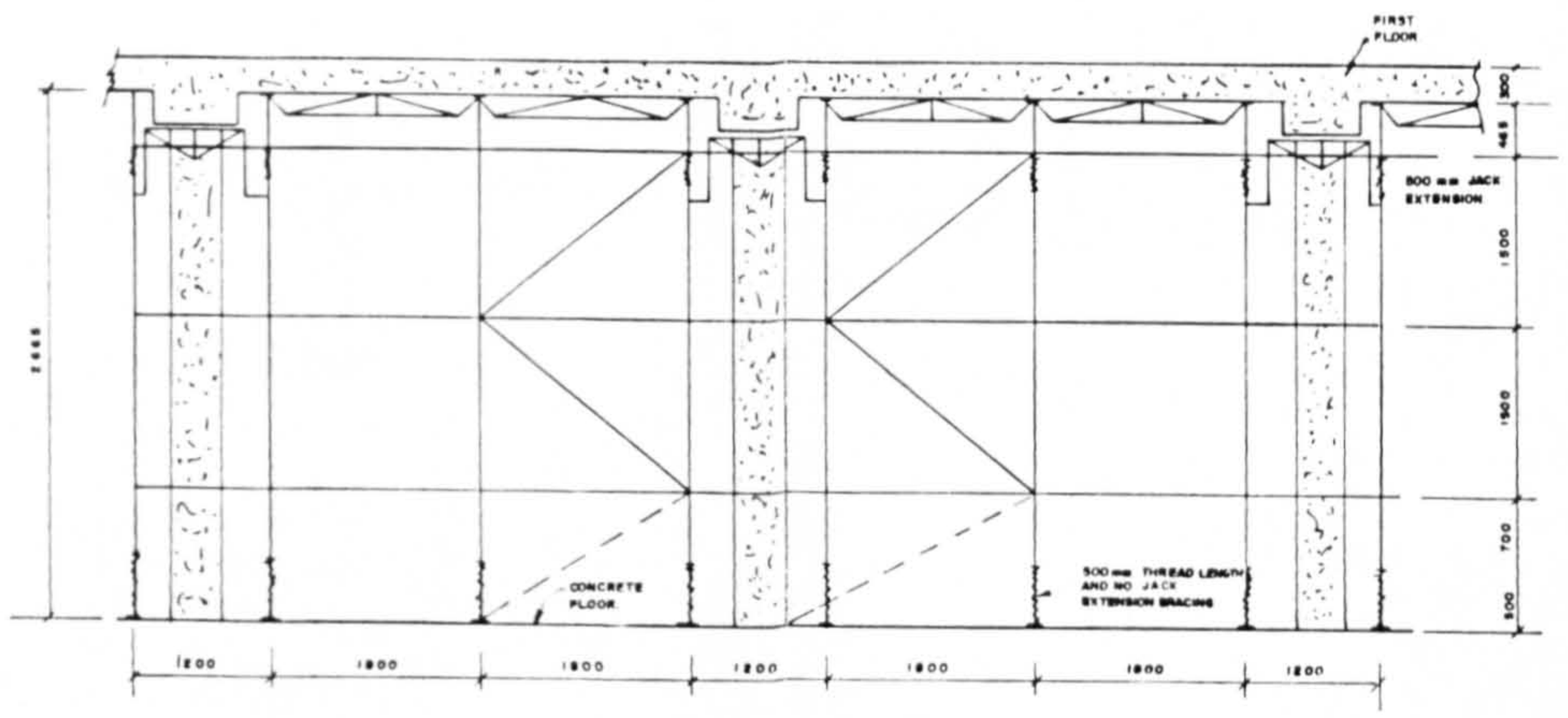
BASE DETAIL B. (Scale 1: 10)



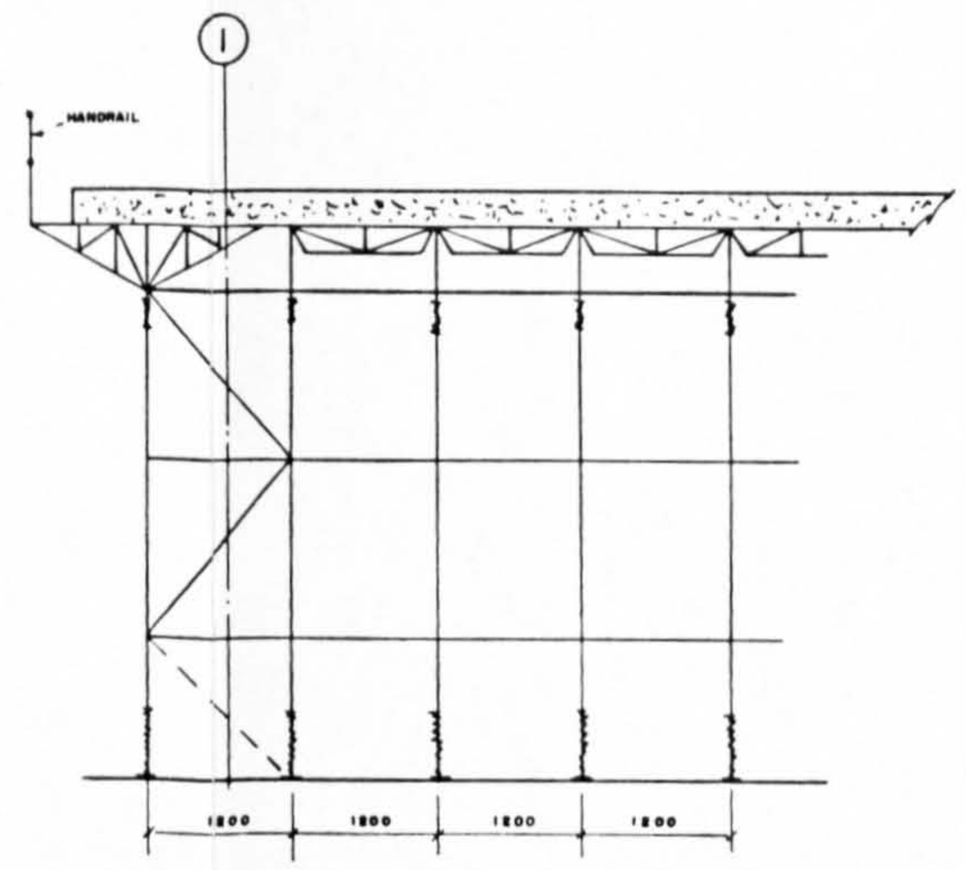
TYPICAL SECTION (Scale 1:100)

GENERAL NOTES

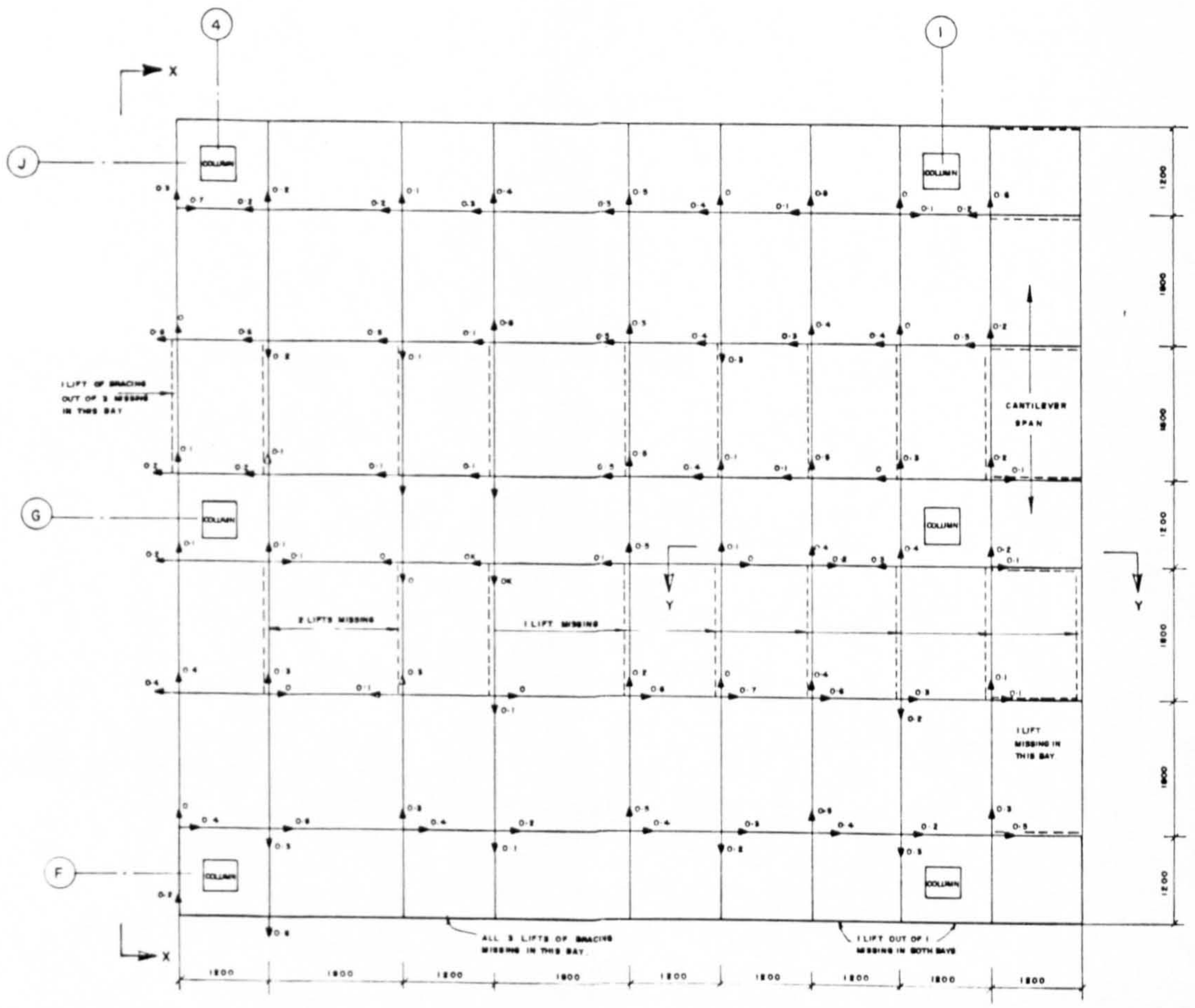
1. SAMPLE SIZE. 49 PROPRIETARY STANDARDS.
2. DESCRIPTION OF SYSTEM. BRIDGE DECK SUPPORTS ON TIMBER AND A COMPOSITE CHANNELS STEEL JOISTS. THE WHOLE FORMWORK IS SUPPORTED ON PROPRIETARY STANDARD BIRDCAGE
3. DESCRIPTION OF SITEWORKS. VIADUCT ON A RELIEF ROAD.
4. DRAWING Nos. WSAP. GA DRG. No. 03350/TE/01 9701 C
   JLCL DRG Nos. CE 504 /68 E
   (FALSEWORK) 22800/5.
5. LABOUR ONLY SUBCONTRACTOR ERECTING THE PROPRIETARY SUPPLIERS EQUIPMENT TO MAIN CONTRACTORS DRAWINGS
6. THE STANDARDS AND LACINGS FORM A PART OF THE PROPRIETARY BIRDCAGE BUT THE BRACINGS ARE TUBES AND FITTINGS.
7. TWC. AND PERMIT TO LOAD SYSTEM ACTIVITIES APPARENT ON THIS.
8. MORE ACTIVE PARTICIPATION FROM RE.
9. INDEPENDENT CHECKER OF FALSEWORK DRAWINGS PROVIDED A CHECKING CERTIFICATE.
10. MAX'M. LEG LOAD = 34·97 KN.
    MAX M. SWL = 40 KN.



SECTION X - X (Scale 1 : 50)



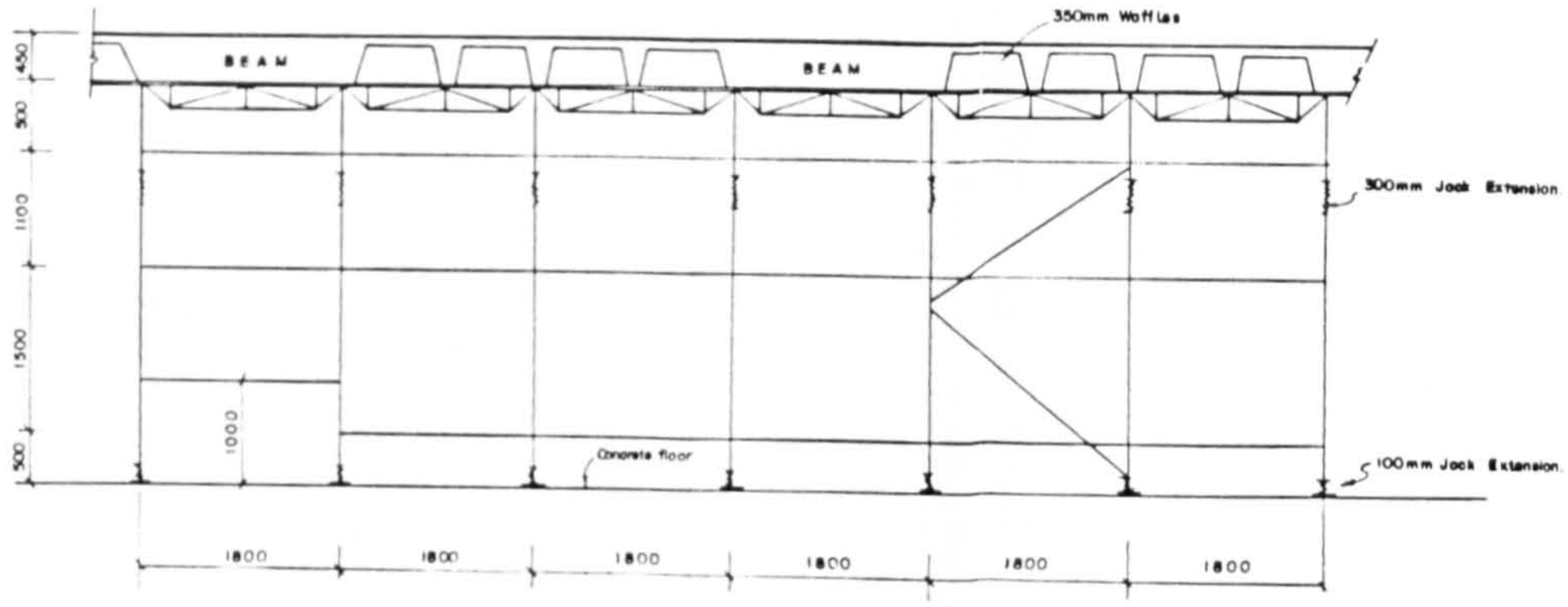
SECTION Y - Y (Scale 1 : 50)



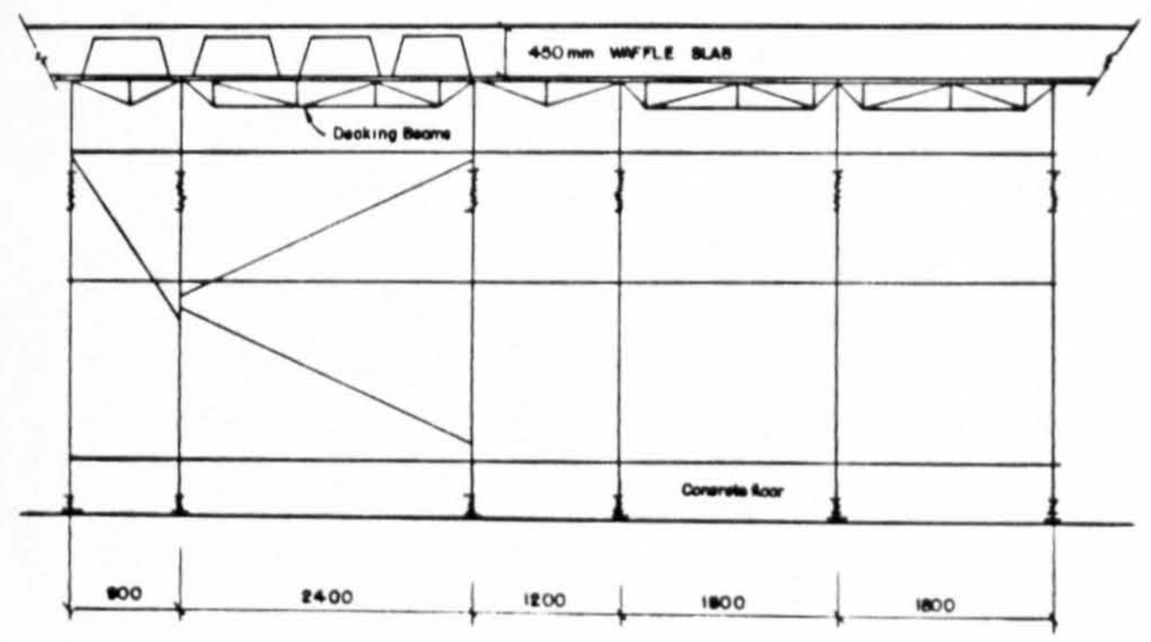
PLAN (Scale 1 : 50)

