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AUSTRALIAN/NEW ZEALAND STANDARD FOR COMPOSITE STRUCTURES, AS/NZS 2327, SEISMIC PROVISIONS DEVELOPMENT

K. A. Cowie[1]

ABSTRACT

This paper outlines the background behind the seismic provisions in the proposed joint Australian/New Zealand standard for composite steel-concrete buildings. The standard has commenced drafting and currently has three sub-committees working on composite slabs, composite beams and composite columns. The standard will be developed as a single document which builds on the historical AS2327.1-2003 standard for the design of simply supported composite beams as well as other Australian, New Zealand and international antecedent standards in the steel and composite structures area. It is expected that the standard will be published in 2016.

Introduction

Recent significant activity on the joint development of an Australian/New Zealand Standard for Bridge Structures in Steel and Composite Structures has highlighted the need and galvanised the industry to begin to develop a harmonised standard for steel-concrete composite structures for buildings. This project submitted to Standards Australia was initially titled "Suite of Standards for Composite Structures for use in Buildings and other non-bridge infrastructure incorporating existing AS2327.1-2003, AS2327.2-201X, AS2327.3-201X and ASS2327.4-201X" which received approval in November 2011 and commenced drafting in July 2012 and is due for completion by December 2015. The project is now referred to as the AS/NZS 2327, Composite Structures and will be a single document.

Composite structures using steel-concrete composite construction techniques generally tend to be the preferred method of construction for steel framed buildings in Australia, New Zealand and most developed countries. Composite construction tends to reduce the amount of structural steel being used and thus lends itself to greater sustainability benefits than other methods of construction. Furthermore, composite construction also provides steel-frames with the robustness of concrete frames by possessing the added advantages of light-weight which has many other potential benefits for the construction process.

Composite structures have been demonstrated to perform well in earthquakes. The 2010-2011 Christchurch earthquake sequence showed the performance of composite steel structures was generally better than anticipated especially given the levels of ground shaking which were more than twice that considered explicitly in design. Furthermore, unlike many reinforced concrete structures, a lot of damage was repairable. These earthquakes have resulted in composite steel being the construction material of choice in the Christchurch rebuild.

[1]Steel Construction New Zealand Inc.

Currently in Australia, the design of composite structures for buildings is covered in a piecemeal fashion by three standards AS2327.1-2003, AS3600-2009 and AS4100-2012 (Standards Australia 2003, 2009 and 2012) and in New Zealand by NZS 3404, (Standards New Zealand, 2007). The development of AS/NZS 2327 will improve harmonisation, will allow innovative aspects of composite construction and design to be incorporated in one standard and will also allow state of the art international research to be incorporated into a single document.

AS/NZS 2327 includes specific requirements for composite structures designed for seismic. The background behind the seismic provisions is outlined in this paper

Current Composite Structures Seismic Requirements

The current seismic requirements for composite structures are significantly different in Australia and New Zealand. This is a reflection in the level of seismic activity in each country. New Zealand has a much higher level of seismic activity. While New Zealand and Australia share the same Loadings Standard, the seismic loadings are separate and are a different approach.

Current New Zealand Requirements

In New Zealand a composite structure must be designed to possess an appropriate level of ductility as well as satisfying the required level of earthquake loading provisions of NZS 1170.5 (SNZ, 2004). Sufficiently ductility is provided through designing the seismic resisting elements according to NZS 3404 (SNZ, 2007).

NZS 3404 broadly speaking incorporates the provisions for bare steel member design from AS4100:1990 Steel Structures Standard and has additional provisions for seismic and composite design. There is a section in NZS 3404 on seismic design (section 12) and a section on design of composite members and structures (section 13). For design of composite structures subject to earthquake loads or effects, the design engineer must ensure that relevant performance and prescriptive criteria from both the seismic and composite sections are complied with.

