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THE NEW AUSTRALIA/NEW ZEALAND STANDARD ON COMPOSITE STEEL-CONCRETE BUILDINGS, ASNZS2327

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ABSTRACT

This paper will provide a summary of the new Australia-New Zealand Standard on the design of composite steel-concrete buildings ASNZS2327 which is due for release in 2017. This standard which has included over five years of development has harmonized design provisions across the Tasman Sea, in steel, concrete and composite structures. This project was carried out in parallel to the standard for bridge structures (ASNZS 5100.6) and thus there was significant commonality and cross-over. ASNZS2327 covers the design of structural elements such as slabs, beams, columns and joints, as well as addressing the system behaviour for serviceability and fire which are highly pertinent for the design of steel and composite structures. Methods for the design for earthquake have also been included. The standard allows for the increase in concrete compressive strength up to 100 MPa and steel strengths up to 690 MPa. In addition, the standard has involved significant amounts of structural reliability studies to be carried out. This paper will provide a summary of some of the salient issues as well as highlighting future areas of interest which may be considered for future revisions.

INTRODUCTION

The concept of steel-concrete composite construction generally produces structural behaviour where the overall response is greater than the sum of the parts. This concept holds true for composite beam behaviour where the introduction of longitudinal shear connection can provide flexural stiffness and strength of a member which is greater than the constituent parts, namely the structural steel section and the reinforced concrete slab. Throughout the latter half of the twentieth century this concept has been further applied to composite steel-concrete columns to produce column stiffnesses and strengths which are greater than the sum of the parts of the steel section and the reinforced concrete elements. These benefits have been further exploited by taking advantage of the confinement effects that steel tubes can provide to interior concrete infill and the subsequent benefits provided by the concrete infill on delaying local buckling of the steel shell. This concept is now so widespread that in the last calendar year, more than 50 % of all tall buildings constructed worldwide, utilized composite frames, typically incorporating concrete filled steel columns (Council of Tall Buildings and Urban Habitat, 2016).

In Australia, builders of the recently completed Perth Tower (the tallest tower in Perth), chose to adopt composite construction throughout the entire structure and a concrete filled steel column solution. In order to secure this type of solution the builder pre-ordered and stored all spirally welded steel tubes in the columns (see Figure 1) to ensure steel cost fluctuations were minimized and construction costs were able to be controlled (Australian Steel Institute, 2010). The emphasis in Australia has been mainly focussed on construction economy when it relates to steel and steel-concrete composite structures.

(a) Completed building

(b) Building during construction

Fig. 1 - BHP Billiton Tower, Perth, Australia

In New Zealand the emphasis in steel and steel-concrete composite construction whilst also concerned with construction economy, is heavily influenced by seismic behaviour and performance. The new 14-storey 20 Customhouse Quay in Wellington (see Figure 2) is due to be completed in 2017 to replace the earthquake damaged BP House on Wellington's waterfront. This building was designed post Christchurch earthquake and utilizes base isolators (Schouten, 2015), resulting in an estimated seismic resilience of up to 180% of code. The building incorporates many steel-concrete composite components, including a steel diagrid external frame and long span composite cellular beams.