GENERAL NOTES

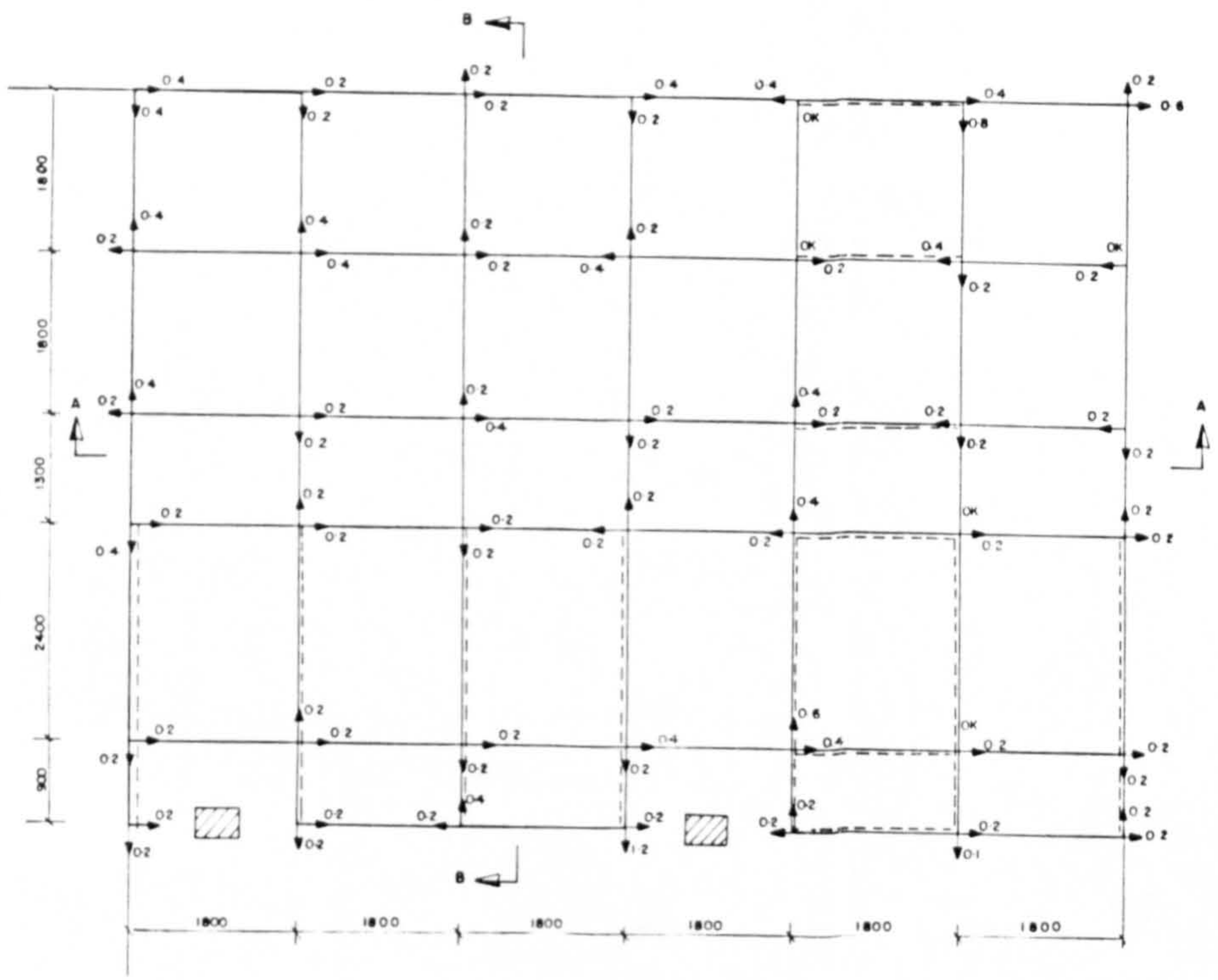
1. SAMPLE SIZE - 56 PROPRIETARY STANDARDS.
2. DESCRIPTION OF SYSTEM - QUICK STRIPPING PROPRIETARY SYSTEM WHERE SOFFIT PLYWOOD IS SUPPORTED ON STANDARD BEAMS AND PROPRIETARY STANDARDS
3. DESCRIPTION OF WORK - CROWN COURT.
4. POUR SIZE 60 cu. m APPROX - SKIP USED.
5. NO DRAWINGS AVAILABLE.
6. SAMPLE TAKEN IN THE MIDDLE SECTION OF THE POUR.
7. LABOUR ONLY CONTRACTOR ERECTING FALSEWORK SUPPLIED BY THE MAIN CONTRACTOR DRAWING SUPPLIED BY THE PROPRIETARY EQUIPMENT SUPPLIER.
8. TWC APPOINTED BUT NOT VERY EXPERIENCED IN FALSEWORK PM HAD ACTIVE INTEREST IN FALSEWORK.
9. NO INVOLVEMENT FROM CLIENTS REPRESENTATIVE ON SITE WITH RESPECT TO FALSEWORK.
10. MAX M LEG LOAD = 33·86 KN.
    MAX M SWL. = 40 KN.



SECTION A-A (Scale 1:50)



SECTION B-B (Scale 1:50)



PLAN (Scale 1:50)

GENERAL NOTES

1 SAMPLE SIZE – 42 No PROPRIETARY STANDARDS

2 DESCRIPTION OF SYSTEM – WAFFLE SLAB ON PRIMARY AND SECONDARY DECKING BEAMS. THE BEAMS ARE SUPPORTED BY A PROPRIETARY BIRDCAGE

3 DESCRIPTION OF SITE WORKS – MULTI STOREY OFFICE BLOCK.

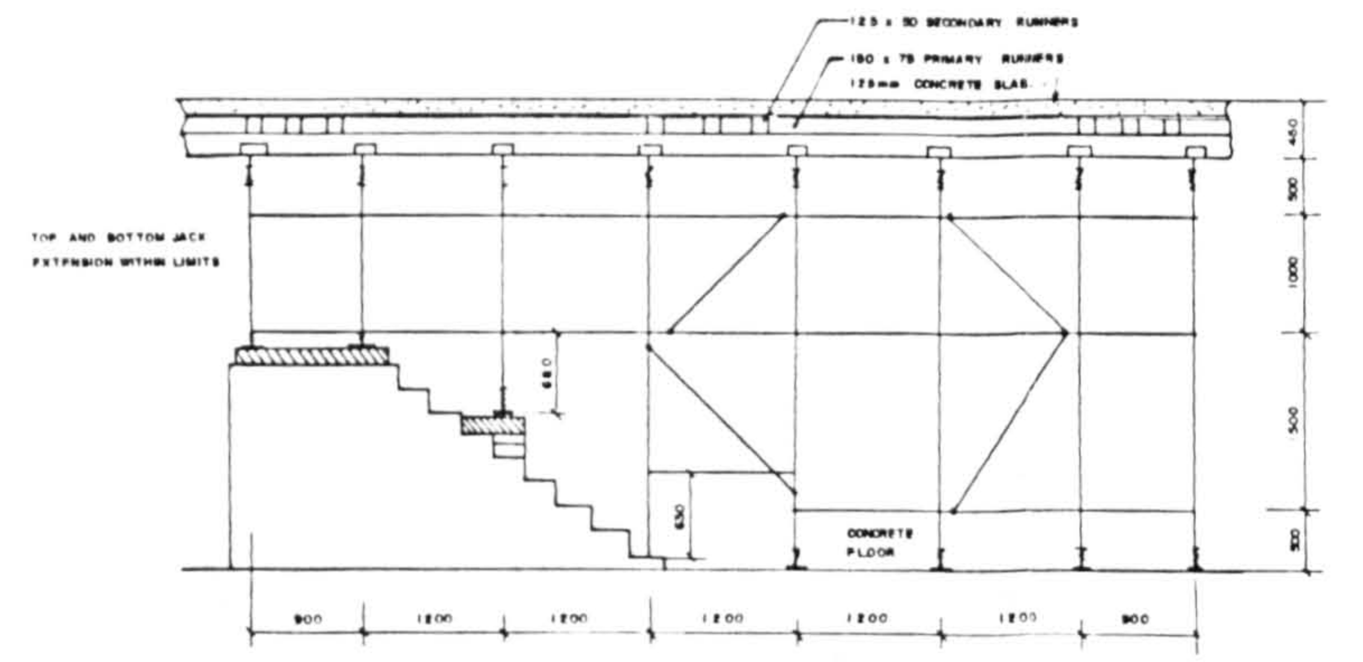
4 SIZE AND METHOD OF POUR – APPROXIMATELY 40cu.m POUR BY CRANE AND SKIP

5 DRAWING DETAILS SITE ENGINEER MADE THE DRAWINGS AVAILABLE TO RESEARCHERS ON SITE ONLY.

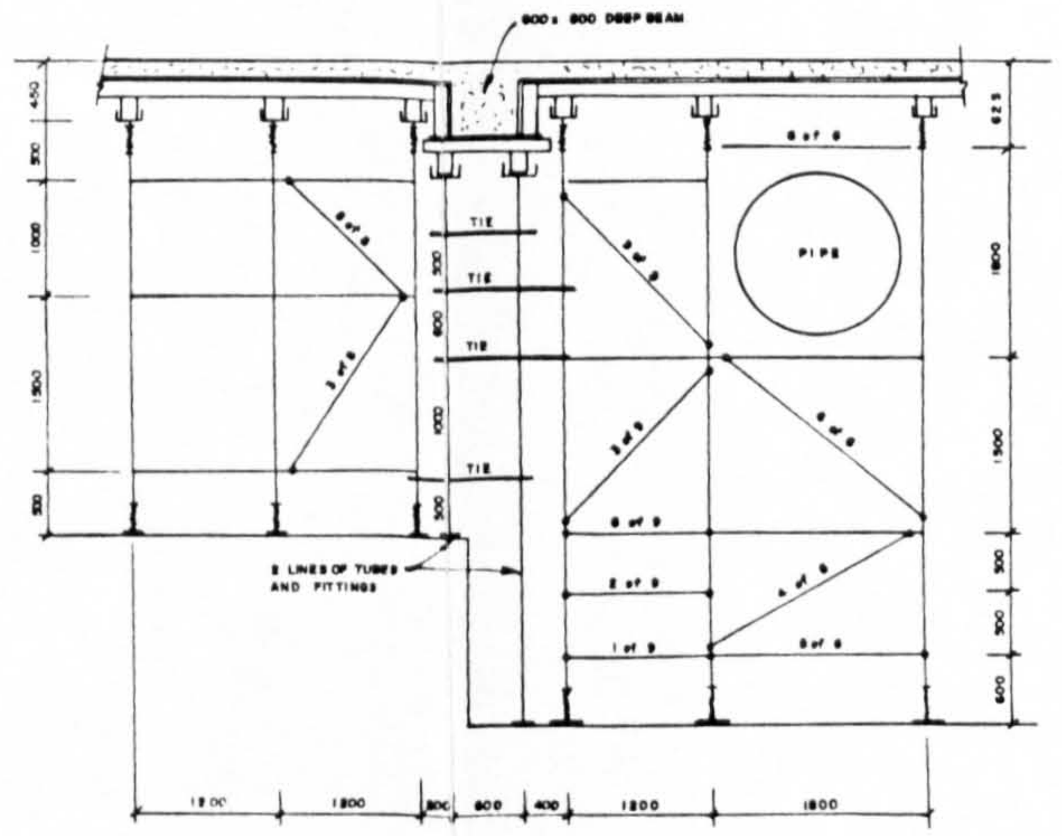
6 SUBCONTRACTOR HAS BEEN USING THIS PARTICULAR EQUIPMENT FOR LAST 10 YEARS AND PREFERED THIS TO OTHER SYSTEMS. THIS LABOUR FORCE WAS USED TO THE SYSTEM.

7 COMPANY POLICY AND TWC RELATED DUTIES ARE KNOWN TO THE SITE EMPLOYEES BUT THESE ARE NOT COMPLIED TO THE FULLEST EXTENT ON THE SITE.

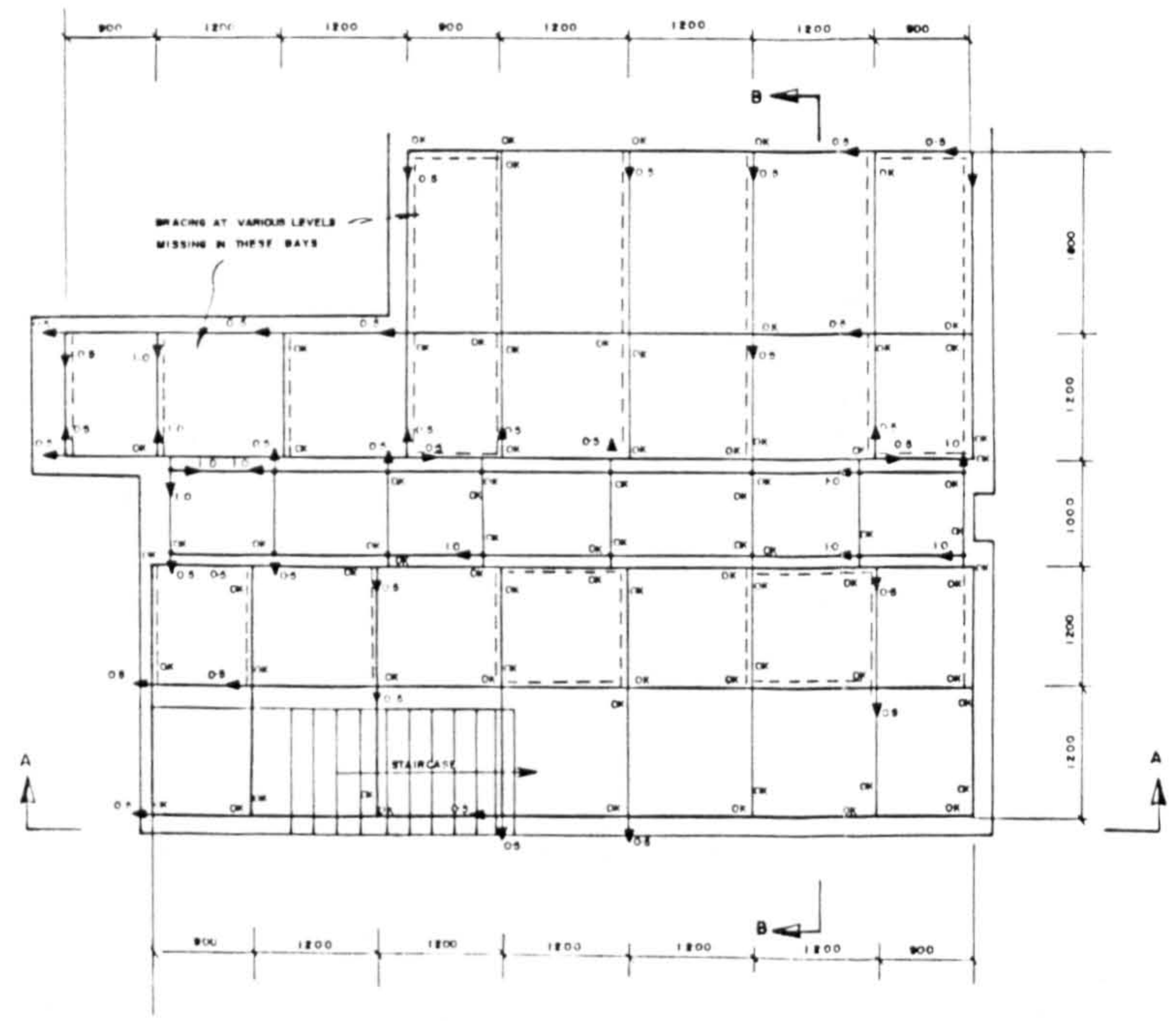
8. MAXM. LEG LOAD = 38·88 KN.
MAXM SWL. = 40 KN.



