Steel Reinforcement Institute of Australia

ISSUE No 43/3 September 2017

# STRUCTURAL INTEGRITY REINFORCEMENT

The ACI Standards requires structural integrity reinforcement in both slab/column and beam/column connections as it will substantially enhance the overall integrity of a structure and increase the resistance of the structural system to progressive collapse. Only minor changes are required in the detailing of reinforcement and connections to achieve significant improvements in the robustness of the structure.

**For slabs**, according to Clause 6.3 of ACI 352.1R-11, at connections without beams, continuous bottom slab reinforcement passing within the column core in each principle direction should have an area not less than:

$$A_{sm} = \frac{0.5 w_u l_1 l_2}{\phi f_y}$$

Where $\phi = 0.9$, $w_u$ = factored uniformly distributed load, but not less than two times the slab dead load (N/mm$^2$), $l_1$ = length of span in direction that moments are being determined, measured centre to centre of supports (mm) and $l_2$ = length of span in direction perpendicular to, $l_1$, measured centre to centre of supports (mm).

If bars can only be placed in one direction (due to say a penetration), then provide $2A_{sm}$ in that direction. For perimeter columns, provide two thirds of $A_{sm}$ perpendicular to the slab edge and for corner columns, provide $0.5A_{sm}$ in each principle direction (see **Figure 1**).

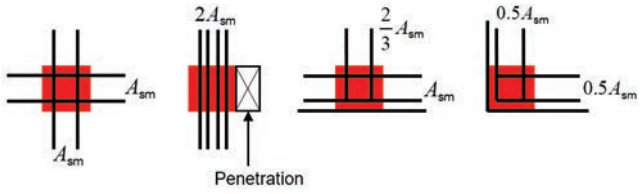


**Figure 1** Arrangement of structural integrity reinforcement

If beam depths at the column/support are at least two times the slab depth, then adequate structural integrity is provided by following the recommendation in ACI 318M-14 for the transverse beams.

**For beams,** structural integrity reinforcement mainly involves providing continuity of both the top and bottom reinforcement, so that if a support is damaged, some catenary action can be provided so that the structure has a higher probability of maintaining overall stability.

Clause 9.7.7 of ACI 318R-14 requires one half of the top flexural reinforcement (which is typically terminated past the point of inflexion), to be extended and spliced at or near midspan. Note that Clauses 8.1.10.1 and 8.1.10.3 of AS 3600 only requires one third of the total negative moment tensile reinforcement to be extended for either a minimum distance $D + L_{sy,t}$ past the theoretical cut off point or $D$ past the point of contra-flexure respectively.

Similarly, rather than simply extending the required bottom reinforcement into the support, it should be made continuous, or spliced with bottom reinforcement from the adjacent span. If the beam depth changes, the bottom bars of the deeper beam are terminated into the support and the bottom reinforcement of the shallower beam is extended into and fully developed in the deeper member.

Clause 8.1.10.4(a) of AS 3600 outlines the minimum required reinforcement that must be anchored at a simple support. For continuous supports, Clause 8.1.10.4(b) requires one quarter of the total positive reinforcement required at midspan to continue past the near face of the support. Rather than just extending this reinforcement past the near face of the support, ACI 318R-14 requires that it be spliced with the bottom reinforcement from the adjacent span to provide continuity.

Also, longitudinal beam bars should be confined by fitments over the length of the support, as it has been shown that top reinforcement may tear out of the concrete if not adequately confined.

The provision of well anchored and/or continuous bottom bars to prevent progressive collapse is well recognised and therefore encouraged in every reinforced concrete structure.

# ANCHORAGE OF FITMENTS IN BEAMS

Whether columns or beams, fitments must be adequately anchored to allow the bars to achieve strength over relatively short distances. The commentary to ACI 318M-14 Clause 25.7 states that fitments should be 'extended as close as practicable to the compression face of the member because, near ultimate load, the flexural tension cracks penetrate deeply toward the compression zone.' Also, 'the lack of a standard fitment hook may make the stirrup ineffective as it crosses shear cracks near the end of the stirrup'.