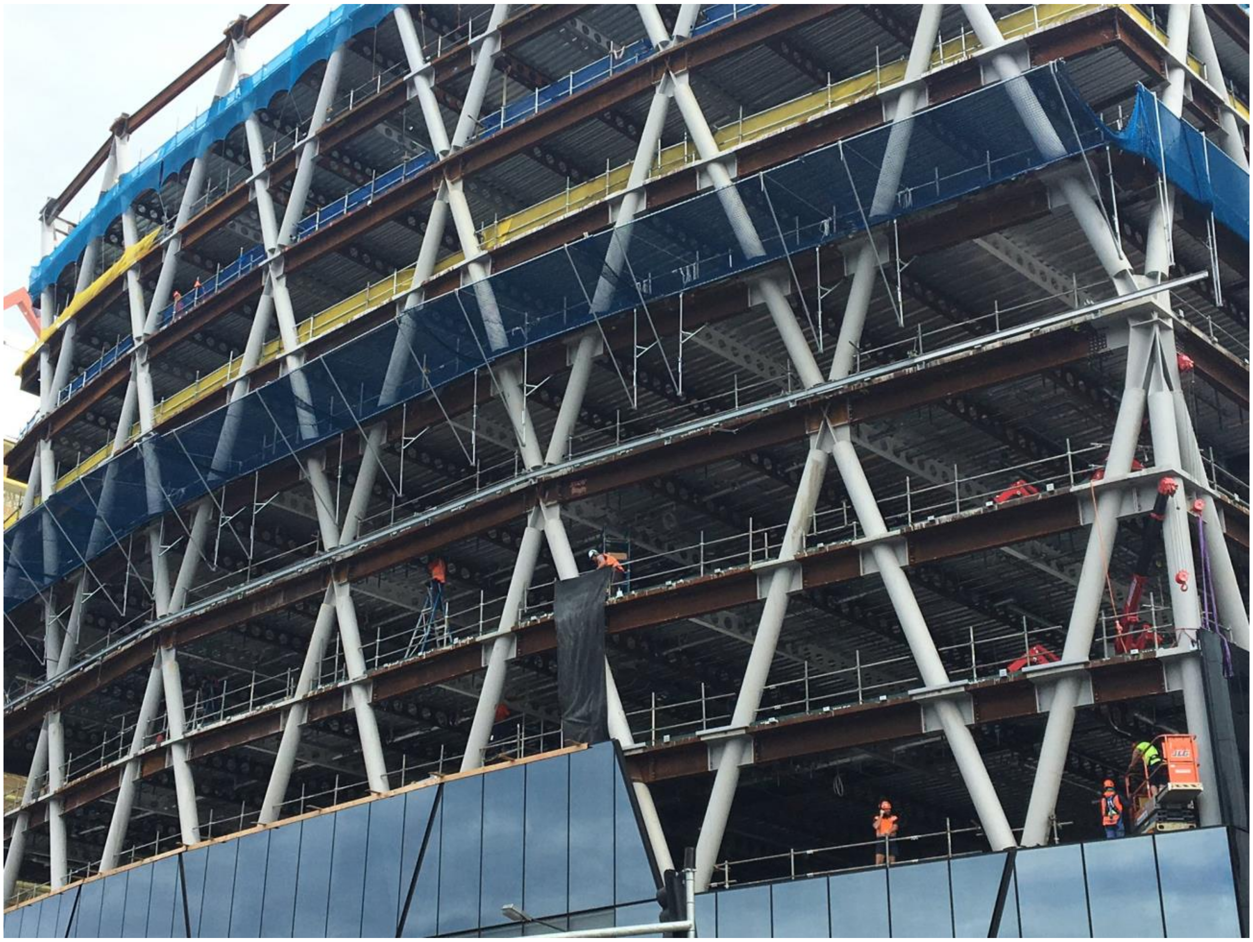


Fig. 2 – 20 Customhouse Quay, Wellington, New Zealand

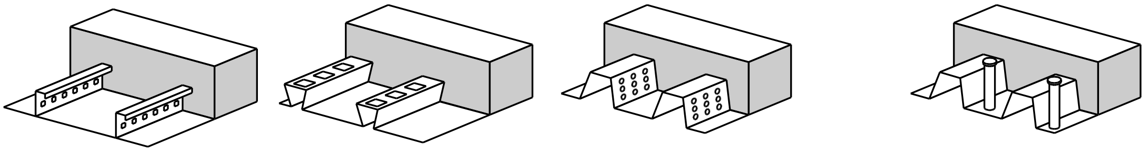
DRAFT BUILDING STANDARD FOR STEEL-CONCRETE, ASNZS 2327

The Australian Standard for composite steel-concrete structures in buildings, AS2327.1 only ever covered the design of simply supported composite beams (Standards Australia, 2003). A major initiative some 5 years ago involved ensuring that all forms of composite systems, including beams, slabs, columns and joints would be covered for design and has resulted in the Australia/New Zealand harmonisation of the standard, ASNZS2327 (Standards Australia, 2017). The standard table of contents is shown below and salient features of the standard will described herein

SECTION 1 GENERAL
SECTION 2 DESIGN OF COMPOSITE SLABS
SECTION 3 DESIGN OF COMPOSITE BEAMS
SECTION 4 DESIGN OF COMPOSITE COLUMNS
SECTION 5 DESIGN OF COMPOSITE JOINTS
SECTION 6 DESIGN OF COMPOSITE FLOOR SYSTEMS
SECTION 7 SYSTEM DESIGN FOR FIRE RESISTANCE
SECTION 8 DESIGN FOR EARTHQUAKE
APPENDICES

