CODE

COMMENTARY

strength of a reinforced concrete section equal that of an unreinforced section is about twice that for a rectangular section or that of a T-section with the flange in compression. It was concluded that this higher amount is necessary, particularly for cantilevers and other statically determinate situations where the flange is in tension.

10.5.3 — The requirements of 10.5.1 and 10.5.2 need not be applied if at every section the area of tensile reinforcement provided is at least one-third greater than that required by analysis.

R10.5.3 — The minimum reinforcement required by Eq. (10-3) or (10-4) must be provided wherever reinforcement is needed, except where such reinforcement is at least one-third greater than that required by analysis. This exception provides sufficient additional reinforcement in large members where the amount required by 10.5.1 or 10.5.2 would be excessive.

10.5.4 — For structural slabs and footings of uniform thickness the minimum area of tensile reinforcement in the direction of the span shall be the same as that required by 7.12. Maximum spacing of this reinforcement shall not exceed the lesser of three times the thickness and 18 in.

R10.5.4 — The minimum reinforcement required for slabs should be equal to the same amount as that required by 7.12 for shrinkage and temperature reinforcement.

Soil-supported slabs such as slabs on grade are not considered to be structural slabs in the context of this section, unless they transmit vertical loads from other parts of the structure to the soil. Reinforcement, if any, in soil-supported slabs should be proportioned with due consideration of all design forces. Mat foundations and other slabs which help support the structure vertically should meet the requirements of this section.

In reevaluating the overall treatment of 10.5, the maximum spacing for reinforcement in structural slabs (including footings) was reduced from the $5h$ for temperature and shrinkage reinforcement to the compromise value of $3h$, which is somewhat larger than the $2h$ limit of 13.3.2 for two-way slab systems.

10.6 — Distribution of flexural reinforcement in beams and one-way slabs

10.6.1 — This section prescribes rules for distribution of flexural reinforcement to control flexural cracking in beams and in one-way slabs (slabs reinforced to resist flexural stresses in only one direction).

R10.6 — Distribution of flexural reinforcement in beams and one-way slabs

R10.6.1 — Many structures designed by working stress methods and with low steel stress served their intended functions with very limited flexural cracking. When high strength reinforcing steels are used at high service load stresses, however, visible cracks must be expected, and steps must be taken in detailing of the reinforcement to control cracking. To assure protection of reinforcement against corrosion, and for aesthetic reasons, many fine hairline cracks are preferable to a few wide cracks.

Control of cracking is particularly important when reinforcement with a yield strength in excess of 40,000 psi is used. Current good detailing practices will usually lead to adequate crack control even when reinforcement of 60,000 psi yield is used.

Extensive laboratory work[10.12-10.14] involving modern deformed bars has confirmed that crack width at service

CODE

COMMENTARY

loads is proportional to steel stress. However, the significant variables reflecting steel detailing were found to be thickness of concrete cover and the area of concrete in the zone of maximum tension surrounding each individual reinforcing bar.

Crack width is inherently subject to wide scatter even in careful laboratory work and is influenced by shrinkage and other time-dependent effects. The best crack control is obtained when the steel reinforcement is well distributed over the zone of maximum concrete tension.

10.6.2 — Distribution of flexural reinforcement in two-way slabs shall be as required by 13.3.

10.6.3 — Flexural tension reinforcement shall be well distributed within maximum flexural tension zones of a member cross section as required by 10.6.4.

R10.6.3 — Several bars at moderate spacing are much more effective in controlling cracking than one or two larger bars of equivalent area.

10.6.4 — When design yield strength f_y for tension reinforcement exceeds 40,000 psi, cross sections of maximum positive and negative moment shall be so proportioned that the quantity z given by

$$z = f_s \sqrt[3]{d_c A} \tag{10-5}$$

does not exceed 175 kips/in. for interior exposure and 145 kips/in. for exterior exposure. Calculated stress in reinforcement at service load f_s (kips/in.^{2}) shall be computed as the moment divided by the product of steel area and internal moment arm. Alternatively, it shall be permitted to take f_s as 60 percent of specified yield strength f_y.