SECTION A–A (Scale 1:50)



SECTION B–B (Scale 1:50)



PLAN (Scale 1:50)

GENERAL NOTES

1. SAMPLE SIZE 48 No PROPRIETARY STANDARDS AND 16 No TUBES UPRIGHTS.
2. DESCRIPTION OF SYSTEM. 125 mm. SLAB AND 600 x 800 DEEP BEAM SUPPORTED ON PRIMARY AND SECONDARY TIMBERS. FORMWORK IS SUPPORTED ON A COMBINATION OF PROPRIETARY STANDARDS AND TUBES AND FITTINGS.
3. DESCRIPTION OF SITE WORKS BUILDING FOR WATER TREATMENT WORKS
4. DRAWINGS PREPARED BY TWC ON SITE.
5. ALTHOUGH TWC ON SITE NUMBER OF BRACES WERE MISSING AND IN SOME AREAS BRACES WERE NOT INSTALLED IN THE BAYS SHOWED IN THE SITE SKETCHES
6. MAIN CONTRACTOR SUPPLYING HIS OWN EQUIPMENT AND USING HIS OWN LABOUR FORCE TO ERECT THE EQUIPMENT
7. DETAILED COMPANY POLICY / PROCEDURES DOCUMENTATIONS AVAILABLE ON SITE
8. MAX M. LEG LOAD 10 · 15 KN; MAX M. SWL. 40 KN. } 25 A

   MAX M. LEG LOAD 6 · 19 KN; MAX M. SWL. 40 KN } 25 B

APPENDIX G

Matrix and definition of variables

	CASE STUDY NO.	20	22	36	28	4	8	10	41	48	40	29	34	38	15	26	6	17	37	45
	VARIABLES																			
1	Size of Contractor	L	VL	VL	M	M	VL	L	VL	VL	L	M	VL	L	VL	M	M	VL	M	VL
2	Building/Civil Engineering	C	C	B	B	B	B	B	C	C	B	C	C	B	B	C	B	B	C	C
3	Location	L	M	NE	EA	M	M	WW	L	N	WW	EA	NE	M	N	EA	N	L	NE	WW
4	Size value of contract	M	M	L	S	M	L	M	VL	VL	L	L	S	M	M	M	M	M	M	L
5	Duration	M	M	M	S	M	L	M	M	M	M	M	S	M	M	M	L	M	M	L
6	Technical complexity	H	H	M	M	M	M	L	H	H	M	L	M	M	M	H	M	L	H	H
7	Changes to method statement	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	Y	Y
8	Potential for design/training	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y
9	Policy (evidence of)	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	Y
10	Falsework co-ordinator	H	H	N	N	N	L	N	H	H	N	H	N	H	N	N	N	N	N	H
11	Permit to load	Y	Y	N	N	N	N	N	Y	Y	N	N	N	Y	N	N	N	N	N	Y
12	Formal checking	H	H	L	N	N	N	N	H	H	N	L	L	H	N	L	N	N	N	H
13	Routine checking	H	H	L	L	H	H	L	H	H	L	L	H	H	L	H	H	L	H	H
14	No. of engineers on site	M	L	L	L	L	H	L	M	H	L	M	L	L	L	M	L	M	M	H
15	Employment status of erectors	LO	LO	D	D	SF	SF	SF	LO	LO	SF	LO	LO	SF	D	LO	SF	LO	D	LO
16	Sub suncontractor	O	O			O	O	Y	O	O	O	O	O	O		O	O	O		O
17	Selection of subcontractor	R	C			R	R	CR	C	C	RC	RC	CR	CR		C	CR	C		C
18	Type of erectors	S	S	S	J	J	S/J	S	S	S	L	J	J	S	J	L	J	S	J	S
19	Competence of erectors	H	M	H	H	H	H	H	H	H	M	M	L	H	M	M	H	H	L	M
20	Fragmentation	4	2	2	2	3	2	5	3	3	3	4	2	3	2	3	3	4	2	2
21	Task group specialisation	4	2	2	2	2	1	3	3	3	3	3	2	3	1	3	2	4	2	3
22	Supplier of equipment	H	O	O	H	H	H	H	H	O	H	H	O	H	H	H	H	O	O	O
23	Proprietary brand equipment	3	3	3/4	4	3	2	2	3	3	1	2/3	3	3	2	2	3	3	6	3
24	Type of predominant fwk system	1	1	11	3	2	1	2	1	1	2	1	1	2	1	1	1	1	1	1
25	Additional props/tubes & fittings	P		T				P												
26	Availability of drawing	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
27	% penalty score	0	0	0	0	1	2	2	3	4	4	5	5	5	6	6	7	9	9	9

TABLE 1 'GOOD' QUALITY SITES ; VARIABLES

CASE STUDY NO.		52	3	53	42	14	25	46	11	31	5	32	30	12	49	33	47	13	51	1
VARIABLES																				
1	Size of Contractor	VL	M	L	S	L	VL	M	VL	L	VL	L	L	L	L	S	S	L	M	M
2	Building/Civil Engineering	B	B	C	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
3	Location	M	M	M	N	M	EA	WW	WW	NE	M	NE	M	M	WW	NE	M	M	M	WW
4	Size value of contract	L	S	S	S	L	L	L	M	M	L	VL	M	M	M	S	S	M	S	M
5	Duration	M	M	S	S	M	M	L	M	S	L	M	M	M	L	M	S	M	S	M
6	Technical complexity	M	M	L	M	M	L	M	L	M	M	M	M	L	M	L	L	L	L	M
7	Changes to method statement	N	N	N	N	N	N	N	N	Y	N	Y	Y	N	N	Y	N	Y	N	Y
8	Potential for design/training	Y	N	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	Y
9	Policy (evidence of)	Y	N	Y	N	N	Y	N	Y	Y	Y	N	N	Y	N	N	N	Y	N	Y
10	Falsework co-ordinator	H	N	N	N	N	H	H	H	H	L	N	N	N	N	N	N	N	N	H
11	Permit to load	Y	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	Y
12	Formal checking	H	N	N	N	N	L	H	H	L	L	N	N	L	H	N	N	N	N	H
13	Routine checking	L	L	L	L	L	H	L	L	H	H	N	H	H'	L	L	L	L	H	L
14	No. of engineers on site	M	L	L	N	L	M	H	M	L	L	H	M	L	M	L	N	L	L	L
15	Employment status of erectors	SF	LO	SF	SF	SF	LO	SF	SF	D	LO	SF	LO	LO	SF	D	LO	SF	LO	SF
16	Sub suncontractor	N	N	N	N	N	N	N	Y		N	N	N	N	N		Y	N	N	N
17	Selection of subcontractor	C	CR	C	C	C	CR	CR	C		CR	CR	CR	C	CR		C	C	C	CR
18	Type of erectors	S	J	J	J	S	S	L	S	S	J	S	S	J	J	J	S	J	L	J
19	Competence of erectors	H	H	M	M	H	M	M	H	H	M	M	M	L	M	L	M	M	L	M
20	Fragmentation	3	3	3	3	3	2	3	4	2	3	2	3	3	3	2	4	3	3	3
21	Task group specialisation	3	2	2	2	2	3	3	3	3	2	2	3	2	2	2	3	2	3	2
22	Supplier of equipment	H	H	H	H	H	0	H	H	0	0	H	0	H	H	H	H	H	H	H
23	Proprietary brand equipment	3	1	1	1	3	3	1	3	2	3	5	3	1	1	3	3	2/3	3	1
24	Type of predominant fwk system	1	2	1	2	2	1	2	2	1	2	4	2	1	1	2	1	2	2	2
25	Additional props/tubes & fittings					P	T							P			P	P		P
26	Availability of drawing	Y	Y	N	Y	Y	N	Y	Y	Y	Y	N	Y	Y	Y	N	Y	N	Y	Y
27	% penalty score	10	11	12	16	17	18	19	20	23	24	24	25	26	26	26	27	27	27	28

TABLE 1 'FAIR' QUALITY SITES : VARIABLES

	CASE STUDY NO.	39	19	54	27	50	43	24	9	44	18	2	23	21	7	35	16
	VARIABLES																
1	Size of Contractor	L	S	L	VL	S	L	S	L	S	VL	L	S	L	L	S	L
2	Building/Civil Engineering	C	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
3	Location	M	WW	L	EA	M	WW	EA	WW	M	L	M	EA	L	M	NE	N
4	Size value of contract	M	S	L	M	S	M	S	M	S	M	M	M	VL	M	S	VL
5	Duration	M	M	M	M	S	M	M	M	M	M	M	S	M	M	M	L
6	Technical complexity	L	M	M	M	H	M	L	L	M	L	M	M	H	L	L	L
7	Changes to method statement	N	Y	N	N	Y	N	N	N	N	N	N	N	Y	N	N	Y
8	Potential for design/training	Y	N	Y	Y	N	Y	N	Y	N	Y	Y	N	Y	Y	N	Y
9	Policy (evidence of)	Y	N	N	Y	N	N	N	Y	N	Y	N	N	Y	N	N	Y
10	Falsework co-ordinator	H	N	N	N	N	N	N	L	N	L	N	N	L	N	N	L
11	Permit to load	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
12	Formal checking	H	N	N	N	N	N	N	L	N	L	N	N	L	N	N	L
13	Routine checking	H	N	L	L	L	L	N	L	L	N	L	N	L	N	N	L
14	No. of engineers on site	M	N	L	H	N	L	N	L	N	L	L	N	L	L	H	H
15	Employment status of erectors	LO	LO	SF	SF	D	SF	D	SF	SF	SF	SF	SF	SF	SF	D	LO
16	Sub subcontractor	N	N	N	N		N		N	N	N	Y	N	N	N		N
17	Selection of subcontractor	C	C	RC	C		C	CR	CR	C	CR	C	R	CR	CR		C
18	Type of erectors	J	J	J	J	J	J	S	SJ	J	J	J	J	J	J	J	SJ
19	Competence of erectors	M	L	H	L	M	L	M	M	M	L	M	M	M	L	L	M
20	Fragmentation	3	2	2	2	2	3	2	3	3	2	4	3	2	2	1	4
21	Task group specialisation	2	2	1	1	2	2	2	2	2	2	3	2	2	1	1	3
22	Supplier of equipment	H	H	H	H	H	H	H	H	H	H	H	H	H	H	O	H
23	Proprietary brand equipment	3	1	4	4	4	2	1	1	4	4	1	4	4	4	1	3
24	Type of predominant fwk system	1	3	3	3	3	2	1	1	3	3	1	3	3	3	3	1
25	Additional props/tubes & fittings	P															
26	Availability of drawing	Y	Y	N	N	Y	Y	Y	Y	Y	N	Y	N	N	N	N	N
27	Penalty score	32	32	32	33	33	38	39	40	40	41	42	43	45	55	67	74

TABLE 1 'INADEQUATE' QUALITY SITES : VARIABLES

Definition of Variables

1.Size of contractor

Small (S), Medium (M), Large (L), Very large (VL).

The four bands used were:

Small up to £5m turnover p.a.
Medium from £10m - £50m p.a.
Large from £85 - £400m p.a.
Very large above £800m p.a.

This categorisation was used since it conveniently clustered firms within the bands selected and more over approximately corresponds with what is commonly understood by the terms large, small etc. No firms in the sample fell outside these bands. Turnover figures relate to firms which are legally identifiable in their own right or which form part of a larger parent company of which the firm in the sample belongs.

2.Building (B) Civil engineering (C)

Classification on the strength of the type of contract used, J.C.T. or variant, I.C.E. or variant, G.C. works (not encountered) distinction would be evident from the type of structure, type of control personnel.

3.Location of the study site

Midlands (M), North East (NE), West and Wales (WW), East Anglia (EA), London (L), North and North West (N).

4.Size of contract

Small (S), Medium (M), Large (L), Very Large (VL).

Total value of contract was taken as an index of size:

Small less than £1m.

Medium £1.1m -£5m.

Large £5.1 - £10m.

Very large above £10.1m.

5.Duration

Short (S), Medium (M), Long (L).

A measure of contract duration:

Short 0-52 weeks.

Medium 53-156 weeks.

Long above 157 weeks.

6.Technical complexity

High (H), Medium (M), Low (L).

A measure of the erection difficulties likely to be encountered by virtue of the nature of the requirement of the falsework which reflects site conditions and the characteristics of the permanent works. Thus, poor and irregular ground conditions, heavy loadings, multi-storey, exposure to wind, high lifts, non-rectangularity in plan and elevation, irregularities and complicating features in the permanent works caused by the presence of service ducts, stair wells, beams etc.

7.Changes to method statement

Yes (Y), No (N).

Indicates the extent of changes that were made during the course of erection to the design and/or planned method of construction. The research revealed that changes of some kind (sometimes very minor) always occurred. The measure distinguishes those falseworks where practitioners themselves considered that significant changes had been necessary.

8.Potential for Design/Training

Yes (Y), No (N).

The presence of a temporary design and/or planning department was taken as a loose index of a firm's capacity to provide design experience to site personnel and to train them in supervision.

9.Evidence of a falsework policy

Yes (Y), No (N).

Evidence found on the site of the main contractor having a formal, documented falsework policy.

10.Falsework Coordinator

High (H), Low (L), None (N).

'High' means the appointment of a F.W.C. carrying out the site checking duties envisaged in the Code of Practice. He has acquired the necessary training and experience and effectively carries out his duties on site. He has good knowledge of the Bragg Report and Code of Practice. He may or may not be an engineer. A high score does not mean that he is performing the full integrating function envisaged by Bragg and the Code of Practice as regards design, erection and dismantling.

'Low' means that the designated F.W.C. has not acquired the appropriate level of experience and is less able to carry out his duties than someone who scores 'high'. He has scanty or no knowledge of either Bragg or the Code.

'None' means that there is no F.W.C. On two sites a F.W.C. came into existence at the question whether there was one. Subsequent interviews revealed that effectively no appointment had been made.

11.<u>Permit to Load</u>

Two categories are considered - Yes (Y), No (N).

'Yes' means there is evidence of a Permit to Load system on site and it is effectively used.

'No' means there is no Permit to Load system or that there are the necessary forms available on site, but are not used.

12.<u>Formal checking</u>

High (H), Low (L), None (N).

'High' means that the site operates with a well defined company policy and procedures regarding falsework; they are well documented and evidence was available on site. The forms for Permit to Load and Permit to Dismantle are available and used, and necessary and adequate records are kept of falsework activity. Usually a F.W.C. is associated with this level of checking but to qualify for this category there need not be one.

'Low' means that although the company may have a policy and required procedures, evidence of them on site was scanty.

'None' means that there was no evidence on site of any company policy or procedures, no permit to load or formal records kept of falsework activity.

13.<u>Routine checking</u>

High (H), Low (L), None (N).

'High' means that there is some kind of checking procedure used on site whereby individual members of staff tacitly assume responsibility for checking falsework either during erection and/or just before concreting. There were no explicit procedures followed by the individuals who did such checking. Typically individuals undertaking such checks have adequate knowledge and training but consider a highly documented system as unnecessary. Everything is done verbally. It is important to note that routine checking can co-exist with formal checking. This would mean that some members of staff administer the formal system whilst, in addition, others perform routine checks.

'Low' means that the degree of checking was somewhat more erratic and less thorough than high routine checking. Typically the reasons were lack of experience and knowledge or a heavy workload elsewhere. In this category were placed cases where a difference was found between what staff said their responsibilities were and what they were seen to do.

'None' means that during erection and immediately prior to concreting no single person took responsibility for checking.

14.<u>Number of engineers on site</u>

High (H), Medium (M), Low (L), None (N).

High means there were more than 6 engineers on site.

Medium means 4-6.

Low means 1-3.

None means no engineers.

Engineer was defined as a member of staff who was recognised as an engineer whatever his educational background or level of experience. The measure thus includes personnel with building qualifications but does not include trainee engineers.

15.Employment status of erectors

Direct (D), Labour only (LO), Supply and Fix (SF).

Indicates the employment status of the erectors with respect to the main contractor. The extent of sub-sub-contracting is indicated below (16). Whether or not erectors were self-employed but working for a sub-contractor is not recorded since the data are considered unreliable.

16.Sub-sub-contracting

Yes (Y), No (N).

In certain instances a labour only sub-contractor was employed by a sub-contractor (typically supply and fix) to erect the falsework element.

17.Selection of sub-contractors

Cost (C), Reputation (R), Cost and Reputation (CR), Reputation and cost (RC).

An estimate was made on the basis of interview responses to the question of why a particular sub-contractor was appointed.

Cost: where cost was given as the dominant reason.

Reputation: where the appointment was made on the basis of direct experience or knowledge of the reputation of a sub-contractor and not bothering to get alternative quotations.

Cost and reputation: where cost was the main reason but choice being influenced by reputation etc., to the extent of not taking the lowest price.

Reputation and cost: where reputation was given as the main reason but with cost having been taken into account.

18. Type of erectors

Labourers (L), Joiners (J), Scaffolders (S), Scaffolders and joiners (SJ).

Occupational background of the operatives who erected the falsework only. The categories assume that joiners and scaffolders may be assisted by labourers. The labourers category may be composed of anyone from a conventionally understood labourer, steel erector, plasterer or 'milkman'.

19. Competence of erectors

High (H), Medium (M), Low (L).

An evaluation of the competence of the erectors, independently of the falsework they actually erected in the study sample, based on interviews with them concerning experience, formal certification (where this applied), formal training, knowledge of different proprietary systems, ability of at least some members of the operative work group to read and interpret drawings. Assessment of competence was made by experienced and qualified engineers in the research team unaware of the quality scores for the sample falseworks.

20. <u>Fragmentation</u>

Scores given are a direct measure of the number of independent economic units (firms) who participated in the process by which the falsework and formwork were designed and erected.

21. <u>Task group specialisation</u>

Scores given are a direct measure of the number of separate workgroups amongst which the total falsework and formwork process is divided. The maximum number of separate task groups generally encountered was three where one designed the falsework and formwork, a second erected the falsework and a third erected the formwork. A logical fourth where the falsework and formwork are designed by different workgroups was rarely found in the sample. What is important about formwork design is that it is a task (just as supply is) but it is performed differentially by the main contractor, sub-contractor, supplier and is very difficult to distinguish as a single task by a separate group. It would only be entered in our score here if the formwork design were carried out by a separate economically independent unit for example, a formwork consultant.

22. <u>Supplier of equipment</u>

Hired (H), Owned (O).

Relates to whether the main contractor owned or hired the equipment, for example, on a supply and fix sub-contract where the sub-contractor may own or hire the entry here is 'hire'.

23. <u>Proprietary brand of equipment</u>

Three main proprietary systems equipment encountered in the study are numbered (1), (2), (3) and extendable props (4).