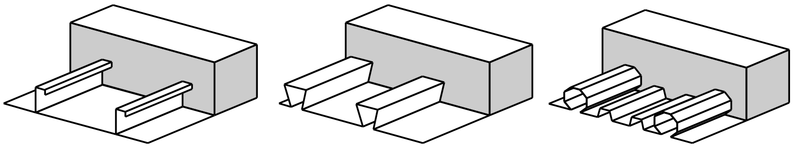
DESIGN OF COMPOSITE SLABS

Section 2 of ASNZS2327 covers the comprehensive design of composite slabs. The intent of this section is to cover the strength and serviceability design of composite slabs utilising metal decking. Issues including flexural strength, longitudinal shear and vertical shear provisions are covered in this section. Concepts of partial interaction are also considered and this section also links quite closely to that being proposed for testing in the Appendices of the standard. Furthermore, post-tensioned concrete construction is also extremely prominent in Australian buildings and recent innovations into post-tensioning concrete slabs with metal decking have been carried out. One of the major issues is the changes that need to be introduced to deal with the presence of the metal decking for serviceability and strength provisions and these will be considered as part of this section, namely the concepts of non-uniform shrinkage (Al Deen et al., 2015).



(a) Mechanical interlock

(c) End anchorage
by through-deck
welded studs



(b) Frictional interlock

Fig. 3 – Types of interlock for composite slabs

Fig. 4 – Post-tensioned composite slabs

DESIGN OF COMPOSITE BEAMS

Section 3 of ASNZS2327 covers the comprehensive design of composite steel-concrete beams. This section covers the design of composite beams, considering flexural strength, shear strength and combined actions as well as serviceability provisions. Partial shear connection approaches are also highlighted for the design of simply supported and continuous beams. This section also considers the design of composite beams using hollow core slabs (Uy and Bradford, 2007).

