CODE

23.2.10 Brackets and corbels with shear span-to-depth ratio $a_v/d < 2.0$ designed using the strut-and-tie method shall satisfy 16.5.2, 16.5.6, and Eq. (23.2.10).

$$A_{sc} \geq 0.04(f_c'/f_y)(b_w d) \qquad (23.2.10)$$

23.2.11 The shear friction requirements of 22.9 shall apply where it is appropriate to consider shear transfer across any given plane, such as an existing or potential crack, an interface between dissimilar materials, or an interface between two concretes cast at different times.

23.2.12 Members designed using strut-and-tie models that are part of seismic-force-resisting system shall meet the additional requirements of 23.11, if applicable.

23.3—Design strength

23.3.1 For each applicable factored load combination, design strength of each strut, tie, and nodal zone in a strut-and-tie model shall satisfy $\phi S_n \geq U$, including (a) through (c):

(a) Struts: $\phi F_{ns} \geq F_{us}$
(b) Ties: $\phi F_{nt} \geq F_{ut}$
(c) Nodal zones: $\phi F_{nn} \geq F_{un}$

23.3.2 ϕ shall be in accordance with 21.2.

23.4—Strength of struts

23.4.1 The nominal compressive strength of a strut, F_{ns}, shall be calculated by (a) or (b):

(a) Strut without longitudinal reinforcement

$$F_{ns} = f_{ce} A_{cs} \qquad (23.4.1a)$$

(b) Strut with longitudinal reinforcement

$$F_{ns} = f_{ce} A_{cs} + A_s' f_s' \qquad (23.4.1b)$$

where F_{ns} shall be evaluated at each end of the strut and taken as the lesser value; A_{cs} is the cross-sectional area at the end of the strut under consideration; f_{ce} is given in 23.4.3; A_s' is the area of compression reinforcement along the length of the strut; and f_s' is the stress in the compression reinforcement at the nominal axial strength of the strut. It shall be permitted to take f_s' equal to f_y for Grade 280 or 420 reinforcement.

23.4.2 Effective compressive strength of concrete in a strut, f_{ce}, shall be calculated in accordance with 23.4.3 or 23.4.4.

COMMENTARY

R23.2.11 A construction joint between a corbel and face of a column is an example of an interface where the shear friction requirements of 22.9 apply.

R23.3—Design strength

R23.3.1 Factored loads are applied to the strut-and-tie model, and the forces in all the struts, ties, and nodal zones are calculated. If several load combinations exist, each should be investigated separately. For a given strut, tie, or nodal zone, F_u is the largest force in that element for all load combinations considered.

R23.4—Strength of struts

R23.4.1 The width of strut, w_s, used to calculate A_{cs} is the dimension perpendicular to the axis of the strut at the ends of the strut. This strut width is illustrated in Fig. R23.2.6a(i) and Fig. R23.2.6b. If two-dimensional strut-and-tie models are appropriate, such as for deep beams, the thickness of the struts may be taken as the width of the member except at bearing supports where the thickness of the strut must equal the least thickness of the member or supporting element.

The contribution of reinforcement to the strength of the strut is given by the last term in Eq. (23.4.1b). The stress f_s' in the reinforcement in a strut at nominal strength can be obtained from the strains in the strut when the strut crushes. Detailing requirements in 23.6 must be met including confinement reinforcement to prevent buckling of the strut reinforcement.

R23.4.2 In design, struts are usually idealized as prismatic compression members. If the area of a strut differs at its two ends, due either to different nodal zone strengths at the two ends or to different bearing lengths, the strut is idealized as a uniformly tapered compression member.