Current Australian Requirements

In Australia a composite structure is typically designed to the earthquake loading provisions of AS 1170.4. AS 1170.4 requires structures designed for high level of ductility, $\mu > 3$, to be designed in accordance with NZS 1170.5. The design of composite structures for buildings is covered in a piecemeal fashion by three standards AS2327.1-2003, AS3600-2009 and AS4100-2012 (Standards Australia 2003, 2009 and 2012).
AS 3600 Concrete Structures and AS 4100 Steel Structures both reference the corresponding New Zealand standards, NZS 3101 and NZS3404, for structures designed for a high level of ductility.

AS/NZS 2327 SEISMIC REQUIREMENTS

Development of AS/NZS 2327 Seismic Provisions

The seismic requirements for composite structures are more extensive in New Zealand standards. As such the seismic provisions being proposed in AS/NZS 2327 are heavily influenced by the current provisions in NZS 3404. It is expected that designers of composite structures for seismic will require both AS/NZS 2327 and NZS 3404. The specific seismic provisions for AS/NZS 2327 were first developed by a working group in New Zealand, consisting of researchers and designers of composite structures.

Proposed Structure in AS/NZS 2327

It is proposed that for composite structures designed in accordance with AS 1170.4 Earthquake actions in Australia there are no specific seismic provisions in AS/NZS 2327. There will be a specific section that will cover the additional minimum design and detailing requirements of composite members and structures for the earthquake loading provisions of NZS 1170.5.

This specific section modifies and supplements the seismic requirements of NZS 3404.

AS/NZS 2327 Specific Seismic Provisions

This section will highlight some of the salient aspects that are proposed to be included in the specific seismic provisions in AS/NZS 2327. This is not meant to be the exact table of contents, rather an indication of the main specific seismic sections that will be covered in the standard.

X.1 Scope and General

This section covers the scope that the specific seismic provisions are the additional minimum design and detailing requirements of composite members and structures for the earthquake loading provisions of NZS 1170.5. This scope mentions that the specific seismic provisions modifies and supplements the seismic requirements of NZS 3404.

X.2 General Design and Analysis Philosophy

This section covers the general seismic design and analysis philosophy for composite structures. It is proposed that this section is similar to what is currently in NZS 3404 section 12.2. This will include structural performance factors, classification of composite structural systems and classification of composite seismic members. The philosophy of capacity design is described. In capacity design of a seismic-resisting system, the principal energy dissipating elements of mechanisms (the primary seismic-resisting elements) shall be chosen and suitably designed and proportioned to the requirements of this Standard, while all other elements of the seismic-resisting system (the secondary seismic-resisting elements) are provided with sufficient reserve strength to ensure that the chosen energy dissipating mechanisms within the seismic-resisting system are maintained throughout the deformations that may occur.

It was considered important by the committee to include most of NZS 3404 section 12.2 into AS/NZS 2327 for the designer using AS/NZS 2327 to understand the general seismic design and analysis philosophy without referring to NZS 3404. This is particularly important for designers in Australia who may not be familiar with the requirements in NZS 3404.

X.3 Methods of Analysis and Design

This section covers the methods of analysis and design. The approach is in keeping with NZS 3404. The effect of concrete encasement and interaction with the floor slabs on frame stiffness and earthquake response are to be considered by the designer.

The clauses pertaining to composite members from Appendix N of NZS 3404 are proposed to be included. Appendix N of NZS 3404 provides composite section properties to be used in ultimate and serviceability limit state calculations for deflection. For beams composite over the midspan region with shear connectors terminated at a distance of 1.5d away from the face of support there is a simple approach where the bare steel beam stiffness (I value) is increased by 20% for ULS and 30% for SLS based on (Morrison, 1974). It is proposed that this be replaced by a simple equation to determine an equivalent constant second moment of area I_{eq} for the entire span as follows:

$$I_{eq} = 0.6I_1 + 0.4I_2 \tag{1}$$

where

I_1 = second moment of area in positive (sagging) bending (uncracked section) using an effective width on each side of the web as given in Table 1

I_2 = second moment of area in negative (hogging) bending (cracked section) using an effective width on each side of the web as given in Table 1

The research used as the basis for this approach is described in (Plumier and Doneau, 2001). The report presents research activities on the seismic behaviour of composite steel concrete moment frames coordinated in Europe within the ICONS project. That research was used to develop design rules in Eurocode 8: *Design of structures for earthquake resistance*.