24.Type of falsework system

Four main types of falsework system were used in the studies:

1. Proprietary system/traditional decking (timber/aluminium).

2. Proprietary system/proprietary decking.

3. Adjustable steel props/traditional decking (timber/aluminium).

4. Tube and fittings/traditional decking (timber/aluminium).

25.Additional props/tube and fittings

Props (P), Tube and fittings (T)

On a number of ('B') sites an additional falsework system was used, typically in the 'infill' slab areas.

26.Availability of drawing

Yes (Y), No (N).

This records whether adequate drawings or sketches were available on site which enabled the erectors to construct, and the researchers to check, the falsework structure.

APPENDIX H

Questionnaire checklist

Questionnaire Checklist

MAIN CONTRACTOR

1). STRUCTURE OF THE FIRM.

A. Project Manager/Site Agent.

a) Obtain an organisational chart from the Project Manager of his staff on site.

b) Establish relationship between the Head Office or Regional Office and site and assess the degree of autonomy that the site has in making certain decisions.

c) Presence of Company Safety Officer and his involvement in falsework activities.

d) Relationship with TWD Office - regarding checking of falsework drawings from whatever source to their participating in site activities.

e) Evidence of company policy/procedures on falsework activities, eg. training programme details on falsework, monitoring of the policy/procedures by Head Office (or is it just cosmetic?). Evidence of company policy documents to be obtained if possible, Planning and Buying Department and their function at tender stages.

2). STRUCTURE OF STAFF ON SITE.

A. Project Manager/Site Agent.

a) Name, age, qualification and experience to date.

b) Current position and number of years with the company.

c) Duties and responsibilities in the current position (Is this the only site he is responsible for?).

d) Details regarding any falsework training acquired to date - knowledge of Bragg Committee Report, BS 5975 and further details on any design experience.

e) Names and types of other companies o site and their contractual relationships with the main contractor, eg. type of main contracts, sub-contracts and, most importantly, the reason for having such contractual configurations on the site.

f) What is the company staffing policy, ie. how each individual came to be appointed, the extent to which the formal procedures are routinised and, in particular, the reason why falsework activities related appointments are made, if any.

g) When does the PM first become involved with this contract - brief details required from his first involvement to the commencement of works on site.

h) If he is not the TWC to whom he has delegated this responsibility and to what extent. Brief details from him required for the reason of appointing a particular person on site.

B. Senior Engineer.

(TWC or in charge of certain falsework activities).

First four steps a) to d) as in Project Manager/Site Agent.

e) Details of falsework activities under his direct supervision.

f) Types of decisions allowed to make and actually made - give examples if possible.

g) Brief details on assistance from others such as his Project Manager, TWD Office, General Foreman, supplier etc. in order to carry out his falsework duties.

h) Extent to which he can control sub-contract labour force. Determine the degree of "orders" given by him to the sub-contract labour force under the contractual terms. Identify any problem in this area.

i) Percentage of time spent on falsework related activities.

C. Works Manager/General Foreman.

First four steps a) to d) as in Project Manager/Site Agent.

e) The extent to which he is involved with falsework activities.

f) The measure of control he has on sub-contract labour force.

g) The extent of occupational expertise used.

h) Percentage of time spent on falsework related activities.

D. Company Safety Officer.

The first four steps a) to d) as in Project Manager/Site Agent.

e) The extent to which he is involved with falsework activities.

3) ACQUISITION OF FALSEWORK EQUIPMENT/DESIGN.

A. Project Manager/Site Agent.

a) What role did he play in choosing the falsework system, decision made for choosing a particular system, either at design brief stage or as Project Manager on site.

b) Nature of contract for the erection of falsework. Why supply and fix, labour only or use of own labour force for erection and dismantling. Economic constraints and reasons required here. (Sub-contracting cheaper than in-house hire of material? etc.).

c) Number of companies dealt with at tender stage with respect to falsework contract. Brief details of activities required here.

d) Previous experience with the present supplier of equipment/drawings.

e) Reason for choosing particular equipment eg. cheapest or best suited for particular construction.

f) Comments on quality of design and drawings. Brief details of parties involved in checking and comments on liabilities/responsibilities of these parties and the nature of checks carried out by them.

g) Quality of materials delivered on site. Brief comments only.

B. Senior Engineer.

a) Establish knowledge of falsework equipment - any preference for particular equipment and why.

b) Comments on quality of design and drawings.

c) Comments on quality of materials delivered on site.

C. Works Manager/General Foreman.

a) to c) same as in Senior Engineer.

d) Comments on delivery of materials on site eg. any shortfall, does the material arrive on time etc.

4). RECRUITMENT OF OPERATIVE WORKFORCE.

A. Project Manager.

a) Methods of recruitment of workforce and who in organisation is responsible and what criteria he uses.

b) Knowledge on qualification and experience of labour force. Method of obtaining such information and evidence of, say, certificates of qualification from recognised organisation.

c) Expertise of falsework erectors on particular equipment. Did he know of their capability prior to this job?

d) Case history details on each individual involved with the erection of falsework. Are there any records kept or available?

B. Senior Engineer.

All points mentioned from a) to d) with the Project Manager are to be dealt with here hoping that additional information will either verify what the PM had said or give a different opinion.

C. Works Manager/General Foreman.

Same as a) to d) in Project Manager.

e) His expertise in being able to read drawings.

5. PRODUCTION CONTROL (Or Quality Control).

A. Project Manager.

a) Procedures used for checking and supervision of falsework eg. type of checks carried out, by whom, is there any Permit to Load/Dismantling Systems, and what criteria is used for saying "falsework is ready for pour". Establish site procedures on falsework and PM participation in ensuring that these procedures are carried out.

b) TWD involvement in production control eg. direct (by site visits) or indirect (by revising drawings and through correspondence).

c) Comments on quality of workmanship to date and the reasons for achieving a certain quality of workmanship. Is a certain quality related to a certain type of erector?

d) How much time the Project Manager spends on falsework activities in general and, in particular, what sort of checks he personally carries out.

B. Senior Engineer.

All points mention from a) to d) with the Project Manager are to be dealt with here, hoping that additional information will either verify what the PM has said or give a different opinion.

e) Comments on the rate of production in relation to programme. Assess here the type of problem that arises on site if the rate of production cannot be maintained.

f) Quality of falsework and type of erectors. Does a certain type/category of erector mean a certain quality of falsework.?

C. Works Manager/General Foreman.

All points mentioned from a) to d) with the Project Manager are to be dealt with here, hoping that additional information will either verify what the PM has said, or give a different opinion.

e) Comments on trade practices of the falsework erectors. Obtain information if possible on his opinion of work carried out by direct labour force and the sub-contract labour force.

f) Degree of his control over sub-contract labour force. By questioning and observing the falsework activities on the site the researcher should establish whether the erectors are making decisions on their own or whether they rely upon the General Foreman to make decisions.

SUB-CONTRACTOR

1. STRUCTURE OF THE FIRM.

A. Managing Director (or equivalent).

a) Brief details of the company. Details such as formation of the company, number of people employed, type of jobs undertaken, annual turnover, size of the largest and the smallest jobs, types of companies worked under, geographical spread of company activities, location and details of staff at Head Office and any future prospects. Organisation structure may be produced here.

b) Procedures for obtaining contracts.

c) Brief details on current workload.

d) Various contractual relationships. Is he aware of the legal/contractual responsibilities he undertakes when formulating contractual relationships with the main contractor? How is he covered for unforeseen events?

e) Any company procedures on site safety training.

2. STRUCTURE OF THE STAFF ON SITE.

A. Managing Director (or equivalent).

a) Name, age, qualification, trade experience to date.

b) Duties and responsibilities in the current position.

c) Details of any falsework training and attainment of any qualifications.

d) What is the company staffing policy for Head Office staff and the site staff for all types of work carried out by his firm.

e) Percentage of staff fully employed or self-employed.

f) A typical site staff organisation structure - his opinion to what is necessary to carry out all functions, say, on a building site.

g) His opinion on quality of staff required to supervise falsework. His opinion on what sort of occupational expertise is best suited for this position.

B. General Foreman.

Points a) to c) same as Managing Director.

d) Fully employed or self-employed.

e) Years of employment with present company.

3. ACQUISITION OF FALSEWORK EQUIPMENT/DESIGN.

A. Managing Director (or equivalent).

a) Role played in choosing the system on site eg. system chosen by himself or MC.

b) Reason for having a particular type of contract on the site eg. supply and fix or labour only.

c) Any falsework design experience. Anybody in company with design experience.

d) Comments on quality of equipment/design.

e) Reasons for choosing the particular supplier on this site - general policy and reasons for choosing a particular supplier can be discussed here, eg. past experience with the supplier, cheapest etc.

f) Any stock of own equipment. Brief details on stock of equipment, eg. if mostly hired, reason for doing so.

B. General Foreman.

a) Comments on quality of equipment/design.

b) Any problem of erecting the equipment.

c) Any comments on setting out, ground conditions, access, delivery of materials in time, facilities available on site, etc. Comments generally on services provided by the main contractor.

d) Design drawings. Assess the capability of reading drawings. Where was the knowledge acquired? Assess the quality of comments made on drawings. Does he know the capability of the erectors to read the drawings?

e) Establish the extent of the occupational expertise exercised. Ascertain the type of decisions he is allowed to make and what sort of decisions he actually makes on site.

4. <u>RECRUITMENT OF OPERATIVE WORKFORCE.</u>

A. Managing Director.

a) Methods of recruitment of workforce and who in organisation is responsible and what criteria he uses? How does he employ the workforce, considering that continuity of work is difficult to arrange? Where do his men come from and how does he employ them?

b) Knowledge on qualification and experience of the existing labour force. Method of obtaining such information and evidence of, say, certificates of qualification from recognised organisations. What is the standard requirement of employing somebody for erecting falsework?

c) Formulate the typology of workforce from the Managing Director's point of view. eg. Type 1, Type 2, Type 3.

d) Case history details on each individual involved with the erection of falsework. Are there any records kept or available?

B. General Foreman.

a) Does he have any say in employing the workforce?

b) His comments on the ability of his workforce.

c) His comments on qualification/experience of his workforce.

d) His comments on the capability of his erectors dealing with certain types of falsework equipment.

e) Comments on pay and conditions and availability of work.

f) Formulate the typology of workforce from the General Foreman's point of view eg. Types 1, 2 and 3.

C. Erectors.

a) Establish the complete study of all activities carried out by erectors from the falsework material coming on the site until the material is delivered off the site.

b) Establish individual case history with respect to experience to date.

c) Establish individual qualifications. Ask for proof of qualifications.

d) Individual likes and dislikes of certain types of equipment. Obtain comments on the system they are working and their normal preference for a particular type of equipment.

e) Establish trade practices and formulate the typology eg. Type 1, Type 2, Type 3 of each erector interviewed.

f) Advantages and disadvantages of being fully employed or self-employed.

g) Establish where they have learned the skill of reading drawings. Can they read drawings competently? Their comments on the drawings.

h) Establish their knowledge of codes and standards.

i) Establish the extent of occupational expertise exercised. Ascertain the type of decision they make.

General Note:-

1) A SUB-CONTRACTOR CAN BE OF THREE TYPES:-

a) Main sub-contractor for the whole concrete frame where the falsework is included as a part of the total package. Here he normally supplies the falsework equipment (either his own or hired) and provides the labour (his own or employs labour only sub-contractor) to erect it.

b) Supply and fix sub-contractor - He contracts with the main contractor or the main sub-contractor to supply the equipment and labour force to erect it.

c) Labour only sub-contractor - He contracts with the main contractor or the main sub-contractor, or even the supply and fix sub-contractor, and provides labour only to erect the falsework.

2) The falsework drawings, if available, are supplied by the main contractor's TW Design Office or sub-contractor's Design Office or supplier's Design Office (under hire or sale terms).

3) Although the questionnaire comes under one heading of sub-contractor the researchers should use it comprehensively and choose the relevant topics in order to achieve all possible information in order to fit the three categories of sub-contractors.

CLIENTS' REPRESENTATIVES

Four types:

Resident Engineer

Architect

Inspector (RE)

Clerk of Works (Architect)

When dealing with clients' representatives the researchers are interested in the nature and the degree of their involvement and should ascertain whether they have any effect on the occupational and economic orders that prevail on the site. They are usually present to ensure that the legal order in the form of contract conditions, HSE requirements, duty of care etc. are maintained. Whether or not they contribute directly or indirectly to the quality of falsework erection depends on the extent of their direct involvement in falsework activities on site. The following points can be useful to achieve certain knowledge in this direction:-

From main or sub-contractor ascertain the degree of involvement of the clients' representatives. If any of the above mentioned show any practical and contributory interest then interviews with them should reveal the following information:-

1) Reason for their involvement. Is it a part of contract conditions between the main contractor and the clients' representatives?

2) Type of structure ie. complicated structure requires more involvement, bridge works compared to multi-storey building site.

3) Nature and extent of their involvement. Is it clear to all parties the nature and extent of their involvement? Types of decisions they make.

4) Effect on quality of drawings/erection. Does any special checking carried out by them result in better quality of falsework, or create friction amongst the contracting parties?

5) General knowledge of falsework eg. on types of equipment, suppliers, Bragg Committee Report, BS 5975 requirements, TWC responsibilities etc.

6) Lack of involvement. Reasons required, ie. all responsibilities left to the MC under the main terms of the contract, no expertise available similar to checking of reinforcement, concreting and shuttering etc.

7) General comments on quality of design/workmanship - if any. Note any comments on access scaffolding in particular.

APPENDIX I

Sample of temporary works policy, permit to load. (Case 20)

TEMPORARY WORKS

PROCEDURES AND RESPONSIBILITIES

This Division is introducing, until further notice, the following procedures for the design, erection, loading and striking of falsework together with guidance on all temporary works.

In implementing these prodcedures please ensure that the individual responsibilities are continuous with an alternative person taking responsibility during periods of absence from work for holidays or any other cause.

Where the work is a sub-contract package of design and erection, either by a nominated or direct sub-contractor, the meeting (Procedures 2) will lay down safety procedures as applicable to our responsibilities under the Health and Safety at Work etc., Act 1974.

SUMMARY OF ESSENTIAL FEATURES

ALLOCATION OF RESPONSIBILITIES

1. Soon after Contract Award.

a) Identify design requirements	)
b) At a formal meeting appoint:	)
i) Temporary works co-ordinator (TWC)	)
ii) Designer	) Use Form T.W.1.
iii) Temporary works supervisor (TW Sup)	)

DUTIES

2. Temporary works co-ordinator (T.W.C.) - to ensure that the design is carried out competently and is suitable, to ensure that the work on site is in accordance with the design, to ensure that an independent check is made on the design and the completed works and to issue a permit to load within 24 hours before loading - use form T.W.2.

3. Designer - to produce a safe, suitable and economic design taking account of existing conditions and restraints and materials available, and present the design in a manner which is easily understood on site.

4. Temporary works supervisor (T.W.Sup) to ensure that the temporary works are constructed in accordance with the drawings and to inform the Site Manager and T.W.C. of any changes or difficulties.

TEMPORARY WORKS PROCEDURES AND RESPONSIBILITIES

CONTENTS

PAGE

TEMPORARY WORKS CO-ORDINATOR (T.W.C.)

DUTIES AND RESPONSIBILITIES

1. To ensure that all appropriate liaison is done.

2. To ensure that the design brief is adequate and in accordance with the actual conditions on site.

3. To satisfy himself that each element of the design has been checked by a competent person and that the temporary works have been considered as an integrated whole and approved by a competent person.

4. To ensure that the design has been passed to the Engineer and his comments acted upon.

5. To check, or have checked, that the actual loads encountered on site, particularly the live loads, are no greater than those assumed by the Designer.

6. To ensure that there is a realistic programme for the delivery of the materials to site.

7. To ensure that any significant change of materials has been referred to the Designer and his approval obtained.

8. To satisfy himself that each element of the temporary works and the whole assembly has been inspected and the faults rectified or alternatives to the design approved.

9. To see that where faults have been revealed, they have been corrected to the satisfaction of the checker.

10. To ensure that the loading programme agreed on site is in accordance with the Designer's assumptions and intentions.

11. To undertake or commission an independent check on the temporary works before it is subjected to load.

12. For every temporary works to issue reports/certificates to both the site manager and the temporary works supervisor.

    a) At any time when the work is found to be unsuitable, or improperly supported.

    b) On its satisfactory completion, stating that the temporary works have been properly constructed and is in accordance with the design. This should be not more than 24 hours prior to the loading (use form T.W.2).

    c) Sign approval to strike/dismantle document as appropriate.

TEMPORARY WORKS DESIGNER

DUTIES AND RESPONSIBILITIES

1. Check that the design brief (See Procedure 3) includes all information necessary to produce a suitable, safe and economic design. Where necessary request further information from Site Manager or T.W.C. and/or visit the site to obtain first hand knowledge of conditions.

2. Design and detail the temporary works in accordance with the brief, current B.S. codes of practice, and the recommendations of equipment suppliers. Where the Designer's own knowledge and ability is inadequate he should seek help from appropriate experts, especia[illegible] for foundation arrangements.

3. Present the design information in a form which is easily understood by the people who will erect/install and use the temporary works.

4. Liaise with the Site Manager and T.W.C. over any problems which may arise and also to ensure that the scheme being prepared suits all requirements. It is suggested that a preliminary issue of drawings is made as early as possible to allow the Site Manager and T.W.C. to make comments before the details are finalised.