Clause 8.1.10.7 of AS 3600 states that 'compressive reinforcement required for strength in beams shall be adequately restrained by fitments in accordance with Clause 10.7.4', which details the requirements for fitments in columns. When considering fitments in accordance with Clause 10.7.4, be aware that internal fitments having a cog at one end may not be suitable for beams.

To improve the effectiveness of the anchorage, it is generally regarded as desirable to anchor the typical 135° fitment hooks in the compression zone, which is unlikely to crack and thus influence the anchorage. While this is generally not a problem in columns, for beams, problems arise in regions of negative moment. So where should fitment hooks be located?

The ACI commentary to Clause 25.7 states that 'A longitudinal bar within a fitment hook limits the width of any flexural cracks, even in a tension zone' and that 'such a fitment hook cannot fail by splitting parallel to the plane of the hooked bar'. This suggests that while cracking may occur in negative moment regions of a beam, to place all hooks consistently along the top edge of the beam is still a satisfactory practice.

Steel Reinforcement Institute of Australia

If a slab exists at the top of the beam, the logical location for fitment hooks is on the slab side of the beam, as concrete in this area is unlikely to spall off in an extreme event. With no slab, either one of the top two corners of the beam would generally be preferred as this is generally the compression zone.

# UPDATES

### AS 3600 Concrete structures

Expected to be released for public comment late August with publication expected in late-2017 for referencing in NCC 2019.

### AS/NZS 4671 Steel reinforcing materials

Work is continuing on development of a proposal to update various sections of the Standard for lodgement with Standards Australia in 2017.

### AS/NZS 1554.3 Structural steel welding – Welding of reinforcing steel

Revised text amendments are expected to be published in 2017.

### Technical Note TN7

This Technical Note which is intended to reduce the time required to determine the tensile development and lap lengths for reinforcing bars, and includes valuable background information and worked examples is available for free download from the SRIA website.

# SEISMIC DESIGN AND DETAILING OF REINFORCED CONCRETE BUILDINGS IN AUSTRALIA


For those interested in learning more about this essential topic, the SRIA has produced the *Guide to Seismic Design and Detailing of Reinforced Concrete Buildings in Australia*. The publication is available as a free download from the SRIA website, or for purchase as a hardcopy for a nominal cost of $37.00 including delivery anywhere within Australia.

A webinar covering this topic, which is based on a successful National Seminar Series with the CIA and AEES, is also available from the CIA website (www.concreteinstitute.com.au)


**For further information the SRIA can be contacted through its national office:**

**Executive Director: Scott Munter**
**National Engineer: Eric Lume**

t 02 9144 2602
f 02 9449 6459
e info@sria.com.au

Pymble Corporate Centre
Suite 1 Level 1 Building 1
20 Bridge St
Pymble NSW 2073


# SRIA REGISTRATION FORM

To keep informed of the most recent industry developments, releases and presentations on steel reinforcement and to maintain your professional development, register now for the SRIA website database. Your details will remain highly confidential and we will ensure your reinforcement knowledge remains up-to-date.

You may register online at **www.sria.com.au/registration.html**

or fill out your details below :

**Title:** ❑ Mr ❑ Mrs ❑ Ms ❑ Dr

**First name:** _____

**Last name:** _____

**Position:** _____

**Company:** _____

**Postal address:** _____

_____

**Phone number (work):** _____

**Mobile Phone number:** _____

**Email:** _____

Or email, fax or post your details to SRIA National Office:

Post: PO Box 418 Roseville NSW 2069
Fax: 02 9449 6459
Email: info@sria.com.au

# PRIVACY STATEMENT:

SRIA will only collect information that is necessary for communication. By submitting your contact details you agree that the measures that SRIA take with respect to privacy and the disclosure of information as expressed in the privacy statement on the SRIA website are reasonable and that you consent to the scope of the disclosure being proposed.