Fig. 5 – Precast hollowcore units

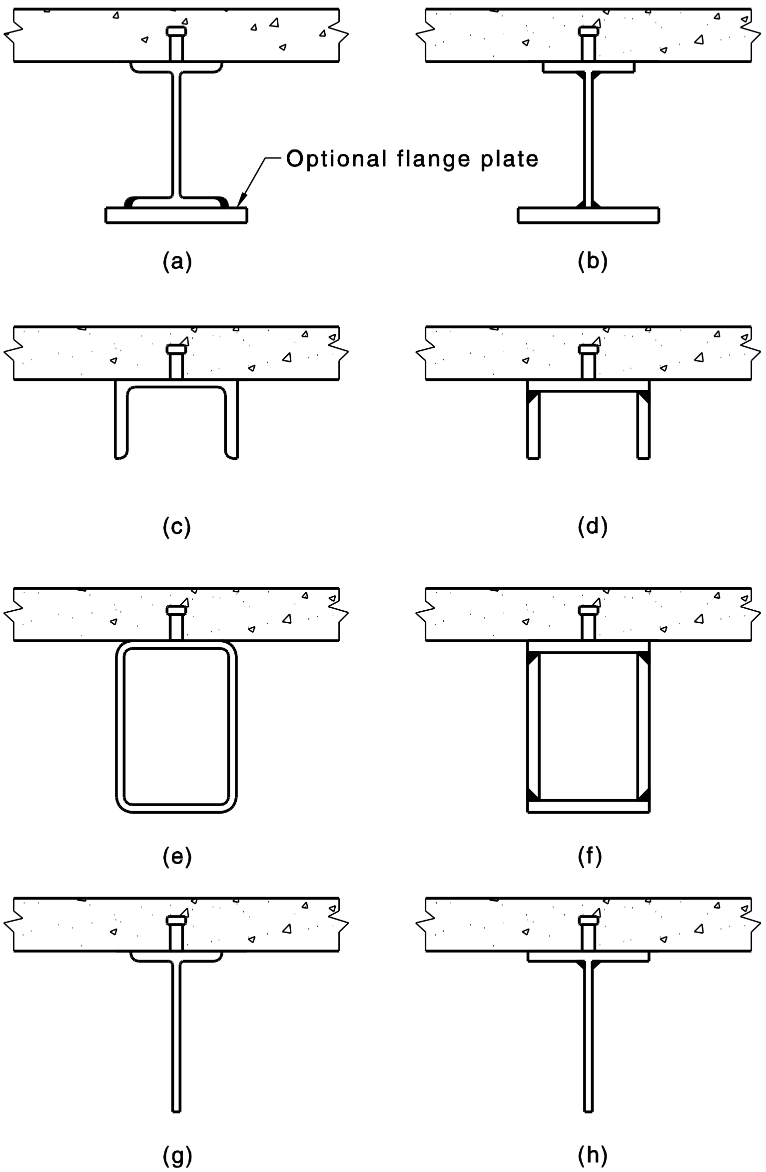


Fig. 6 – Alternative steel beam types

DESIGN OF COMPOSITE COLUMNS

This section is proposed to cover the design of composite columns and will closely follow the approach in the AS/NZS 5100 Part 6 (Standards Australia/Standards New Zealand, 2017). The design of composite columns for strength, stability incorporating axial force, uniaxial and biaxial bending will be considered. In particular, the important effects of confinement are covered by this section. Furthermore, the capacity factor for concrete in compression is proposed to be 0.65 based on reliability analyses using the design assisted by testing method provided in EN 1990 Annex D.8 (European Committee for Standardization, 2002). The reliability analyses were carried out for 1583 CFST columns included in the Tao et al.'s database (Tao et al., 2008). Figure 7 shows the analysis results along the squash load ratio of steel, where the average capacity factors for concrete are above 0.65. If a practical range of squash load ratio such as 0.1~0.6 is considered, the average capacity factor will even further increase.

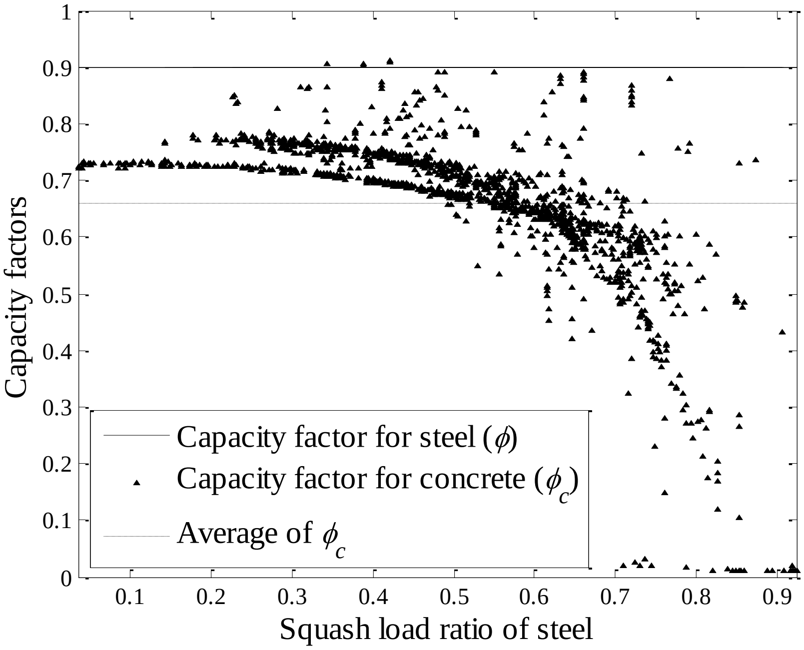


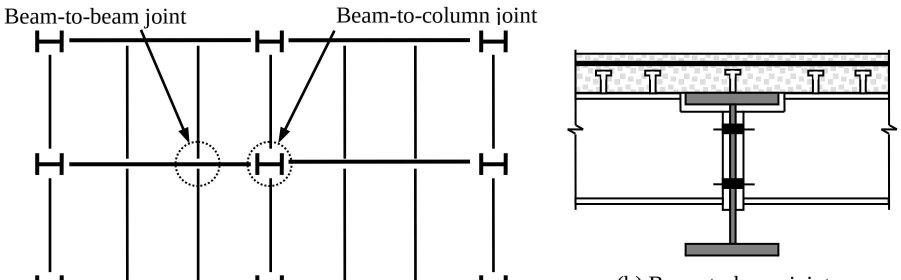
Fig. 7 – Calibrated capacity factors for concrete in compression when the capacity factor steel is fixed to be 0.9

One major area of innovation which this section will cover includes the use of high strength concrete (cylinder strengths up to 100 MPa) and high strength steel (nominal yield strengths up to 690 MPa) (Aslani et al., 2015a, b). In addition the standard has involved calibration and has been extended to permit spiral welded tubes to be used in design (Aslani et al., 2017; Aslani et al., 2015c).