DUTIES AND RESPONSIBILITIES

1. On receipt of temporary works drawings liaise with Site Manager and T.W.C.

2. Ensure that there is an adequate supply of the correct materials on site.

3. Monitor erection/installation of temporary works strictly in accordance with the design drawings.

4. Inform Site Manager and temporary works co-ordinator immediately of any:-

   a) Change of materials.

   b) Change of procedure.

   c) Change of ground conditions from design brief.

5. Give adequate notice to the Site Manager and temporary works co-ordinator of when the scheme is installed/in use.

6. Monitor loading to ensure that this procedure is carried out strictly in accordance with the agreed procedure.

7. Monitor striking/dismantling of the temporary works.

TEMPORARY WORKS PROCEDURES 1 - IDENTIFY ALL TEMPORARY WORKS at Commencement of Contract

SITE MANAGER AND PLANNING ENGINEER

1. At the start of the Contract prepare a schedule showing.

   a) ALL the tempoary works schemes that are required.

   b) The date when each drawing is to be completed to allow sufficient time for approvals, ordering and deliveries of materials/equipment/plant.

   See form T.W.1. which should be used for this item.

2. Update schedules and re-issue as necessary.

3. Arrange a meeting with the Contracts Director, Contracts Manager and Divisional Design Engineer. This meeting to take place as soon as possible after the start of the Contract and preparation of the Schedule. (See Procedure 2).

TEMPORARY WORKS PROCEDURES 2 - ALLOCATING TEMPORARY WORKS

Formal temporary works meeting between the Contracts Director, Contracts Manager, Site Manager, Planning Engineer and the Divisional Design Engineer.

This meeting will examine the temporary works schedule, relevant client's drawings, scope of the various temporary works, and any information to hand regarding ground conditions relevant to the temporary works and categorise each item as follows:-

a) Design by central Civil Engineering Office who will appoint at T.W.C. (Site Manager will appoint a T.W. Sup.).

b) Design by Divisional Head Office (This meeting appoints a T.W.C. Site Manager appoints a T.W. Sup.)

c) Design by site (This meeting appoints a T.W.C. - Site Manager appoints a T.W. Sup).

d) Design by proprietary equipment supplier. (This meeting appoints A. T.W.C. - Site Manager appoints a T.W. Sup).

Complete Form T.W.1.

TEMPORARY WORKS PROCEDURES 3 - AGREEING THE DESIGN CRITERIA

AFTER APPOINTMENT OF T.W.C.

SITE MEETING

Site Manager) T.W.C.) Designer) T.W. Sup. (Optional)	Formal meeting to discuss the temporary works scheme before design is commenced.

Agree/Distribute design brief which shall include.

1. All relevant client's drawings and specifications.
2. Details of bore holes/trial holes as appropriate and arrange further investigations of ground conditions if applicable.
3. Method and sequence of loading.
4. Permanent design requirements concerning deflections and tolerances.
5. Any special access required over/under/through the temporary works design for access/public/vehicles.
6. Availability of any materials/equipment/plant from Company resources.
7. Restrictions on method of construction.
8. Any other relevant detail to enable the designer to produce drawings to meet the exact site requirements (e.g. access and egress).

TEMPORARY WORKS PROCEDURES 4 - AGREEING THE FINAL DESIGN

After the production of the temporary works drawings a further formal meeting between Site Manger, T.W.C., T.W. Designer and T.W. Sup.

Discuss the scheme fully and ensure that all are in agreement with the Designer's scheme and assumptions.

T.W.C. Ensure that the drawings:-

a) Are checked by a qualified/competent person (if the scheme has been produced on site ensure that the design is checked off site, preferably by Divisional Design Officer).

b) Are seen by the client and his comments acted upon.

SITE MANAGER

Order the equipment/Materials/Plant Ensure that the equipment/materials/plant are on site in good time.

TEMPORARY WORKS PROCEDURES 5

ERECTION, LOADING AND STRIKING

T.W.C.

1. Liaise with Site Manager and T.W. Sup.

2. Ensure that the temporary works are installed/used/maintained in accordance with the agreed design. (if not resident on site visit as often as possible).

3. Ensure a final check is made and sign approval to load document (see Form T.W.2.).

4. Sign approval to strike/dismantle document as appropriate.

SITE MANAGER

1. Ensure that the T.W. Sup. is aware of his responsibilities.

2. Keep T.W.C. informed of progress on site.

3. Advise T.W.C. of any alteration in materials/equipment/plant method of loading.

T.W. SUP

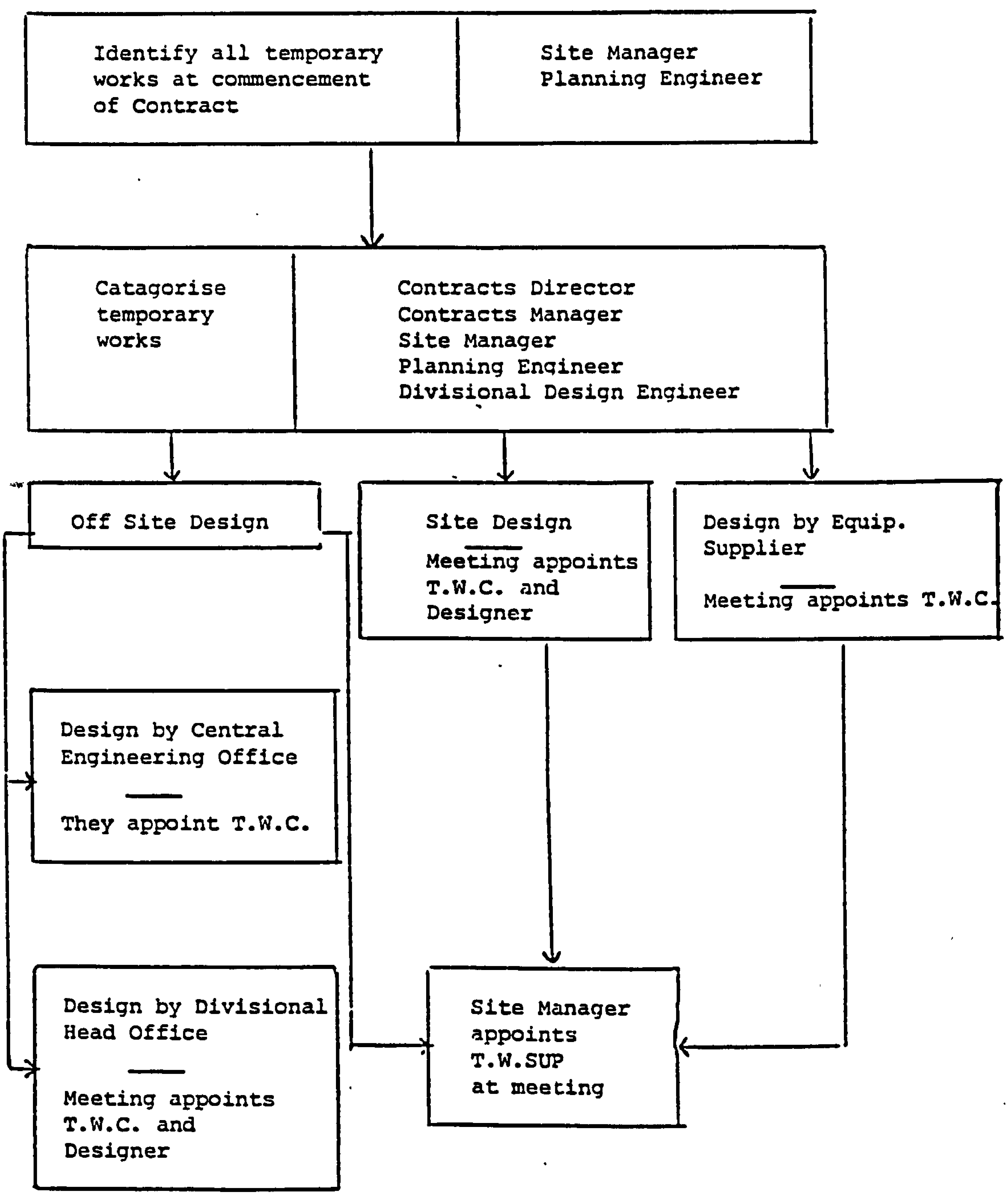
1. Monitor erection/installation of tempoary works materials to the Designer's drawings/specification.

2. Ensure no unsound materials are incorporated into the works.

3. Inform Site Manager and T.W.C. of any change in materials/equipment/plant to that assumed on the design.

APPENDIX I

TEMPORARY WORKS PROCEDURES

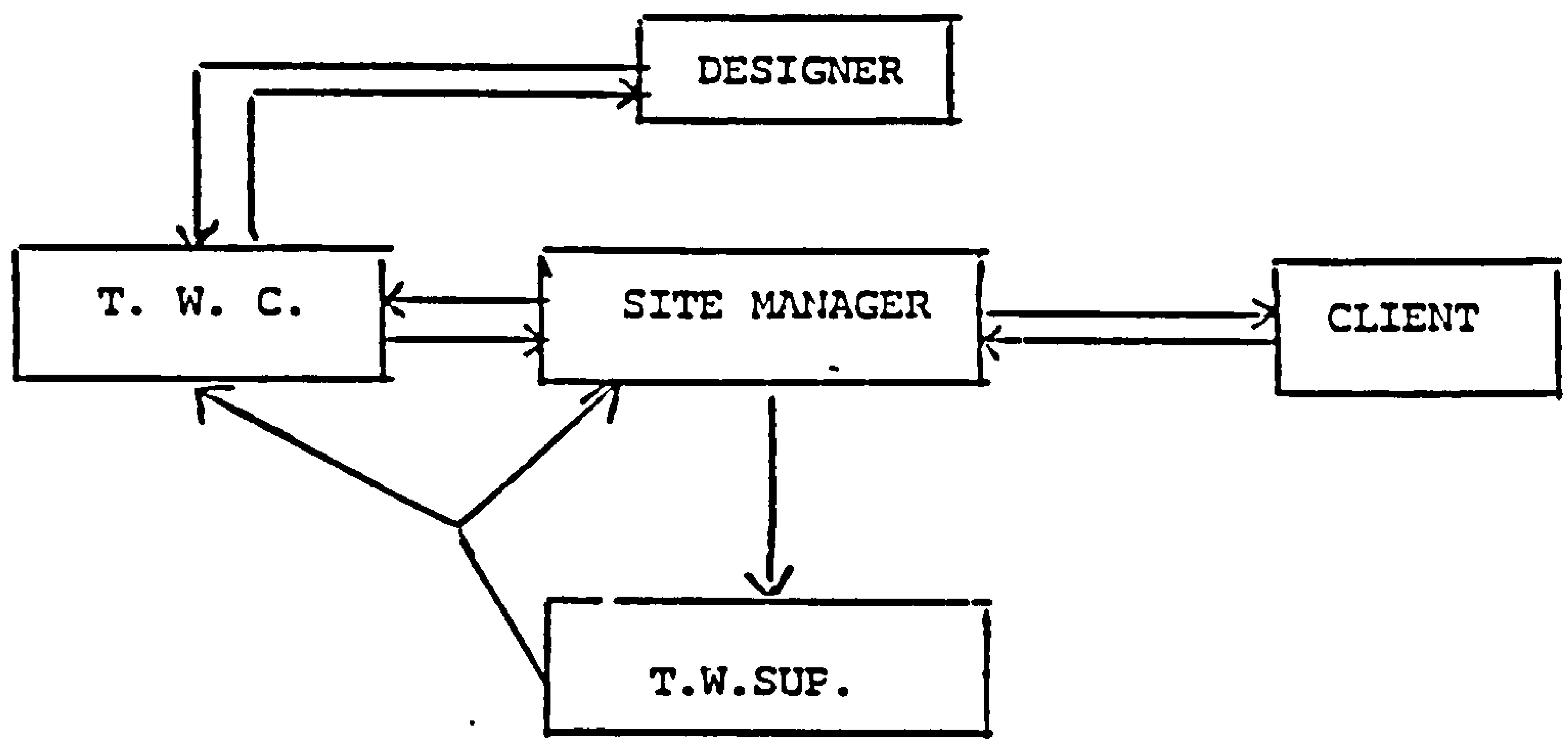


TEMPORARY WORKS LIAISON

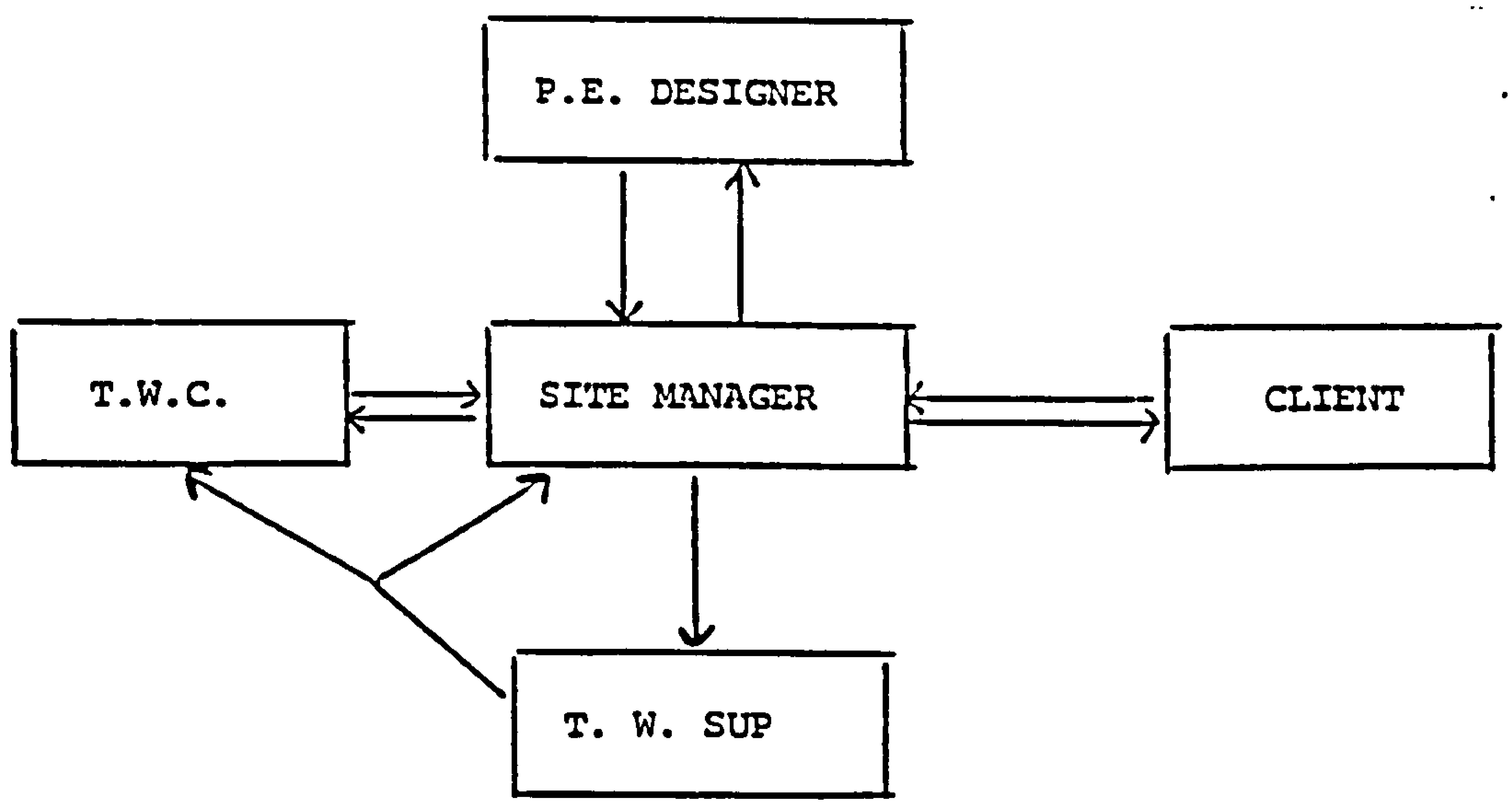
Written communication and instructions follow the below procedures.

Verbal communication desirable between any parties but any written confirmation should follow the below procedures.

FAIRCLOUGH DESIGN



PROPRIETARY EQUIPMENT SUPPLIER



FORM T.W.1 SHEET ..... OF ......

CIVIL ENGINEERING LIMITED

SOUTHERN DIVISION

TEMPORARY WORKS DESIGN AND ERECTION — ALLOCATION OF RESPONSIBILITIES

CONTRACT .... NO ....

PRESENT AT MEETING .... DATE OF MEETING ....

← TO BE COMPLETED BEFORE MEETING AND FORM AGENDA† → | ← TO BE COMPLETED AT MEETIN

STRUCTURE	ELEMENT	PRELIM DESIGN REQ'D	FINAL DESIGN REQ'D	T W C	DESIGNER	T.W. SU

DISTRIBUTION: Contract Director, Contract Manager, Agent†, Planning Eng.† Div Design Eng. ←

.. File

CIVIL ENGINEERING LIMITED
SOUTHERN DIVISION

TEMPORARY WORKS DESIGN AND ERECTION – PERMIT TO LOAD

TEMPORARY WORKS CO-ORDINATOR..........

