

**THE NEW JOINT BRIDGE DESIGN STANDARD ON STEEL AND COMPOSITE CONSTRUCTION:
AS/NZS 5100.6**

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ABSTRACT

In August 2010, Standards Australia approved the review of the Australian Bridge Design Standard (AS 5100). The original scope for the review included: general reviewing and updating all parts; updating Part 2, Design Loads, to align it to the earthquake code; updating Part 4, Bearings and Deck joints, to address new materials for these elements; and updating Part 5, Concrete, in line with changes to AS 3600. The project is expected to be completed within 3-years. The review is being conducted by the Standards Australia Steering Committee BD-090, which consists of representatives from Austroads, State Road Authorities, rail, consultants, research institutes, universities and contractors. Part 6, which gives design provisions for steel and composite construction, is unique in that it will be the only joint Australian and New Zealand part of this new suite of standards for bridge design.

This paper presents some of the innovations that will be included in the new AS/NZS 5100.6, which reflect international best practice. In addition, advances through recent Australian and New Zealand research are implemented which, in some cases, result in design provisions that go beyond those given in North American and European Standards

Introduction

In August 2010, Standards Australia approved the review of the Australian Bridge Design Standard (AS 5100). The original scope for the review included: general reviewing and updating all parts; updating Part 2, Design Loads, to align it to the earthquake code; updating Part 4, Bearings and Deck joints, to address new materials for these elements; and updating Part 5, Concrete, in line with changes to AS 3600. The project is expected to be completed within 3-years. The review is being conducted by the Standards Australia Steering Committee BD-090, which consists of representatives from Austroads, State Road Authorities, rail, consultants, research institutes, universities and contractors. Part 6, which gives design provisions for steel and composite construction, is unique in that it will be the only joint Australian and New Zealand part of this new suite of standards for bridge design.

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Alternative steel materials

In the interests of Closer Economic Relations (CER), the New Zealand Steel Bridge Group together with other key-stakeholders confirmed the wish to revise the steel and composite bridge design Standard AS 5100.6 (2004) as a joint AS/NZS document. Due to the long history of successfully using overseas structural steels (for example, the cost-effective use of weathering steel which eliminates the need for applied corrosion protection systems, see Figure 1), coupled with an existing market share of 50% for steel in construction, it was required by New Zealand designers that steel products conforming to BS

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EN 10025 (2004), JIS G 3106 (2004) and JIS G 3136 (2005) should be supported by the resulting AS/NZS 5100.6. In response to concerns that the use of overseas steels might cause an erosion to the safety margins required by AS/NZS 1170.0 (2002), Uy *et al.* (2012) undertook a structural reliability investigation, which is summarized in an accompanying paper by Hicks and Uy (2013). From several analyses, it was demonstrated that the recommended capacity factor of 0.90 for beams in bending, which is given in AS 4100 (1990) and AS 5100.6, was on the conservative side for steel sections complying with overseas manufacturing Standards; this finding has led to a proposed appendix to AS/NZS 5100.6 which, as well as providing design rules for these alternative steel materials, gives guidance to practitioners on the minimum standards of workmanship that are required to ensure that the design assumptions are valid.



Figure 1: New Zealand's first weathering steel bridge (State Highway 1 Mercer to Longswamp Off-ramp, opened in 2006)

Corrugated web beams

In Europe corrugated web beams have been used, in particular, in Germany and Austria (see Figure 2). The main benefit for this type of beam is that the corrugated webs increase the beam's stability against buckling, which may result in a very economical design via the reduction of web stiffeners. Furthermore, the use of thinner webs results in lower material cost, with cost savings of between 10 to 30% in comparison with conventional fabricated sections and more than 30% compared with standard hot rolled Universal Beams. Due to these economies, design provisions for corrugated web beams are presented in AS/NZS 5100.6.



Figure 2: Corrugated web bridge girders

Composite construction

The majority of composite highway bridges are of 'deck type' beam and slab construction, where a reinforced concrete deck slab sits on top of I-section steel girders and acts compositely with them in bending. There are two common forms of deck type bridge: multi-girder bridges; and ladder deck bridges. In multi-girder construction a number of similarly sized longitudinal plate girders are arranged at a uniform spacing across the width of the bridge. The deck slab spans transversely between the longitudinal girders and cantilevers transversely outside the outer girders. The girders are braced together at supports and intermediate positions. Composite action between the reinforced concrete deck slab and the longitudinal girders is achieved through the provision of shear connectors welded to the top flanges of the steel girders. Conversely, ladder deck bridges consist of two main girders, with the slab supported on cross-girders that span transversely between the two main girders: the slab then spans longitudinally between the cross girders. This arrangement is referred to as ladder deck construction, because of the plan configuration of the steelwork, which resembles the stringers and rungs of a ladder.