Table 1: Effective width b_{eff} of slab on each side of web for elastic analysis of the structure

Location	**Transverse element**	**b_e for I (Elastic)**
At interior column	Present or not present	For negative M: 0.05 L For positive M: 0.0375 L
At exterior column	Present	
At exterior column	Not present, or re-bars not anchored	For negative M: 0 For positive M: 0.025 L

The location of interior and exterior columns, transverse elements as described in table 1 are identified in figure 1

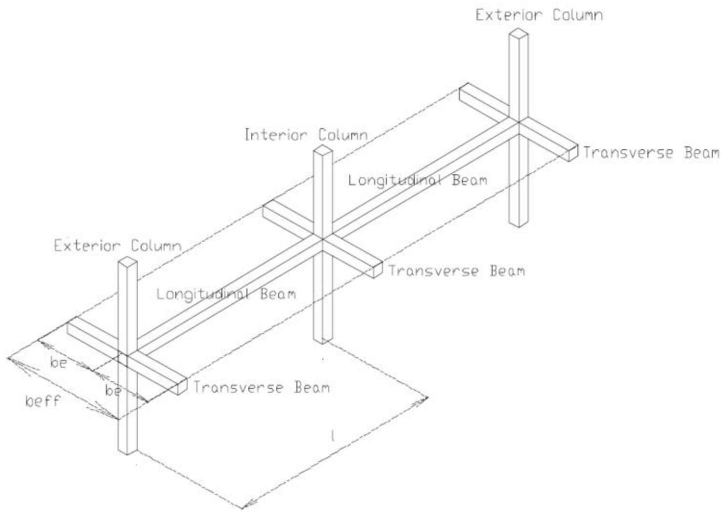

Figure 1: Definition of elements in moment frame structures (Plumier and Doneau, 2001)

For composite columns the flexural stiffness is cross referenced back to the general composite column flexural stiffness equation in AS/NZS 2327.

X.4 Material Requirements

This section will cover the material requirements for structural steel, concrete and reinforcing for composite structures. Material requirements have been taken from NZS 3404 and NZS 3101. The structural steel components of composite steel members subject to ductility demands that may form plastic hinges are to meet the material requirements for seismic category 1 or 2 members in NZS 3404. The specified concrete strength is limited to 70 MPa for ductile elements and elements of limited ductility. Reinforcing bars are to conform to AS/NZS 4671 and be ductility Class E.

X.5 Design and Detailing of Composite Members

This section will cover the design and detailing requirements of composite slab diaphragms, composite beams with shear connectors, composite encased steel beams, composite concrete encased composite steel columns and composite concrete filled structural hollow steel sections.

Composite slabs are to be designed, where required, to transfer horizontal seismic induced diaphragm shear actions into supporting beams. The determination of diaphragm forces was considered by the committee to be best covered by the Loadings Standard, NZS 1170.5. The shear strength of composite diaphragm is taken as the nominal shear strength of the reinforced concrete above the top of the steel deck ribs.

NZS 3404 section 13 detailing requirements for composite beams have been included. The major change from NZS 3404 is that provisions only cover composite beams designed for inelastic action when composite action is curtailed adjacent to the support. In the region where composite action is curtailed the design is based on the steel beam alone. This approach reflects the practice in New Zealand.

The current approach in NZS 3404 section 13 for composite concrete encased columns designed for earthquake actions will be included. This approach requires composite encased columns to be designed in accordance with NZS 3101 provided some minimum reinforcement requirements are also met.