TEMPORARY WORKS SUPERVISOR ....

CONTRACT .... STRUCTURE .... POUR ....

	DESIGN					ERECTION			
	DESIGNED BY	DATE	CHECKED BY	DATE		SITE SUPERVISOR	DATE	DESIGNER	DATE
GROUNDWORKS									
SCAFFOLDING									
STEELWORK									
FORMWORK									

SIGNED (WITHIN 24 HOURS OF POUR)........................ TEMPORARY WORKS CO-ORDINATOR

FALSEWORK CHECK LIST

1) Foundation
   a) Fully prepared.
   b) Comply with assumptions.

2) Sole plates
   a) Correct type
   b) Correct location

3) Base plates central on sole plates.

4) Spaces of vertical members correct.

5) Adjustable bases within design extension.

6) Vertical members plumb.

7) Joints staggered
   a) Vertical
   b) Horizontal

8) Couplers fittings etc correctly tightened.

9) If props - proper couplers used.

10) Lacing and Bracing in correct place.

11) Joints as close as possible to node.

12) Adjustable forkheads within design extension

13) Bearers central to forkheads.

14) Wedges
   a) Correct shape
   b) Correctly placed
   c) Nailed

MATERIALS

All materials should be inspected before use for suitability.

TIMBER

1) Where drawings specify a particular grade, has that grade been provided ?

2) Are there any patent defects, shakes and splits, winds, loose knots, excessively large knots or crushed or damaged areas ?

3) Are there protruding nails and/or fixings from previous use ?

STRUCTURAL STEEL

1) If drawings specify high tensile steel in whole, or most particularly in part, is the high tensile materia clearly marked and checked ?

2) Have fabricated sections been checked for compliance with the drawings ?

3) Have web stiffeners been provided ?

4) Is material in good condition and in accordance with section detailed ? With second hand material check for pitting, holes, welds and cut outs from previous use. If in doubt have checked by design office.

SCAFFOLDING

1) Is tube as specified, straight, with no excessive pittings, or dents?. Are the ends square and free from splits

2) All fittings complete and undamaged? Are threads and nuts free from corrosion or other patent defects and threads undamaged?

PROPRIETARY EQUIPMENT

PROPS

1) Are welds intact between plates and tube and are the plates at right angles to the tube ?

2) Is the tube straight and free from excessive pitting or dents ?

3) Are the threads in good condition ?

4) Has it been provided with a high tensile pin and chain (no substitute should be permitted) ?

OTHER MATERIALS

1) Are they as the brochure describes ?

2) Have they had any unofficial repairs ?

3) Does permanent formwork (GRC panels etc) comply with drawings and specification.?

APPENDIX J

Clause 8A.

The enclosed is the wording of a typical addendum clause 8A and completed temporary works certificate for a project not included in the study and hence no need for confidentiality. Acknowledgements to Galliford and Sons for kind permission to include this.

Clause 8

After Clause 8 the following Clause is added:-

8A 1) Without prejudice to the other provisions of this Contract the Contractor shall in connection with temporary supports to bridge deck and method of lifting the deck submit to the Engineer prior to the commencement of the relevant parts of the Works a certificate or certificates in the form prescribed in sub-clause (2) of this Clause.
Each certificate shall be signed by an Engineer with appropriate qualifications and experience who has not been concerned with the original design of the element of the Contractor's erection proposals and details of Temporary Works to which the certificate relates.

(2) The certificate required under sub-clause (1) of this Clause shall be in the following form:-
"I certify, but without undertaking any responsibility other than towards (insert name of Contractor), that in my opinion the Contractor's erection proposals and proposed Temporary Works details specified in the schedule attached hereto relating to the part of the Works listed in Clause 8A(1) of the Conditions of Contract for the Construction of (insert title of the Contract) are satisfactory for the proper discharge of his responsibilities under the Contract for the safety of the said part of the Works and for their safe execution in accordance with the Drawings and Specification and without detriment to the related Permanent Works."

(3) The Engineer shall provide to the Contractor such design criteria relevant to the Permanent Works or any Temporary Works designed by the Engineer as may be necessary to enable the Contractor to comply with sub-clause (1) of this Clause.

A member of the Galliford Group

Galliford and Sons

Civil engineering contractors

Galliford and Sons Limited
Wolvey Hinckley
Leicestershire

Telephone Hinckley (0455) 220333
Telex 341255

Your Ref | Our Ref | Date 20th December 1985

SOUTH YORKSHIRE COUNTY COUNCIL

MORTHEN HALL BRIDGE

DECK JACKING WORKS

Temporary Works Certificate

"I certify, but without undertaking any responsibility other than towards Kottler & Heron Limited, that in my opinion the Contractor's erection proposals and proposed Temporary Works details specified in the schedule attached hereto relating to the part of the Works listed in Clause 8A(1) of the Conditions of Contract for the Construction of MORTHEN HALL BRIDGE are satisfactory for the proper discharge of his responsibilities under the Contract for the safety of the said part of the Works and for their safe execution in accordance with the Drawings and Specification and without detriment to the related Permanent Works".

W.D. Sulley

W. D. SULLEY
B.Eng., M.I.C.E., M.I. Struct. E.

APPENDIX K

Instructions to Resident Engineers on Temporary Works

(Case 22)

TEMPORARY WORKS AND FALSEWORK

1. Contractor's proposals for load bearing Falsework or Temporary Works on contracts let on behalf of the Department of Transport will be checked both for adequacy in providing an acceptable standard of completed Permanent Works and also for safety and ability to sustain the load applied during construction. You should bear in mind that if you are satisfied with the proposals the Conditions of Contract require you to give consent to the Temporary Works only insofar as they lead to the satisfactory completion of the Permanent Works.

2. The Contractor should therefore be asked to provide particulars of his proposed Temporary Works and Falsework in sufficient time for you to carry out your investigations well before he starts to erect the particular items with which he is concerned. Your purpose will be to make a check on the drawings, basic assumptions, and design philosophy rather than undertake a numerical check of any calculations and for this you will require in addition from the contractor a description of construction procedures and proposed superimposed loads. In calling for the particulars, you should draw the Contractor's attention to the desirability of following the recommendations of BS 5975 : 1982, Code of Practice for Falsework.

3. Items which may affect completed Permanent Works and safety of Temporary Works, and which need particular attention include :

   a. Adequacy of the Temporary Works foundations individually and collectively at each stage and in all weathers during the construction.

   b. Adequate capacity for carrying all loads bearing in mind the likelihood of uneven loading and the need to cater for deflection.

   c. Provision against sway and lateral forces.

   d. Stability of all members with due consideration given to the low degree of fixity afforded by temporary connections and their possible deformation.

   e. Eccentricity of application of loads and possibility of accidental increase.

   f. Frequency of use of temporary works and methods of moving and/or dismantling and re-erection.

   g. Compliance with manufacturers recommendations for proprietary items, and their validity in the context of their use.

   h. The quality of the materials which it is proposed to use.

   For this purpose structural calculations should be carried out as necessary. Any unresolved doubts about the proposals should be referred to the Engineer with your comments. Difficulties of analysis beyond the scope of site staff should similarly be referred to the Engineer.

4. If, on completion of your check, you are satisfied with the proposals you should write to the Contractor giving "consent" to his proposals.
NOTE : It should be consent and not approval.

5. Should you have COMMENTS on the proposals because they are unsatisfactory they should be divided into two sections :

   a. Items covering the condition of Permanent Works.

   b. Items covering safety and stability of Temporary Works during construction.

   Your letter to the Contractor should then be on the following lines :

   "I have looked at your proposals for Temporary Works from the point of view of the acceptability of the completed Permanent Works. I consider the proposals will ... [1] which will be unacceptable and if you proceed I would expect to reject the Permanent Works. Modifications to ... [2] would considerably reduce this risk and enable me to consent to the proposals as leading to satisfactory finished Permanent Works provided they are properly executed. Your attention is drawn to the following factors which are related to the safety of the Temporary Works ... [3] The factors I have brought to your attention are not exclusive. I request that you let me know the action you intend to take in regard to both sets of items."

6. You will no doubt discuss with the Contractor's representatives many of the points raised and reach mutual agreement, but any outstanding issues which do not result in modified proposals by the Contractor should be recorded in the form indicated above. Should your letter fail to produce a satisfactory response from the Contractor the matter should be referred urgently to the Engineer, with your recommendations as to what should be done.

7. It is of course as important to ensure that the erection of Temporary Works is as satisfactory as the design, that it is carried out in such a way that the design concept will succeed and also that local instability and deformation are unlikely to result in failure. Your investigation of the proposals should therefore identify areas of possible risk and your inspectors should be instructed to be vigilant during erection and report immediately to you any doubts they may have as to the adequacy of the Temporary Works. If your subsequent investigations confirm their doubts, the Contractor should be informed urgently and if necessary you should write to him. The Engineer should be kept informed of your actions.

8. If the Contractor continues to use the Falsework which is, in your opinion deficient, you should immediately bring the matter to the attention of the Engineer. He may consider it necessary to refer the matter to the Health and Safety Executive and if the safety of the public at large is involved to the Local Authority.

NOTE : 1. Insert comments relating to 5A above.
2. Insert proposed modifications.
3. Insert comments relating to 5B above.

9. If the Contractor is determined to continue after you have advised him as above and reference to the Engineer is not possible, Clause 40 powers may be assumed by you, if not already delegated, so as to protect the Permanent Works. Similarly you may directly contact the Health and Safety Executive, and the Local Authority where appropriate in respect of the inadequate Temporary Works.

10. The above is intended to be a general guide to prevent emergency situations arising and obviously good site co-operation is a key to this.

communication cable in the hard shoulder on the west side will require support and protection.

iii) Temporary Works

An independent check with the submittance of certificates by the Contractor are required for the temporary works to this bridge. See Part 1 Section 3. Some design criteria relevant to the permanent works may be required by the Contractor.

In the first month after each stage the deck shortening will be approximately 45mm. Of this, 35mm is shortening due to prestress. Temperature changes will also cause movement of approximately ±25mm for temperature changes ±28°C.

During the stressing operation, the falsework should be eased near the supports. If this is not done, the upward load on the deck locked in the falsework due to its elastic compression will continue, so that either the deck or the falsework will be overstressed due to excessive upward reaction near the supports.

It is suggested that after stressing half the cables, the falsework approximately 5m either side of an internal support should be eased. At supports C and H in spans CD and HJ this operation is not possible as the total prestress is required near the blind end and passive anchorage zones during stage 1.

iv) Reinforcement

The north and south spines of South Link Bridge will be constructed concurrently. Special attention should be made to the positioning of reinforcement bars which extend from each spine into Stage 3 Section. These bars should be positioned so that they do not bend during shortening of the deck after prestressing.

"Gewi-steel" type couplers are used to obtain full strength connections at positions of temporary access in both the north and south spines. To ensure a satisfactory connection the installation of the couplers must comply with the manufacturer's instructions. See Note 12 Drg. W11294.1.10-1/18. The couplers are supplied by Dividag Systems Ltd.

APPENDIX L

Body of Knowledge and Competence in Falsework

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Body of Knowledge and Competence in Falsework

Introduction

Falsework design and construction could be defined as the body of knowledge that is applied and informs the activities of those engaged in falsework construction. Taking the wider definition of falsework, in Chapter 2, falsework to support arches, earth retaining structures, building facades and so on, has been designed and erected for hundreds of years. Assuming that these operations have not been performed in an entirely random manner, this signifies that some body (or bodies) of knowledge has governed the falsework process. This thesis is concerned with the process of design and construction of falsework to support soffit formwork to reinforced concrete. The term, body of knowledge, is used to describe the physical and/or mental skills, practical know-how, work practices, theoretical knowledge obtained by practical training and/or experience often supplemented by formal education. The occupational order referred to in the previous chapter defines how rights of occupational control are distributed and legitimated. These rights in and over a particular process derive from a recognised ownership of a particular body of knowledge. It is necessary therefore to ascertain whether falsework is a relatively coherent body of knowledge, generated and shared by a significant group of practitioners, who can variously claim ownership. The occupational order assumes that by virtue of membership of a particular occupational specialism or group with legitimised ownership of the relevant body of knowledge, a person is competent to exercise his skills, expertise, knowledge and so on. It is thus necessary to be able to assess the competence being exercised since it affects the effective functioning of the occupational order and hence, it is postulated, the attainment of quality.

Levels of competence in the design and construction personnel are continually debated by practitioners. The Bragg and Code of Practice committees, addressed the problems of training and education. With the interest of Bragg, Government, and Health and

Safety Executive in 1974, attention was focused upon falsework and engineers began to take notice. The Code of Practice, textbooks and articles that emanated from the concern of the seventies, strengthened the potential expertise of engineers and their rights of ownership over a body of knowledge.
Some practitioners argue that technical developments in equipment and the increased complexity and size of some permanent works have outstripped the trades practices and practical know-how previously and currently applied. There are some who assert that many of the practitioners involved in falsework today are not even versed in this possibly out-dated or imperfect knowledge and are unfamiliar with the basic ground rules (the 'milkman' or factory worker, referred to in comments later). These assertions were and are made in a climate where very little training was taking place and where competition of sub-contractors increased the tendency to employ cheaper operatives. The potential for occupational control by the workforce has diminished with the erosion of trades practices and the competence of those claiming to exercise those trades practices.

This leads on to the pressures of economic control. The availability or potential for competence is affected by the economic order as is the exercising of this competence. Unlike the permanent works where the client and/or his professional representatives exert some control over quality standards, falsework is seen as a temporary means to the permanent end; professionals are often thankful to consider it as none of their business. Under these conditions, and the climate of the economic order, quality standards in falsework are prone to be eroded by competitive market forces. The main constraint on the contractor is avoidance of collapse or excessive deformation resulting in rebuilding or major repair (economic damage).

The increased incidence of scaffolding and falsework collapses during the construction boom, led to concern among the factory inspectorate in the late 1960's and early 1970's. The Bragg Committee of enquiry was set up and finally reported in 1975. In parallel, the Falsework Code, (BS 5975) was prepared (over a ten year period) and was finally published in 1982. The Code formalises a set of rules and recommended design criteria for falsework. The acceptance and awareness of these rules and actual commitment to applying them has been discussed earlier (Chapters 15 and 16). A number of personnel in contracting firms and falsework equipment suppliers think it is wise to operate within the Code requirements, if only to be seen as behaving responsibly in the event of a possible collapse. For some personnel, the Health and Safety at Work Act of 1974 is seen as a major constraint, placing as it does, legal, statutory obligations on all levels of management in contracting and sub-contracting to provide a safe place of work, that is a structurally stable falsework system.

Body of Knowledge and Skill

The use of the term 'body of knowledge' and more importantly the concept of ownership suggested by Sharrock (1974), provides the means for describing the nature of occupational control. The embracing term is preferred to the nebulous concept of skill. It is beyond the scope of this study to discuss the definition of skill which can be ascribed to different functions of mental or conceptual skills of the manager, or manual skills or dexterity in the worker.

Skill may be:

> "the alliance of manual dexterity with knowledge. Thus when we speak of a carpenter's skill we are referring to the combination of his manual skill in sawing, planing, and so on, with his knowledge of different sorts of wood, different types of joint and so on."
>
> (More 1980, p 15).

or:

> "Any combination, *useful to industry*, of mental and physical qualities which require considerable training to acquire."
>
> (H. Renold quoted by More *op cit*, italicised here).

More stresses that skill may be 'socially constructed' or 'socially negotiated' according to Clarke (1983).

> "that a category within the workforce may ritually undergo a period of apprenticeship, just to acquire preferential hiring rights or wage levels,

> but do not, in fact, manifest any particular abilities which may not be otherwise quickly mastered and practised."
>
> (More 1980, p 17).

Some practitioner's comments appearing later in the chapter suggest that the competence seen necessary in the manual workforce is regarded as minimal, to be exercised by labourers, semi-skilled operatives or even 'monkeys'.

Of particular relevance to the whole debate on skill, divisions of labour, training and so on as Clarke (1983) points out, is who is attempting to define skills and for what purpose.

Psychologists and ergonomists address issues such as manual dexterity, fatigue, psychological effects and so on with a view to ensuring health, safety and more importantly, increasing production; just as Taylor and his disciples of scientific management were interested in work measurement and skill. Economists, sociologists and managers may be concerned with costs of re-skilling, de-skilling, training and so on. Some sociologists would be more concerned with the erosion of power brought by de-skilling (for example the Braverman debate).

Apart from the literature from the ergonomists and psychologists on dexterity and fatigue, no assistance can be given in assessing competence levels qualitatively, let alone quantitatively. Most of the literature addressing skills in the construction industry are concerned with implications for training, effects of labour only sub-contracting, self-employment, Government regulation and so on. Clarke (1983) is recommended as is Gann (1987,1988), Piore and Sabel (1984) and Rainbird (1987) for the commentaries on the current situation. Jensen (1983, 1984) also addresses cooperative skills and implicitly the strength of what is described in this thesis as the occupational order.

