CODE

23.4.4.1 The size effect modification factor, λ_s, shall be determined by (a) or (b), as applicable:

(a) If distributed reinforcement is provided in accordance with 23.5, λ_s shall be taken as 1.0.
(b) If distributed reinforcement is not provided in accordance with 23.5, λ_s shall be taken in accordance with Eq. (23.4.4.1).

$$\lambda_s = \sqrt{\frac{2}{1+0.004d}} \leq 1 \qquad (23.4.4.1)$$

23.5—Minimum distributed reinforcement

23.5.1 In D-regions designed using the strut-and-tie method, minimum distributed reinforcement shall be provided across the axes of interior struts in accordance with Table 23.5.1.

Table 23.5.1—Minimum distributed reinforcement

Lateral restraint of strut	Reinforcement configuration	Minimum distributed reinforcement ratio	
Not restrained	Orthogonal grid	0.0025 in each direction	(a)
	Reinforcement in one direction crossing strut at angle α_1	$\dfrac{0.0025}{\sin^2\alpha_1}$	(b)
Restrained	Distributed reinforcement not required		(c)

23.5.2 Distributed reinforcement required by 23.5.1 shall satisfy (a) and (b):

(a) Spacing shall not exceed 300 mm
(b) Angle α_1 shall not be less than 40 degrees.

23.5.3 Struts are considered laterally restrained if they are restrained perpendicular to the plane of the strut-and-tie model in accordance with (a), (b), or (c):

(a) The discontinuity region is continuous perpendicular to the plane of the strut-and-tie model.
(b) The concrete restraining the strut extends beyond each side face of the strut a distance not less than half the width of the strut.
(c) The strut is in a joint that is restrained in accordance with 15.2.5 or 15.2.6.

23.5.4 Reinforcement required in 23.5.1 shall be developed beyond the extent of the strut in accordance with 25.4.

COMMENTARY

R23.5—Minimum distributed reinforcement

The strut-and-tie method is derived from the lower-bound theorem of plasticity; therefore, a member designed using this method requires sufficient reinforcement to promote redistribution of the internal forces in the cracked state (Marti 1985). In addition to allowing force redistribution, distributed reinforcement controls cracking at service loads and promotes ductile behavior (Smith and Vantsiotis 1982; Rogoswky and MacGregor 1986; Tan et al. 1977).

Interior struts are typically oriented parallel to compression fields and are therefore oriented perpendicular to diagonal tension fields. Tensile stresses across the strut may also develop where compressive stress at the node spreads out along the length of a strut. Minimum distributed reinforcement helps control cracking from these tensile stresses.

The distributed reinforcement ratio required by 23.5.1 is the total on both faces plus any interior layers placed in wide members. Figure R23.5.1 illustrates unidirectional distributed reinforcement crossing interior struts at angle α_1.

Although minimum distributed reinforcement is not required where interior struts are laterally restrained, distributed reinforcement may be beneficial in large discontinuity regions. A continuous corbel supporting a slab is an example of a discontinuity region that includes struts that are laterally restrained in accordance with 23.5.3(a). Pile caps and beam ledges supporting concentrated loads are examples of discontinuity regions that include struts that are laterally restrained in accordance with 23.5.3(b). The side faces of the strut in 23.5.3(b) are the faces parallel to the plane of the model. For pile caps evaluated using three-dimensional strut-and-tie models, the plane of the model in 23.5.3 is defined by the strut in question and the pile to which it connects.