The section geometry requirements for composite concrete filled structural hollow steel sections for the various seismic members are included. Currently in NZS 3404 the limiting width to thickness ratios are the same for all seismic member categories. These limits are not as tight as other international standards. To be consistent with the general composite column section in AS/NZS 2327 and reflecting international standards it is proposed the section geometry limits be modified from what is currently in NZS 3404 section 13 to that shown in table.

Table 2: Proposed limiting width-to-thickness ratios for elements in composite members subject to earthquake loads or effects

Description of element	Width to thickness ratio	Ductile, category 1 members λ_{e1}	Limited, ductile category 2 members λ_{e2}	Nominally ductile category 3 members λ_{e3}	Elastic category 4 members λ_{e4}
Walls of composite filled rectangular members	b/t	$1.4\sqrt{\frac{E}{f_y}}$	$2.26\sqrt{\frac{E}{f_y}}$	$2.26\sqrt{\frac{E}{f_y}}$	$3.00\sqrt{\frac{E}{f_y}}$
Walls of composite filled circular members	D/t	$\frac{0.076E}{f_y}$	$\frac{0.09E}{f_y}$	$\frac{0.15E}{f_y}$	$\frac{0.15E}{f_y}$

It is proposed the nominal shear strength of the composite concrete filled structural hollow steel sections column is taken as the nominal shear strength of the structural steel section alone, based on its effective shear area.

X.6 Connections

This short section will cover the design and detailing requirements of connections in composite structures. It is proposed that this include general connection design philosophy, design actions for connectors and connection components, principles of moment resisting beam to column connections, column splices and column bases. Reference to NZS 3404 will be made where applicable.

X.7 Composite Moment Resisting Framed Seismic Systems

This section will cover the design of composite moment resisting framed seismic systems. Composite moment resisting frames are moment frames that consist of composite columns and either structural steel or composite beams. It proposed that this section will include some of requirements in NZS 3404 section 12, in particular clauses relating to composite, but will also reference back to NZS 3404.

The section will include provisions to determine the overstrength capacity design actions on the column for the presence of the slab on the steel beam.

It is proposed that this section also include a reference to the design of semi-rigid moment resisting seismic systems. This is intended to cover the sliding hinge moment connection used in a number of projects in New Zealand.

X.8 Composite Eccentrically Braced Framed Seismic Resisting Systems

This section will cover the design of composite eccentrically braced resisting framed seismic systems. Columns shall be encased composite or filled composite. Beams shall be structural steel or composite beams. Links shall be structural steel. Braces shall be structural steel or filled composite members.

This section will refer extensively back to NZS 3404.

X.9 Composite Concentrically Braced Framed Seismic Resisting Systems

This section will cover the design of composite concentrically braced resisting framed seismic systems. Columns shall be encased or filled composite. Beams shall be either structural steel or composite beams. Braces shall be structural steel. It is proposed that this section is brief and will reference the requirements in NZS 3404.

Summary

This paper has provided some background to the development of the seismic provision in a joint Australian/New Zealand standard on composite structures, namely AS/NZS 2327 Composite Structures. The structure and scope of the proposed seismic section in AS/NZS 2327 has been provided. The implications for the seismic design of composite structures in New Zealand have been highlighted. The general design and philosophy approach for seismic design of composite structures in New Zealand remains the same. By including the New Zealand seismic requirements in the proposed new AS/NZS 2327 composite standard enables the complete removal of the composite section 13 in NZS 3404 for a possible future jointing of the New Zealand and Australian Steel Structures Standard.

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Acknowledgment

This paper has been prepared by the author and is meant to be an informative exercise to outline the scope and structure of the proposed seismic requirements in AS/NZS 2327 Composite Structures Standard. The final standard is subject to committee decisions and the public comment phase and thus information herein is subject to change. The input of all the Australian and New Zealand nominating organisations has also been extremely valuable in ensuring that this project received the support in the proposal and drafting stages. We look forward to being able to communicate the progress of this project.

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