Fig. 8 – Spiral welded composite columns, Aslani et al. (2017)

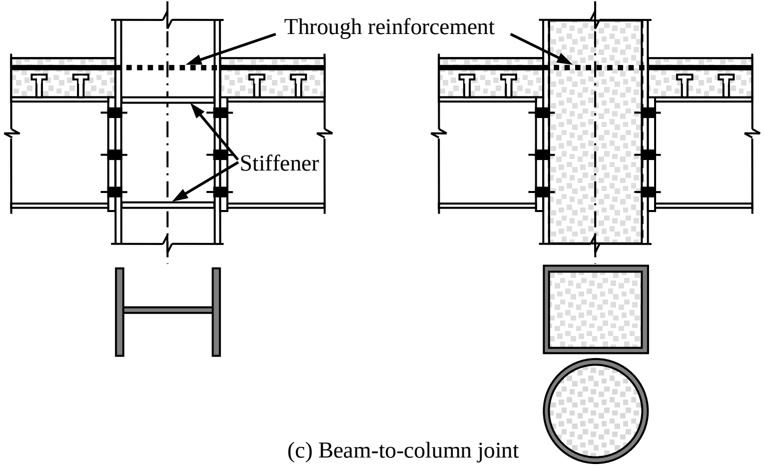
DESIGN OF COMPOSITE JOINTS

This standard has also involved in the development of a section for strength and serviceability design of semi-rigid joints including beam-to-beam and beam-to-column joints as shown in Figure 9. For beam-to-column joints, the column could be either open sections with/without stiffeners or hollow sections with/without infilled concrete. The design of joints to hollow section columns is based on the stiffness model of Thai and Uy (2016) which was calibrated with experimental results of 44 available tests on bolted endplate beam-to-CFST column joints.



(a) Plan view

(b) Beam-to-beam joint



(c) Beam-to-column joint

(d) Composite joints (Thai et al., 2017)

Fig. 9 - Composite steel-concrete beam and slab systems, Australia

DESIGN OF COMPOSITE FLOOR SYSTEMS

The intent of this section is to address system behaviour particularly for deflections and vibrations for panels. This will then give designers the ability to take into account the beneficial effects of system behaviour in addressing these important serviceability provisions which sometimes penalize steel frames structures from a design perspective (Steel Construction Institute, 2012).