R10.6.4 — Eq. (10-5) will provide a distribution that will reasonably control flexural cracking. The equation is written in a form emphasizing reinforcement details rather than crack width w, per se. It is based on the Gergely-Lutz expression:

$$w = 0.076\beta f_s \sqrt[3]{d_c A}$$

in which w is in units of 0.001 in. To simplify practical design, an approximate value of 1.2 is used for β (ratio of distances to the neutral axis from the extreme tension fiber and from the centroid of the main reinforcement). Laboratory tests[10.15] have shown that the Gergely-Lutz expression

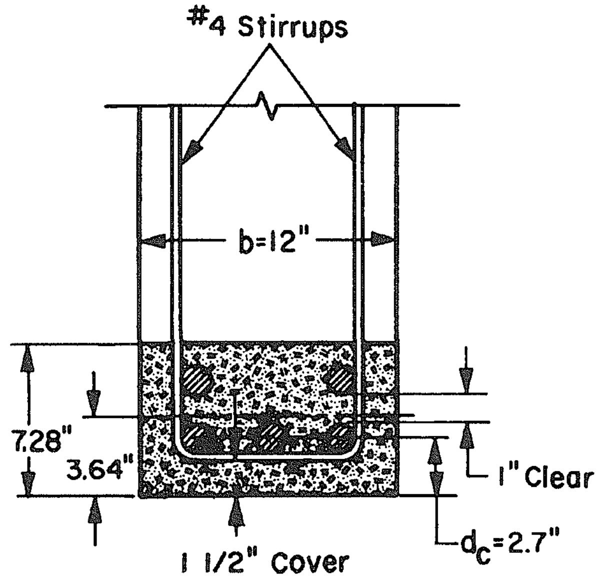

Fig. R10.6.4—Effective tension area of concrete (beam with five No. 11 bars) applies reasonably to one-way slabs. The average ratio β is about 1.35 for floor slabs, rather than the value 1.2 used for beams. Accordingly it would be consistent to reduce the maximum values for z by the factor 1.2/1.35.

The numerical limitations of z = **175 and 145** kips/in. for interior and exterior exposure, respectively, correspond to limiting crack widths of 0.016 and 0.013 in.

The effective tension area of concrete surrounding the principal reinforcement is defined as having the same centroid as the reinforcement. Moreover, this area is to be bounded by the surfaces of the cross section and a straight line parallel to the neutral axis. Computation of the effective area per bar, A (see notation definition), is illustrated by the example shown in Fig. R10.6.4 in which the centroid of the main reinforcement is located 3.64 in. from the bottom of the beam. The effective tension area is then taken as twice 3.64 in. times the beam width $\boldsymbol{b}$. Divided by the number of bars, this gives 17.6 in.^{2} per bar.

10.6.5 — Provisions of 10.6.4 are not sufficient for structures subject to very aggressive exposure or designed to be watertight. For such structures, special investigations and precautions are required.

R10.6.5 — Although a number of studies have been conducted, clear experimental evidence is not available regarding the crack width beyond which a corrosion danger exists. Exposure tests indicate that concrete quality, adequate compaction, and ample concrete cover may be of greater importance for corrosion protection than crack width at the concrete surface. The limiting values for z were, therefore, chosen primarily to give reasonable reinforcement details in terms of practical experiences with existing structures.

10.6.6 — Where flanges of T-beam construction are in tension, part of the flexural tension reinforcement shall be distributed over an effective flange width as defined in 8.10, or a width equal to $^1/_{10}$ the span, whichever is smaller. If the effective flange width exceeds $^1/_{10}$ the span, some longitudinal reinforcement shall be provided in the outer portions of the flange.

R10.6.6 — In major T-beams, distribution of the negative reinforcement for control of cracking must take into account two considerations: (1) wide spacing of the reinforcement across the full effective width of flange may cause some wide cracks to form in the slab near the web and, (2) close spacing near the web leaves the outer regions of the flange unprotected. The $^1/_{10}$ limitation is to guard against too wide a spacing, with some additional reinforcement required to protect the outer portions of the flange.

10.6.7 — If the effective depth $\boldsymbol{d}$ of a beam or joist exceeds 36 in., longitudinal skin reinforcement shall be uniformly distributed along both side faces of the member for a distance $\boldsymbol{d/2}$ nearest the flexural tension reinforcement. The area of skin reinforcement $\boldsymbol{A_{sk}}$ per foot of height on each side face shall be $\geq 0.012(\boldsymbol{d}-\mathbf{30})$. The maximum spacing of the skin reinforcement shall not exceed the lesser of $\boldsymbol{d/6}$ and 12 in. It shall be permitted to include such reinforcement in strength computations if a strain compatibility analysis is made to determine stress in the individual bars or wires. The total area of longitudinal skin reinforcement in both faces need not exceed one-half of the required flexural tensile reinforcement.

R10.6.7 — For relatively deep flexural members, some reinforcement should be placed near the vertical faces in the tension zone to control cracking in the web. Without such auxiliary steel, the width of the cracks in the web may greatly exceed the crack widths at the level of the flexural tension reinforcement.

The requirements for skin reinforcement were modified in the 1989 edition of the code, as the previous requirements were found to be inadequate in some cases. See Reference 10.16. For lightly reinforced members, these requirements may be reduced to one-half of the main flexural reinforcement. Where the provisions for deep beams, walls, or precast panels require more steel, those provisions (along with their spacing requirements) will govern.