The introduction of higher steel grades in AS 4100, together with higher grades of concrete in AS 3600 (2009), has brought some challenges in respect to the development of design rules for composite construction in the new AS/NZS 5100.6. Some areas that have required research and development are summarized below.

Headed Stud Connectors

The most common form of shear connector in composite construction is the headed stud. A recent structural reliability study by Hicks and Jones (2012), which considered the results from the 75 push tests, demonstrated that a capacity factor of 0.8 was justified for the design equations in the existing AS 5100.6; however, this was limited to cases when the characteristic concrete compressive strength did not exceed 35 MPa. Following the introduction of higher grades of concrete in AS 5100.5 (2004), a review of recent international research resulted in the push data to be expanded to include 113 results. A final reliability study (2013) demonstrated that the following design equations can be safely extended to include stud connectors embedded in concrete with a characteristic compressive strength not greater than 80 MPa:

$$f_{ks} = 0.70d_{bs}^2 f_{uc} \quad (1)$$

or:

$$f_{ks} = 0.29d_{bs}^2 \sqrt{f'_{cy} E_c} \quad (2)$$

whichever is smaller.

where d_{bs} is the nominal shank of a shear stud, but $16 \text{ mm} \leq d_{bs} \leq 25 \text{ mm}$; f_{uc} is the ultimate tensile strength of the stud material, but not greater than 500 MPa; f_{cy} is the characteristic strength of the concrete at the age considered, but $16 \text{ MPa} \leq f_{cy} \leq 80 \text{ MPa}$; E_c is the modulus of elasticity of concrete at the age being considered, and may be taken as $E_c = \rho^{1.5} (0.043 \sqrt{f_{cmi}})$ for $f_{cmi} \leq 40 \text{ MPa}$ or

$$E_c = \rho^{1.5} (0.024 \sqrt{f_{cmi}} + 0.12) \text{ for } f_{cmi} > 40 \text{ MPa}.$$

On some bridge projects in Germany, the shank of the studs has been orientated by 90° to the vertical and welded to the web of the girder; in these cases, the top flange of the steel girder has been eliminated, thereby leading to material savings (see Figure 3). Due to the concentrated forces from these 'horizontally lying' studs causing splitting within the depth of the deck slab, design and detailing rules have been developed which are given in Eurocode 4 (2005). To enable Australian and New Zealand designers to enjoy similar economic benefits for studs in this arrangement, the rules for horizontally lying studs have been adapted for AS/NZS 5100.6.

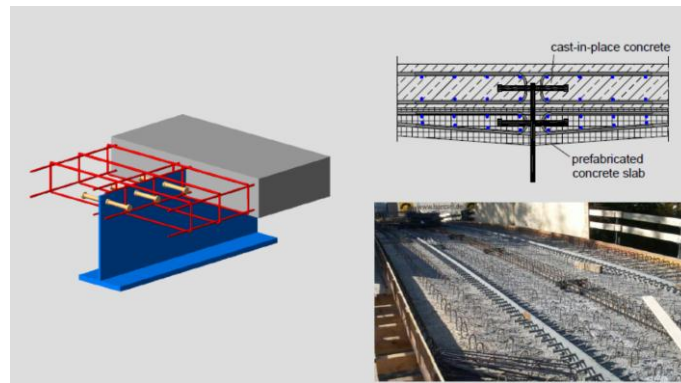


Figure 3: Horizontally lying studs and the elimination of the top flange to the steel girder

Composite Columns

In Eurocode 4, composite columns are limited to steel with a nominal yield strength of $235 \text{ MPa} \leq f_y \leq 460 \text{ MPa}$ and a concrete characteristic compressive strength of $20 \text{ MPa} \leq f_{cy} \leq 50 \text{ MPa}$. Through work that has been led by Prof. Brian Uy of UWS, the provisions for composite columns have been extended in AS/NZS 5100.6 to permit $f_y \leq 690 \text{ MPa}$ and $f_{cy} \leq 100 \text{ MPa}$. Moreover, guidance is given on what shear bond values may be assumed to develop at the interface between the steel section and the concrete for a variety of steel cross-sections.

Conclusions

Bridge design – Part 6: Steel and composite construction, is the only part of the AS 5100 suite being revised as a joint AS/NZS Standard. It is proposed that overseas steels that have historically been used in New Zealand are to be included in an appendix together with minimum standards of workmanship that are required to ensure that the design assumptions are valid. Following the international trend of using less natural resources, design rules for higher strength steel and concrete are given. The new design rules within the proposed AS/NZS 5100.6 provide greater alignment with international best practice and, in some cases, significant improvements are given.

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