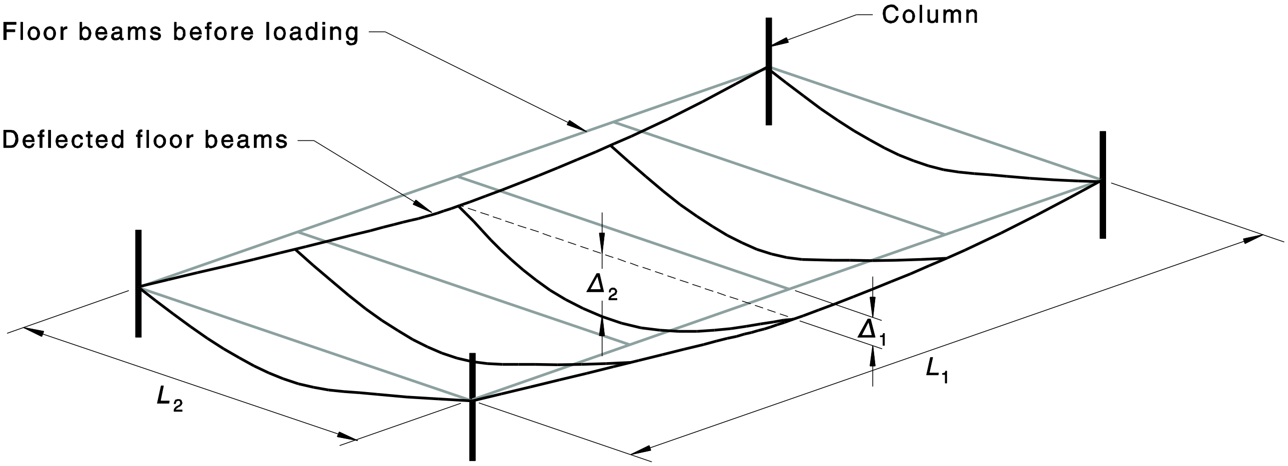


Fig. 10 – Deflection requirements for composite floor systems

SYSTEM DESIGN FOR FIRE RESISTANCE

This section is also intended to give guidance on design for fire using a system based approach, which acknowledges that for indeterminate systems there is a significant degree of redundancy that provides additional structural capacity within a fire that is unable to be addressed considering single elements within a building. State of the art approaches for dealing with this will be provided herein (Steel Construction Institution, 2006; Abu et al., 2011).

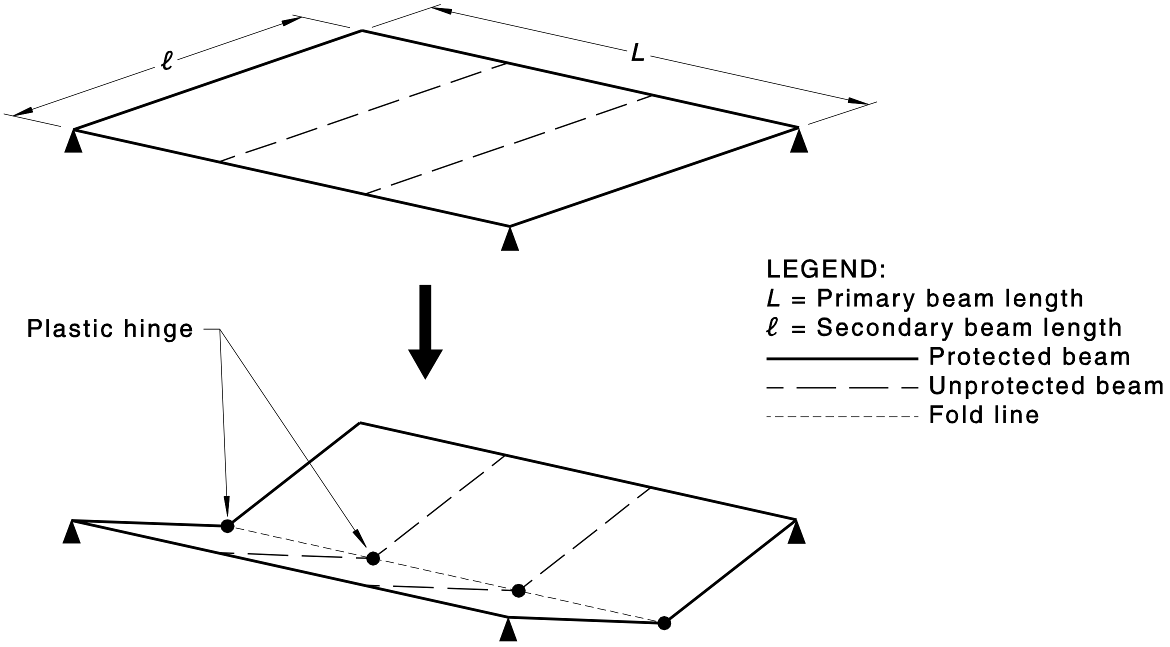


Fig. 11 – Collapse mechanism for an isolated panel

DESIGN FOR EARTHQUAKE

This section covers the design for earthquake of composite frame systems. One of the major elements of the section is the specific guidance provided to Australian and New Zealand designers in accordance with AS1170.4 and NZS1170.5 (Standards Australia 2004 and 2007).

APPENDICES

This section of the proposed standard is meant to provide standard test methods for a number of specific issues which are covered. Push test methods for establishing the strength, stiffness and ductility of shear connectors will be outlined in this section as will test methods for establishing the strength characteristics of composite slabs incorporating profiled steel sheeting. In addition, provisions for evaluating design resistance from tests will also be presented. Finally, ASNZS 2327 will be one of the first international composite design standards to present provisions for beams with both regular and isolated web-openings, thereby supporting the use of long-span cellular beams (Steel Construction Institution, 2011).