Competence depends upon the exposure to trades practices which may differ in content and nature according to occupation, degree of training and so on. Although the Code of Practice and other documents claim to represent and codify trades practices, these are often written in engineering terminology, perhaps foreign to the operative. Where knowledge of the Code of Practice is incomplete, other methods must be adopted to assess the level of competence, or how far trades practice departs from that assumed and prescribed in the Code of Practice. The assessment depends upon careful interviewing and observation and upon a fundamental understanding of the industry in general and falsework in particular and knowledge of the occupations by the researcher. The research attempts to distil the commonsense rationales used every day by practitioners when judging competence of falsework personnel. As was the case of judging quality of workmanship, some measure of judging (relative) competence had to be derived in order to describe the occupational control, and attainment of quality; particularly in the case of building (Chapter 16) where reliance is placed on the competence of the autonomous workgroup by the occupational order. The commonly expressed beliefs, by practitioners and commentators of the industry, on training, erosion of competence, effect of sub-contracting and so on had also to be addressed by obtaining measures of the level of competence which exist on sites.

<u>Content of the body of knowledge</u>

Knowledge of the falsework Code of Practice would be regarded by some practitioners as essential for people involved in falsework. To be a competent practitioner, however, requires a much broader and complex range of knowledge involving practical know-how and experience. In the same way, it takes a lot more than simply memorising the contents of the 'Highway Code' to make a competent motorist. The falsework Code could be regarded as simply a set of constraints to be superimposed on the existing body of knowledge.

The existing body of knowledge comprises a set of separate and overlapping sets of knowledge possessed by occupational groups. It may include the intuitive skills of the designer to predict forces and structural behaviour without having to perform rigorous analyses, those of the carpenter who makes decisions based upon knowledge of the behaviour of timber, the scaffolder who by intuition assesses the rigidity of a structure, excessive strut lengths and so on. Across the various occupational groups of varying skills and education, there exists a knowledge and appreciation of fundamental workmanship standards as addressed in Chapters 4 and 7. The derivation of these standards may be different (for example based upon engineering theories or empirical rules) but they are common to all parties regarded as competent in erecting and judging falsework construction. The nature and content and indeed claim to ownership of the corpus of knowledge may be changing, for example with the continued changes in equipment design, the knowledge becomes more the preserve of the equipment designer - an engineer. As the workforce undergoes de-skilling, either due to innovations in 'idiot-proof' systems or by virtue of lack of training or lack of concern over the amount of competence needed, then the body of knowledge and its ownership passes into the hands of the engineer (the design engineer, civil engineer on site or equipment designer). The necessary body of knowledge required to construct falsework will always require some skills in the workforce of strength, dexterity, a sense of balance, resourcefulness, discretion and so on.

Falsework is being designed, built and dismantled every day without being subject to wholesale collapse (with margins of safety, smaller or greater than those envisaged in the Code). Some body (or separate sets) of knowledge informs and direct those involved in falsework.

<u>Civil/Structural Engineers</u>

Looking first at the body of knowledge acquired during an engineering degree course (bearing in mind it takes more than this for a person to be accepted as a competent engineer), much of this is theoretical (strength of materials, theory of structures) with an emphasis on analytical techniques. Nevertheless, students are taught reinforced concrete and structural steelwork design and so on by lecturers with some practical experience and this goes some way to simulating the 'master-pupil' relationship of 'on the job' training. Falsework design is rarely, if at all, covered by first degree syllabi, no doubt reflecting lack of knowledge among lecturing staff, and the absence of a satisfactory textbook on the subject. (Subsequent to Bragg, Brand (1975), Grant (1982), Irwin and Sibbald (1983) were published, the comparative lack of texts suggests that falsework is hardly regarded as a subject worthy of academic or other study). The reasons may be put forward that falsework is one of many subjects that cannot be covered due to lack of time, in a degree course or are best taught in practice; but basically the subject is either not understood and/or thought not to merit inclusion. The majority of engineers will pass into retirement with neither formal education nor practical training in falsework. Advocates of the education system would point to the fact that the basic education of engineers and the requirements of the professional institutions mean that engineers can acquire the necessary knowledge.

Before the Bragg Committee and the Code of Practice, falsework was hardly recognised as a problem area or given prominence in discussions, conferences and so on.

With the exception of the Joint Report on Falsework (1971) and the Draft Code of Practice (1975) which were only referred to by a narrow range of parties already committed and knowledgeable in falsework; general engineers had no general reference document.

Prior to the publication of the Bragg report and to a greater extent, the Code of Practice, engineers had little opportunity to supplement their knowledge of falsework except by practical experience in checking designs, access to designers and so on.

The Bragg report gave prominence to engineering structures and it is suggested in this thesis that engineers on civil engineering sites have recognised their previous failings. The report and subsequent Code of Practice were structured in engineering terminology. The Code of Practice resembles other design codes of practice, written in engineering terms, presenting design criteria for loading and analysis. The formal procedures are also more likely to be accepted by engineers used to exercising centralised, formal control on site (Chapter 15).

The interim and final Bragg reports laid great emphasis on training at all levels. The Construction Industry Training Board (C.I.T.B.) and the Cement and Concrete Association (C&CA) responded and prepared courses and syllabi. Indeed the C.I.T.B. syllabi appeared in the final Bragg report in 1975. Response to these courses for designers, coordinators, supervisors, since 1975 has been very low. Typically less than twenty people per year have attended appreciation courses in falsework organised by the C.I.T.B. Only two courses have taken place at the C.I.T.B. (with typically 30 participants) since 1975 aimed at coordinators/designers. Response to courses at the C and C.A. for designers and coordinators have been similar and the Concrete Society has organised only two courses. This low response reflects the opinions of the executive in contractors, consultant organisations or a commitment to in-house training or self-education via experience. The majority of participants and the enthusiasm for courses for designers and coordinators comes from the suppliers.

With the publication of the Code of Practice (and to a lesser extent textbooks and availability of courses) the engineers have the facility to supplement their corpus of knowledge and have absorbed the fundamentally engineering language without much difficulty. Thus engineers engaged in design and (more importantly to this thesis) in the construction of falsework have had their potential corpus of knowledge increased and their occupational control, by virtue of owning that corpus, increased (Chapter 16).

Falsework Designers

These are found in design sections of falsework equipment suppliers and in the Temporary Works Departments of large contractors. Some of the very large specialist supply and fix sub-contractors also engage such personnel as do a handful of falsework/formwork consultants. Like structural steel designers they could be regarded as engaged in a specialised brand of civil/structural engineering.

Designers employed by specialist suppliers of proprietary equipment (for example, G.K.N./Kwikform, R.M.D., S.G.B. etc.) adopt a basic structural engineering approach and are well versed in the design criteria of the firm's specialist equipment and short-cut methods, rules of thumb, passed onto them by their seniors. There are also some presentation methods, 'house-styles' for the preparation of drawings and calculations obtained from previous or current employers. They will also have acquired knowledge of practical and 'tried and tested' arrangements from on-site discussion and collaboration with experienced site agents, operatives and so on. Some may have followed falsework courses laid on by the C and C.A., and the Concrete Society; and form the majority of the participants on such courses. The demand for such courses as to above is minimal or almost non-existent in the construction industry. Most of the designers will be acquainted with the Code of Practice for Falsework, although not fully conversant with the rationale behind some of the provisions for example on node stability. It is fair to say that the majority follow the rules of the Code and the particular design procedures of their employer explicitly without fully understanding or needing to understand the full engineering significance. On the other hand, the designers are frequently practical people, well versed in site erection procedures.

Taken collectively these designers do not represent a large group (no more than a few hundred throughout the United Kingdom) and in comparison with other occupations engage in very little interchange of knowledge, techniques and so on, through occupational associations; for example, there is no Institute of Falsework. The Concrete Society provides perhaps the main discussion vehicle and venue for this group. Moreover, proprietary equipment suppliers regard each other as competitors and guard their test data like 'trade secrets' and there is very little openly published on how 'safe working loads' and so on are actually determined. Practitioners frequently bemoan their lack of professional status, frequently referring to how they have to educate other professional engineers, in particular those promoter's representatives.

Temporary works designers engaged in contracting firms, in total, comprise a relatively small group. If the firm has purchased a large stock of proprietary equipment they will be reasonably well versed in design techniques associated with this equipment. They may not have to design themselves, of course, since in a sense they have already purchased the 'free' design service of the equipment suppliers. (Chapter 14). Temporary works designers share the same body of knowledge across all temporary works departments, with a reasonable degree of knowledge in all equipment types, sometimes with access to the 'commercial' data of the test results.

The body of knowledge shared by contractors' and suppliers' designers is of fairly basic engineering content. The majority of design staff are Ordinary and Higher National Certificate technicians in Mechanical, or Civil Engineering. Only basic engineering statics is required for the majority of falsework structures. The senior engineers and managers in the departments are, however, predominately engineering graduates and chartered engineers. In addition to basic engineering knowledge there is required a good deal of practical knowledge, formwork and falsework design requires economic appraisal of production rates, re-use, easy stripping facilities and so on. There is a good deal of interchange of designers and technicians between different suppliers' and contractors' organisations which reflects the reasonably coherent body of knowledge of falsework design.

This thesis is concerned with falsework construction on site and does not address design, hence there is little need to be able to assess competence in design *per se*. Designers and engineers may be involved on site either in a strict design capacity or as members of the site staff as managers, or functional roles of designer or engineers. Such engineers and designers are already versed in falsework design and construction, acquainted with the Code of Practice and recognising and assimilating its recommendations and so on. They are much more likely therefore, to be able to supervise and exercise occupational control, if they are in a position to do so. The concern of this thesis is to be able to assess the competence, in the particular body of knowledge, of those in recognised occupational control. It is the engineers on civil engineering sites who have this control and it is engineers for the reasons expressed above who have their knowledge, and competence enhanced and supplemented by the Code of Practice. It is relatively straightforward for the researcher to assess the competence of those engineers in occupational control in civil engineering; where the body of knowledge of falsework is presumed and claimed by them (as people already in occupational control of all other operations) to be described in engineering terms. Interviews and measures such as routine checking can be used to describe the amount of competence and occupational control exerted by those engineers (Chapter 16).

On building sites the body of knowledge is not publicly recognised as being owned by one occupation (the engineers) but by several, and moreover it is owned and defined by those who actually perform the task, the specialist manual workforce. The occupational control is exercised by this self-regulating competent workgroup (Chapter 16). The assessment of competence in the mixture of occupations of varying ability, education, training and so on is more difficult. The Code of Practice is of limited use in determining competence since it is largely written in engineering terms which are unlikely to be understood by the workforce.

Site Staff

The level of expertise, that is, the breadth and depth of knowledge concerning falsework, possessed by various categories of contractor's site staff may be expected to influence the quality of falsework constructed on site. The level of expertise of men in the economic control positions such as site agent, site manager, project manager, general foreman, works manager may be expected to vary according to occupational background, type and length of (suitable, proper) experience, training courses attended and so on. The same may be said to apply to non-line management (functional) management staff or service occupations such as site engineer. The degree of occupational control exercised will depend upon the nature of the occupational order and the co-existent economic order. Knowledge of the various tolerances, formally presented in the Code, need for diagonal bracing, rigid construction, maximum extensions for head and base jacks without bracing, and so on are to be regarded as fundamental, minimum levels of knowledge required to obtain a reasonable expectation of satisfactory quality.

When practitioners exert occupational control by routine checking (Chapter 16), either as supervisors or as supervisory, senior members of the specialist workgroup, they have to have the requisite knowledge or competence, publicly recognised ownership or possession of that knowledge. When exercising this control, the practitioners claim to be able to judge competence of others; that they can 'spot the poor operative in ten minutes' and so on. How this competence can be measured in the manual (and supervisory) personnel is now addressed; this is of fundamental importance when considering the occupational order in building where occupational control relies upon competence and its effective application within the workgroup.

The methodology has to incorporate the commonsense rationales used by practitioners when judging competence. They can tell by the way the operatives arrive on site, the footwear they wear, the tools they carry, how they go about their business, choosing the right timber, rejecting faulty material and so on, whether the operatives are what they claim. Competence can never be divorced from the constraints of economics, that it is allied to productivity and speed. One sub-contractor director who became particularly excited when asked how he judged competence:

> "When I go walking around the site, I don't just look in the sky at the helicopters, I see a man knocking in a four inch nail where a two inch will do, I rear up on him...it's these things you are looking for, all of the time."

From the data on competence below, many site staff are either not bothering to check upon operative competence and are leaving it to someone else or they do not expect much in the way of competence in the first place:

> "I do not check the certificates etc., as this responsibility lies with the sub-contractor."

In other industries (chemical, engineering construction etc.) it is part of the Health and Safety Policy and Industrial Relations machinery to check all certificates of scaffolders (access scaffolding) before allowing them on site. The certification scheme for scaffolders was introduced jointly by the C.I.T.B. and the Building and Civil Engineering Joint Board in 1979.

The value of certification or tickets is often questioned:

> "I usually check physically every ticket of every erector which was given by this company. You cannot take this ticket seriously. On this site we have fired a lot of people after I have noticed that they are not as competent as they claim."

(Foreman).

and

> "I check the ticket of the sub-contractor's men, but that's not enough, you have to check his capability by asking him to do a certain job, then you can tell whether he's qualified or not, I will spot him out in two or three days."

(Works Manager/Foreman).

The respondent continues to cast doubt over the skills needed, and the status of the scaffolder:

> "The scaffolder is not a tradesman, he is semi-skilled labour. This is because scaffolding is an easy thing to do. You can put it up very quickly. On this site, some people came and they have not got enough experience in falsework. I have chosen them because I thought they were potential labourers and brainy. So these labourers were taught on site how to put up the falsework by some people from the supplier's office, who had come and done some demonstrations for them. Now I think these labourers are doing a good job."

Skilled labour may be rare and more expensive, and is frequently regarded as less important on the 'idiot-proof' proprietary systems:

> "You do not have to ask for any qualifications of the operatives, especially when you are dealing with (supplier Y) system."

and:

> "On this particular falsework system, which is straightforward you do not need skilled labour, whereas with the tubes and fitting system you do need skilful labour."

Specialisation and experience in this albeit minimal (and cheaper) level of skill brings production efficiencies:

> "Yes, I can do it, it is general knowledge i.e. commonsense, when you have been doing it for a long time you know how to put it up quicker, I can do it but it might take me longer, but it will be the same (quality)."
>
> (Foreman).

Some specialised, minimal level of competence or knowledge is therefore assumed and it is economically rational to use such a 'specialist':

> "So what you need to have on putting up falsework is a person who has a brain which is more than average to deal with it besides his speciality in any other trade."
>
> (General foreman).

Whether indeed 'brains' are a useful attribute was put in doubt by another respondent:

> "This stuff's so simple, a monkey can put it up, in fact a monkey could put it up easier."

Another respondent, a self-employed joiner working for a sub-contractor, expressed even more faith in the talents of animals:

> "No you don't need training, anyone can erect that stuff. My dog could erect it."

There are therefore a range of occupations and opinions on what level of competence is required or can be assumed as present in a particular occupation. There are always the pressures of the economic order to implement the most cost-effective solutions by employing the cheapest labour or maximising productivity of the better, more expensive labour.

Competence in the manual workforce

Two obvious categories of manual workers are the scaffolders and carpenters (who also generally erect the formwork). The growth of the use of proprietary systems has also encouraged the deployment of operatives without specialist training or experience; it was reported that a man erecting falsework had previously been engaged in milk delivery, another group were ex-factory workers.

It is also the case that on small-scale work, manual workers have without any formal, separately produced design, erected falsework to support soffit formwork. Supports have probably been conservatively spaced with erection tolerances possibly out of conformity with the Code of Practice. Given the large margins of safety, eccentricity, defective supports and so on may be adequate under these conditions - whereas they may be totally unsafe otherwise. These normative practices, so called 'trades practices' were assessed. The fundamental standards of workmanship of bracing, fixity, verticality and so on explored in Chapters 4 and 7, are basic standards which determine a minimal level of desired competence. A range of competence is encountered and expected to be present, as evidenced by the previous comments and those presented below. At one extreme a 'High' category workman will be skilled at reading drawings, experienced in a large range of falsework structures, knowledgeable in the various erection tolerances, capable of working under minimal supervision, and when changes occur in the design is capable of making decisions which would meet the approval of an engineering or other skilled supervisor. He would also know when the advice of the original designer should be sought or when to seek higher occupational authority. At the other extreme a 'Low' category worker will not be greatly experienced on construction sites or falsework in particular, without the ability to interpret design drawings correctly or set out the construction. If changes occur it is unlikely that his own modifications would meet the approval of a skilled supervisor. Also he may not understand the need to seek the advice or instruction of a higher occupational authority.

Based upon interview data, experience, training, demonstrated knowledge and so on, relatively little difficulty was encountered on identifying 'High' or 'Low' competence personnel in practice. 'Medium' competence personnel were by definition a more grey area which clearly did not belong to the 'High' or 'Low' categories.

Scaffolders

Scaffolders are traditionally regarded as being more than competent to erect falsework as part of their overall expertise and experience. With the introduction, in 1979, of the Scaffolders' Record Scheme, the occupation 'scaffolder' is recognised by the Joint Council for Building and the Joint Council for Civil Engineering, in the working rule agreements for pay and conditions, as equivalent in pay to a traditional craft. It is still classified as a plus-rated skill occupation and regarded by the industry in general as an inferior non-craft occupation. To obtain Basic or Advanced Scaffolders' Certificates requires periods of training on courses at C.I.T.B. and evidence of on the job training with employers. Despite these requirements where it takes a minimum of one year to become a basic scaffolder and two years an advanced scaffolder, and a rigid documentation scheme, the scaffolder is not viewed in the same light as an apprentice - tradesman.

