No further reproduction or distribution is permitted.

CODE

zone by an amount equal to $M_u/(0.9df_y)$, where M_u occurs simultaneously with T_u at that section, except that the longitudinal reinforcement area shall not be less than the minimum required in 9.6.4.

9.5.4.6 For solid sections with an aspect ratio $h/b_t \geq 3$, it shall be permitted to use an alternative design procedure, provided the adequacy of the procedure has been shown by analysis and substantial agreement with results of comprehensive tests. The minimum reinforcement requirements of 9.6.4 need not be satisfied, but the detailing requirements of 9.7.5 and 9.7.6.3 apply.

9.5.4.7 For solid precast sections with an aspect ratio $h/b_t \geq 4.5$, it shall be permitted to use an alternative design procedure and open web reinforcement, provided the adequacy of the procedure and reinforcement have been shown by analysis and substantial agreement with results of comprehensive tests. The minimum reinforcement requirements of 9.6.4 and detailing requirements of 9.7.5 and 9.7.6.3 need not be satisfied.

9.6—Reinforcement limits

9.6.1 *Minimum flexural reinforcement in nonprestressed beams*

9.6.1.1 A minimum area of flexural reinforcement, $A_{s,min}$, shall be provided at every section where tension reinforcement is required by analysis.

9.6.1.2 $A_{s,min}$ shall be the larger of (a) and (b), except as provided in 9.6.1.3. For a statically determinate beam with a flange in tension, the value of b_w shall be the smaller of b_f and $2b_w$. The value of f_y shall be limited to a maximum of 550 MPa.

(a) $\dfrac{0.25\sqrt{f'_c}}{f_y} b_w d$

COMMENTARY

allowing a reduction in the longitudinal torsional reinforcement required in the compression zone.

R9.5.4.6 An example of an alternative design that satisfies this provision can be found in Zia and Hsu (2004), which has been extensively and successfully used for design of precast, prestressed concrete spandrel beams with $h/b_t \geq 3$ and closed stirrups. The seventh edition of the *PCI Design Handbook* (PCI MNL-120) describes the procedure of Zia and Hsu (2004). This procedure was experimentally verified by the tests described in Klein (1986).

R9.5.4.7 The experimental results described in Lucier et al. (2011a) demonstrate that properly designed open web reinforcement is a safe and effective alternative to traditional closed stirrups for precast spandrels with $h/b_t \geq 4.5$. Lucier et al. (2011b) presents a design procedure that satisfies this provision for slender spandrels and describes the limited conditions to which the procedure applies.

R9.6—Reinforcement limits

R9.6.1 *Minimum flexural reinforcement in nonprestressed beams*

R9.6.1.1 This provision is intended to result in flexural strength exceeding the cracking strength by a margin. The objective is to produce a beam that will be able to sustain loading after the onset of flexural cracking, with visible cracking and deflection, thereby warning of possible overload. Beams with less reinforcement may sustain sudden failure with the onset of flexural cracking.

In practice, this provision only controls reinforcement design for beams which, for architectural or other reasons, are larger in cross section than required for strength. With a small amount of tension reinforcement required for strength, the calculated moment strength of a reinforced concrete section using cracked section analysis becomes less than that of the corresponding unreinforced concrete section calculated from its modulus of rupture. Failure in such a case could occur at first cracking and without warning. To prevent such a failure, a minimum amount of tension reinforcement is required in both positive and negative moment regions.

R9.6.1.2 If the flange of a section is in tension, the amount of tension reinforcement needed to make the strength of the reinforced section equal that of the unreinforced section is approximately twice that for a rectangular section or that of a flanged section with the flange in compression. A larger amount of minimum tension reinforcement is particularly necessary in cantilevers and other statically determinate beams where there is no possibility for redistribution of moments.

American Concrete Institute – Copyrighted © Material – www.concrete.org