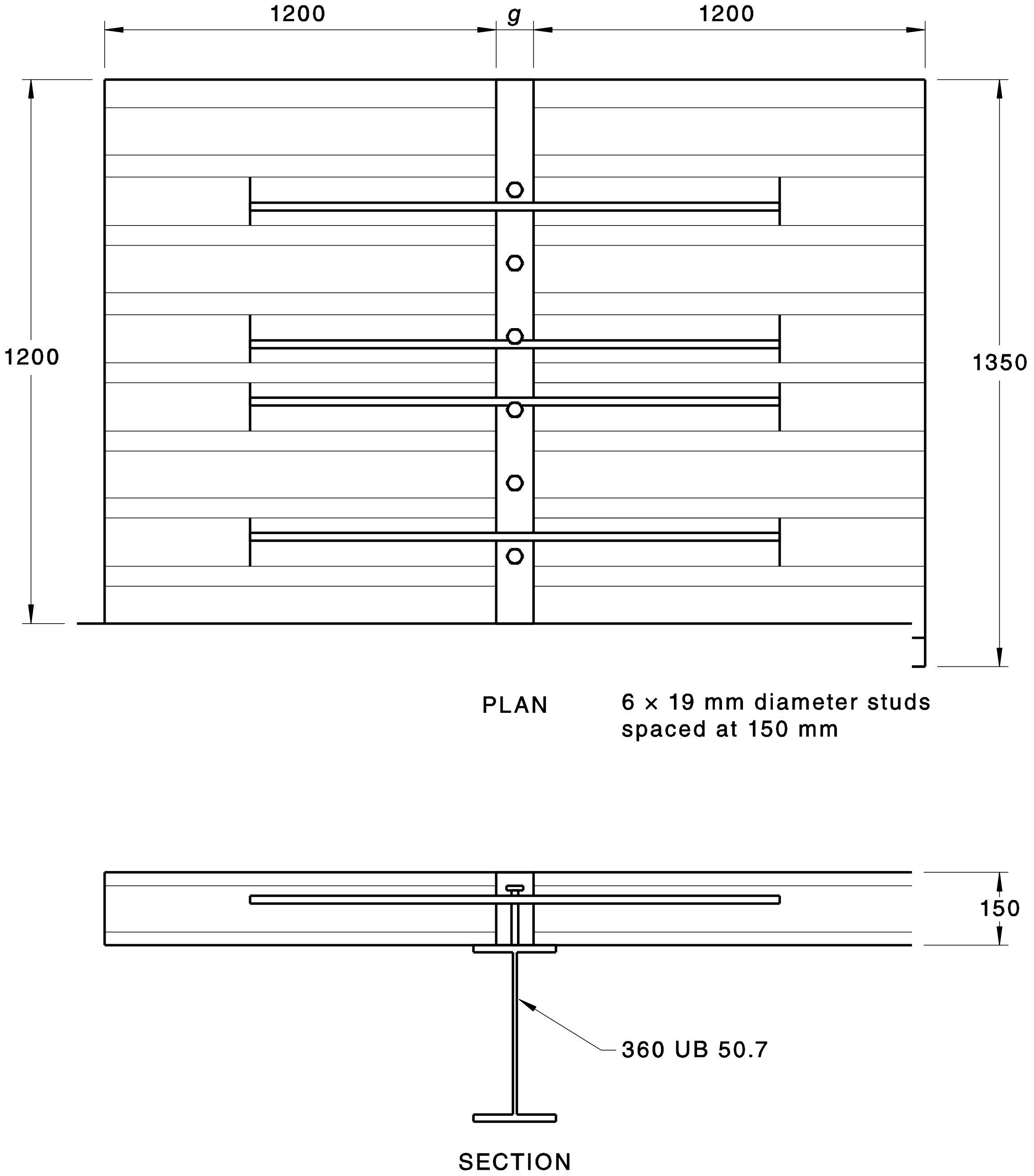


Fig. 12 – Method for determining the longitudinal shear capacity of headed shear studs in voided concrete slabs made composite with steel

CONCLUSIONS AND FURTHER RESEARCH

Whilst there is ongoing research into structural steel and some of the technical issues associated with materials and systems, it is felt that further research will be punctuated by approaches that provide paradigm shifts in the design of steel and steel-concrete composite bridge and building structures. Some of the more prominent issues that will promote these paradigm shifts include precast and prefabricated construction, deconstructability and new and higher performance materials.

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