It is also true to say that less than a third of the certificated scaffolders employed today have undergone formal training and records of experience, on the job training and so on. When the scheme was introduced there had to be a facility for recognising the expertise of the existing workforce. Operatives who could provide evidence from their employers could apply and receive certificates from C.I.T.B.. There was a so-called one year 'walk-in' period, and an appeal procedure such that in the words of one senior C.I.T.B. training manager:

> "it has only been over the last five years (since 1983) that the training scheme has had any bite."

Over recent years, since 1979, training in scaffolding, including Basic, Advanced and Youth Training Schemes, amounts to a fairly consistent 800 per year.

For information, the numbers of certificates issues up to March 1988 are Advanced 10,600, Basic 8,200, with 4700 trainees working towards basic qualification. The vast majority of these scaffolders are employed by the specialist supply and fix access scaffolding companies who also provide most of the apprenticeships and participants in the training courses although at 800 per year the figure is very low.

The vast majority of scaffolders' work is in providing access scaffolding. Such scaffolding is not, of course, restricted to construction sites but to large scale engineering construction work such as power stations, petroleum and chemical plants and so on, plus the provision for access to maintenance works in industrial plants. The requirements for access scaffolding, suspended scaffolding, hoists and so on are reflected in the content of the C.I.T.B. courses. For example, falsework construction is only included for 11 hours out of a total of 70 training hours in the advanced course only. It is a not unreasonable assumption that scaffolders, trained in setting out and reading drawings and capable of erecting bird-cages, truss-out cantilever scaffolding and suspended scaffolds and shoring, will require little specific training in falsework. A similar view is also taken towards proprietary systems.

A scaffolder of the Basic part 2 or advanced class, having experience of tubes and fittings is expected to be able to transfer his skills to proprietary systems without too much difficulty. Thus specific training in proprietary systems only occurs with respect to the use in falsework as part of the 11 hours of the advanced course.

The C.I.T.B. syllabi, interviews with their training personnel and observations made during training courses together with interviews with site personnel and other practitioners provided the basis for the assessment of what competence in falsework implies.

Certain sites or organisations acknowledge that scaffolders possess (own) the specialised knowledge to erect (in an efficient cost-effective manner) falsework.

A general foreman for a supply and fix sub-contractor for example states:

> "Usually I'd appoint an experienced scaffolder with two or three operatives, to put up the falsework in one section, and another experienced scaffolder with his group on another section, and so forth. I'll check their work while they're erecting, but at the end of the day it is the scaffolder in charge who will have the last say, whether the support system is ready to be loaded or not. The scaffolder will tell the R.E. to check the reinforcement and if he is satisfied, the pouring of the concrete will take place. The communications are done verbally, no one from the main contractor's side checks the falsework."
>
> Or the foreman for a main contractor: ......
>
> "On this site there are four scaffolders, one of them has done a basic training in scaffolding, and now he is due to go on an advanced one, while the other three are still young fellows. They are 18 to 30 years old. They work either under my supervision or under the supervision of the other basic scaffolder."

The main requirement is that the first-line supervision is competent. For example one labour only sub-contractor working proprietor, the most qualified and demonstrably competent operative on all sites in the study, employed unqualified, inexperienced labourers who provided the muscle to erect falsework under his close supervision.

The most competent of joiners sometimes realised their limitations:

> "There are two types of shuttering (formwork), the one we have here on site, I think anyone can do it, it's commonsense, and the type in bridges and using towers, there it is totally different, you are talking about a different person."

The above joiner directly employed by the main contractor saw no reason to distinguish between formwork and falsework or scaffolding.

A working director of a labour only sub-contractor expresses similar, commonsense views:

> "You've got to be a proper scaffolder for tubes and fittings and it's a lot more fancier...I could do it...You don't have to be anything special to do tubes and fittings, you're working in the same manner as with systems, it's just a clip instead of a 'cuplok'."

The apparent contradiction in the above statement implies that the respondent could erect tubes and fittings but it would be more difficult and take him longer.
Although it is generally believed and shown by the data, that specific scaffolding expertise is not strictly necessary for all falsework, there is a commonsense view that scaffolders will be called upon to erect tubes and fittings. Falsework and access structures greater than 5 metres in height are generally conceived as requiring scaffolders, the working rule agreements of the National Joint Council for the Building Industry (N.J.C.B.I.) and the Civil Engineering Construction Conciliation Board (C.E.C.C.B.) also stipulate this as a 'rule'. All access scaffolding on construction sites is covered under regulation 20 of the Statutory Instrument Number 94 (The Construction (Working Places) Regulations 1966) whereby in addition to competent people erecting and supervising access structures, it is a Statutory requirement that

structures are formally checked, and recording in a scaffolding register every seven days. This requirement is of course in addition to the general common law and Health and Safety at Work Act. It is also generally understood that access scaffolding in tubes and fittings or proprietary systems calls for the expertise of the scaffolder, although joiners on that site may be erecting more complex falsework. One of the factors in the division of labour, is whether falsework is regarded as part of the formwork task, and easily and expeditiously performed by the same workgroup, that is the formwork carpenter. Bridge structures are usually greater than 5 metres in height and regarded as technically different; and also provide continuity of work for a specific specialist. Of the seven bridge sites in the sample five employed scaffolders to erect the falsework; but nevertheless one large site used formwork carpenters and one, labourers, despite their complexity and requirements under the working rule agreements. The occupational order in civil engineering does not rely upon a high degree of 'know-how' from the manual workforce, what is required from them is to comply with the engineer's instructions (Chapter 16).

Formwork Carpenters

The term 'formwork carpenter' covers a variety of personnel from a variety of trade backgrounds and training. One group derive from the apprentice trade carpenter and joiner. The majority of these people on site are of the age group whereby they have served five year apprenticeships. The remainder range from the comparative 'old-timer' having served seven years plus specialised courses in cabinet making and so on to the younger operatives with three year apprenticeships. Basic training provides these carpenters with transferable skills in setting out, reading drawings, timber design and organising and planning skills in conceptualising and implementing tasks. The general task of formwork carpenter and falsework requires the above skills plus the ability to cut and fix timber, erect scaffolding quickly and not cutting 'dovetail' joints, planing and shaping and finishing timber and so on. Their basic training, education and competence is demonstrated by the comments:

"The points which I have in mind while I am erecting the falsework are as follows:

1) Verticality, the prop should be plumb, you know you can tell from your experience and your commonsense whether the prop is plumb or not.

2) If there is a cantilever you have got to brace it to something solid. You know it's a feeling you have got through your experience.

3) Lacing and bracing, I always make sure that I do not miss out any of them and sometimes I put extra ones in when I feel it is needed."

(Apprenticed joiner).

And another:

"I was taught by a good man plus at college they teach you the prop centres and what timber you should use, but college work is not the same as going on sites."

"I look at what steel is going on, the mass of concrete then work it out. For example on this site they had props every four feet. I thought that it was not appropriate to withstand the load, consequently I added a prop every two feet. I prefer to have drawings; I would not take responsibility but I can work without if I had to."

"All props must be levelled, should be on good ground, props not twisted, rusty etc., props should be plumb, bracing, none is missed out, beams should be nailed to the prop head and wedged both sides and centrally located here I couldn't get them central because of the wall."

The apprentice trades and crafts with their long training periods are traditionally regarded as superior to other specialisms. Furthermore scaffolding could be learned by certain trades without too much difficulty.

A joiner:

"The scaffolders are semi-skilled labourers, they do not serve any apprenticeship, a carpenter has served seven years and if had chance to watch someone (a scaffolder) putting up the complicated falsework for say four weeks he would be able to do it."

The same joiner recognises that, on the other hand, a formwork carpenter requires special skills (predominantly speed, productivity perhaps) over traditional craft carpenters and joiners:

> "If shuttering is complicated you need a proper shuttering carpenter, irrespective of the size of project, most shuttering carpenters are too rough to work on good joinery..., the apprenticeship includes shuttering and can do shuttering and falsework on small jobs."

In response to perceived skill shortages and the particular skills required for formwork the F.C.E.C. recommended a special training course. "Adult Training in Formwork for the Civil Engineering Industry." in 1965; very little occurred despite the intentions being reaffirmed in 1975. It was not until 1982 when the scheme was superseded by a Formwork Training Scheme, formally and jointly controlled by the F.C.E.C. and the National Association of Formwork Contractors, that an actual training scheme and course was devised and implemented. The training on this scheme is performed by the C.I.T.B. Perhaps reflecting attitudes to training in general, and formwork in particular, over the last seven years less than a hundred personnel in total have been trained on these formwork courses.

Formwork carpentry and its corresponding falsework is not generally regarded as a specific skill necessitating formal training. As one working director of a sub-contractor remarked about falsework/formwork erectors: ....

> "They are semi-skilled labourers and they can cope very well with the (R.M.D.) system, they are neither joiners nor scaffolders, they are in between."

This class of operative who are non-scaffolders and non-apprentice craft are regarded as semi-skilled labourers, 'qualified by experience' in assembling construction kits of equipment to the instructions (drawings and brochures).

> "A typical shuttering carpenter is a well-built bloke, able to lift the forms and equipment, and is equipped with a plumb bob, electric saw, hammer, hatchet and crow-bar. Once you've got those you can call yourself a shuttering carpenter."

The operatives themselves are under no illusions. A sub-contract carpenter:

> "We're not really joiners, just chippies, anyone can put it together (Kwikstage tables), once you've seen it done. You get a drawing and you work from that, it's fairly simple, anyone can do it, it's just like a jigsaw puzzle."

And another:

> "I've been in this game 10 years now. I didn't actually do an apprenticeship, just came on site and started. It's only glorified labouring what we're doing anyway. They say it's a trade but it isn't."

Measurement of Competence

There are a range of occupations with a range of skills and formalised training who erect falsework on construction sites. The comments above reflect the commonsense rationales of the competence expected and how it is judged. Practitioners refer to the tools that the operatives carry, even their dress and the language that they use. When interviewing personnel or sub-contractors, site managers refer to the terminology or language that their interviewees use, their familiarity with equipment and production rates and so on. Others rely on observations on site, or set specific tasks. The fluency in the way the operatives express opinions or knowledge can also be taken to demonstrate competence. The operative who can talk openly and knowledgeably about different falsework systems and is willing and able to demonstrate how he sets out the construction, how he reads and interprets a drawing, is familiar with the workmanship standards and tolerances referred to in Chapters 4 and 7, will be judged by informed practitioners and more importantly in this research, in the 'High' category of competence. In the assessment of competence, the researcher has to draw upon the experience as a practitioner, in addition to expertise in interviewing, interpreting responses to questions and attitudes and so on.

In contrast the 'Low' category of operatives will show a lack of knowledge of different systems, little knowledge of basic workmanship standards and tolerances and will have difficulty in setting out and/or interpreting drawings. They will also be less willing to demonstrate their (lack of) knowledge and competence, or may be quite flippant or less serious in their attitude to falsework.

The effective functioning of the workgroup depends upon the competence of the most senior member of the workgroup. That is to say the most senior member of the workgroup in terms of his recognised occupational authority. Assessments of the degree of supervision received or given facilitates the identification of the senior person with the motivation and leadership skills to direct the activities of the workgroup.

Evidence of formal training, length of experience and specialisation are also other factors which assist in categorising the operatives as 'High', 'Medium' or 'Low' competence. It should be remembered however that attendance on courses is no proof that the training is implemented in practice. Experience has to be gained of the right type, in providing high quality structures and so on.

It is crucial to the study that competence assessed is potential competence which is derived independently from the quality of workmanship actually obtained on site and that competence can be measured irrespective of the actual trade or occupation. This thesis maintains that the experience and expertise of the researcher and methodology adopted was adequate to achieve these objectives.

	Falsework System				
Type of erector	Type 1	Type 2	Type 3	Type 4	Total
Scaffolder	11	6	-	1	18
Scaff/Joiner	3	-	-	-	3
Joiner	10	8	11	-	29
Labourer	1	3	-	-	4
Total	25	17	11	1	54

Table 1: Type of erectors used on different falsework systems, number of sites in each category.

	Competence of Erector			
Type of erector	High	Medium	Low	Total
Scaffolder	11	7	-	18
Scaff/Joiner	1	2	-	3
Joiner	5	14	10	29
Labourer	-	3	1	4
Total	17	26	11	54

Table 2: Level of competence of each type of erector, number of sites in each category.

Table 1 confirms the view that joiners erect Type 3 adjustable steel props and scaffolders, tubes and fittings. Scaffolders and joiners are employed to erect proprietary systems, the choice may be made on complexity, height and continuity of work. On three sites falsework was erected by a mixture of scaffolders and joiners. Implicit in these choices is that scaffolders own a great depth of knowledge in scaffolding and falsework. Table 2 shows the levels of competence in each occupational type. This breakdown is for information only. The main finding is that seventeen sites had one or more 'High' competence operatives in control within the workgroup, twenty six with 'Medium' competence, and eleven with 'Low' competence.

The choice of operative personnel, sub-contractors and so on may be based upon an assessment of the structure, and the competence required, and assumptions may be made on the expected levels of competence. What is of relevance to this thesis is the competence actually present on site and the degree to which it is exercised. The nature of the occupational and economic orders may inhibit the application of the potential competence within the workgroup.

Practitioners on site insist that they can and do assess the competence levels of the operatives. In the case of sub-contractors the main contractor claims to ensure competence by direct involvement on site by checking and so on, and by his selection process of the sub-contractor.

In the overall matrix of variables, an assessment was made of the effort placed by the main contractor to ensure the recruitment of competent erectors by the sub-contractors.

Selection of sub-contractors: Cost (C), Reputation (R), Cost and Reputation (C.R) Reputation and Cost (R.C).

An estimate was made on the basis of interview responses to the question of why a particular sub-contractor was appointed.

Cost: where cost is given as the dominant reason.

Reputation: where the appointment was made on the basis of direct experience or knowledge of the reputation of a sub-contractor and not bothering to get alternative quotations.

Cost and reputation: where cost was the main reason but choice was influenced by reputation, to the extent of not taking the lowest price.

Reputation and cost: where reputation was given as the main reason but with cost having been taken into account and pressures being applied to the favoured sub-contractor.

Table 3 suggests that efforts to ensure that a high reputation firm of sub-contractors be appointed are either not made or prove ineffective.

	S/C Selection Criteria					
Competence	C	R	C.R.	R.C.	Total	Direct
Low	5	0	3	0	8	3
Medium	10	1	10	2	23	3
High	6	3	4	1	14	3
Total	21	4	17	3	45	9
(%)	46.6	8.9	37.8	6.7	100	

Table 3: Relationship between sub-contractor selection criteria and operative's competence.

The findings suggest that where reputation is the sole criterion, it does increase the chance of securing high competence erectors, however, the occasions on which this actually occurred were few, and besides, cost as a sole criterion seems, by and large, as good a means as any. In any event there was a 20% chance of getting low competence erectors whatever criteria were adopted (excepting the 3 cases which appear in the reputation/cost category). It has to be admitted that the measure is crude since, at the very least, desirable characteristics in a sub-contractor, whether labour only or supply and fix, include reliability and simply getting any men to site, in the required numbers at the right time, and speed of completion. In chapter 16 it is demonstrated that the employment relationship is not important in respect of the distribution of competence and routine checking.

It would appear that the assessment of competence in the operative workforce of contractor and sub-contractor is not given a high priority and/or that the level of competence expected or deemed necessary is not particularly high. Reliance may be placed on the occupational order for example, control by engineers or the medium of the market in sub-contracting (chapter 16) to achieve quality. The importance that operative competence plays in the selection of sub-contractors is not significant.

Conclusions

Falsework design and construction has been defined as the body of knowledge that is applied and informs the activities of those engaged in falsework construction. Ownership rights in and over the knowledge determines the nature and degree of occupational control exercised on site. The assumption of the occupational order is that those in occupational control have the required level of competence and that competence is applied. It is essential to measure the level of competence that exists and is applied by those in control. On civil engineering sites the engineers can claim and demonstrate ownership of knowledge. Their body of knowledge has been supplemented and enhanced by the Code of Practice which is essentially written in engineering terms. Their competence and interest is evidenced by the degree of control and checking which they implement.

The body of knowledge which exists in the manual workforce is variably distributed. This competence has to be assessed irrespective of their particular occupation and independently of the quality achieved on a particular site. A means of determining the level of competence in the workforce has been derived from assessment of the rationales used by practitioners, fundamental workmanship criteria, training courses and from experience of the researcher.

In contrast to the occupational order in civil engineering the occupational control within the workforce in building has been eroded by lack of training and the pressures of the economic order leading to a decrease in competence.

The potential expertise deployed on any job is clearly an amalgam of that possessed by designers (if any), visitors to site (contracts manager, temporary works department staff, suppliers) site staff and falsework erectors.

The total potential may not be realised if the economic control system inhibits its deployment. The quality achieved depends upon the effective functioning of the occupational order which coexists with the economic order.

Having discussed the content of the body of knowledge and how competence in this knowledge can be assessed and described the occupational control exercised in civil engineering and building can be examined.