CODE

23.4.3 Effective compressive strength of concrete in a strut, f_{ce}, shall be calculated by:

$$f_{ce} = 0.85\,\beta_c\beta_s f_c' \qquad (23.4.3)$$

where β_s is in accordance with Table 23.4.3(a) and β_c is in accordance with Table 23.4.3(b).

Table 23.4.3(a)—Strut coefficient β_s

Strut location	Strut type	Criteria	β_s	
Tension members or tension zones of members	Any	All cases	0.4	(a)
All other cases	Boundary struts	All cases	1.0	(b)
	Interior struts	Reinforcement satisfying (a) or (b) of Table 23.5.1	0.75	(c)
		Located in regions satisfying 23.4.4	0.75	(d)
		Beam-column joints	0.75	(e)
		All other cases	0.4	(f)

Table 23.4.3(b)—Strut and node confinement modification factor β_c

Location	β_c		
• End of a strut connected to a node that includes a bearing surface • Node that includes a bearing surface	Lesser of	$\sqrt{A_2/A_1}$, where A_1 is defined by the bearing surface	(a)
		2.0	(b)
Other cases	1.0		(c)

23.4.4 If use of β_s of 0.75 is based on line (d) of Table 23.4.3(a), member dimensions shall be selected to satisfy Eq. (23.4.4), where λ_s is defined in 23.4.4.1.

$$V_u \le 0.42\phi \tan\theta\lambda\lambda_s\sqrt{f_c'}b_w d \qquad (23.4.4)$$

COMMENTARY

R23.4.3 The strength coefficient $\mathbf{0.85}f_c'$ in Eq. (23.4.3) represents the effective concrete strength under sustained compression, similar to that used in Eq. (22.4.2.2) and (22.4.2.3).

The value of β_s in (a) of Table 23.4.3(a) applies, for example, to a transverse model of a ledger beam used to proportion hanger and ledge reinforcement, where longitudinal tension in the flange reduces the strength of the transverse struts. The low value of β_s reflects that these struts need to transfer compression in a zone where tensile stresses act perpendicular to the plane of the strut-and-tie model.

The value of β_s in (b) of Table 23.4.3(a) applies to a boundary strut and results in a stress state that is comparable to the rectangular stress block in the compression zone of a beam or column. Boundary struts are not subject to transverse tension and therefore have a higher effective strength, f_{ce}, than interior struts (Fig. R23.2.1).

The value of β_s in (c) of Table 23.4.3(a) reflects the beneficial effect of distributed reinforcement.

The value of β_s in (d) of Table 23.4.3(a) applies to interior struts in regions with sufficient diagonal tension strength to satisfy Eq. (23.4.4).

The value of β_s in (e) of Table 23.4.3(a) reflects the requirements for reinforcement or confinement of beam-column joints in Chapter 15.

The value of β_s in (f) of Table 23.4.3(a) is reduced to preclude diagonal tension failure in regions without transverse reinforcement that do not meet or are not evaluated under 23.4.4. Evaluation of test results from the ACI shear database for members without transverse reinforcement indicates that diagonal tension failures are precluded if struts are proportioned based on β_s of 0.4 (Reineck and Todisco 2014). The ACI shear database includes test results for specimens with an average d of 380 mm and not exceeding 960 mm; therefore, size effect would not be expected to significantly reduce the strength of members of this size. Because size effect may be significant for deeper members without transverse reinforcement, evaluation in accordance with Eq. (23.4.4) is considered appropriate.

The influence of concrete confinement on the effective compressive strength of a strut or node is taken into account by β_c. The bearing surface can be a bearing plate or the area from a well-defined compressive load from another member, such as a column. It is the same confining effect as used for bearing areas in 22.8.3. The increase in compressive strength associated with the confinement provided by surrounding concrete for a strut-and-tie model is described by Tuchscherer et al. (2010) and Breen et al. (1994).

R23.4.4 Equation (23.4.4) is intended to preclude diagonal tension failure. In discontinuity regions, diagonal tension strength increases as the strut angle increases. For very steeply inclined struts, V_u can exceed $\mathbf{0.83}\phi\lambda\lambda_s\sqrt{f_c'}\,b_w d$.