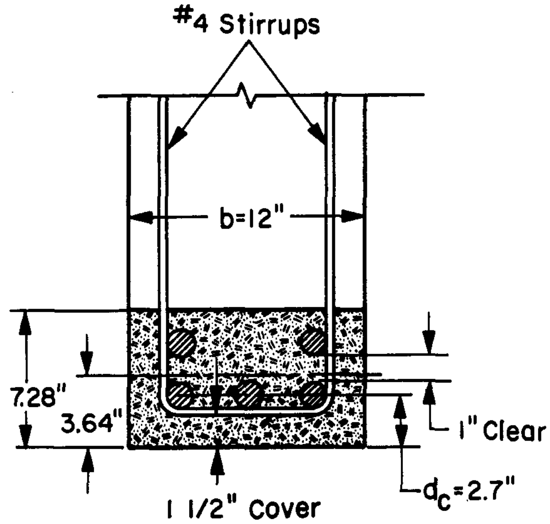

Fig. 10-2 – Effective tension area of concrete (beam with five #11 bars)

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 reinforcing details in terms of practical experiences with existing structures.

10.6.6 – 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 – 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.

10.7 – Deep flexural members

The code does not contain detailed requirements for designing deep beams for flexure except that nonlinearity of strain distribution and lateral buckling must be considered.

Suggestions for the design of deep beams for flexure are given in References 10.13, 10.14, and 10.15.

10.8 – Design dimensions for compression members

With the 1971 edition of the ACI Building Code (ACI 318-71), minimum sizes for compression members were eliminated to allow wider utilization of reinforced concrete compression members in smaller size and lightly loaded structures, such as low rise residential and light office buildings. The engineer should recognize the need for careful workmanship, as well as the increased significance of shrinkage stresses with small sections.

10.8.2, 10.8.3, 10.8.4 – For column design,[10.16] the code provisions for quantity of reinforcement, both vertical and spiral, are based on the gross column area and core area, and the design strength of the column is based on the gross area of the column section. In some cases, however, the gross area is larger than necessary to carry the factored load. The basis of Sections 10.8.2, 10.8.3, and 10.8.4 is that it is satisfactory to design a column of sufficient size to carry the factored load and then simply add concrete around the designed section without increasing the reinforcement to meet the minimum percentages required by Section 10.9.1. The additional concrete must not be considered as carrying load; however, the effects of the additional concrete on member stiffness must be included in the structural analysis. The effects of the additional concrete also must be considered in design of the other parts of the structure that interact with the oversize member.

10.9 – Limits for reinforcement of compression members

10.9.1 – This section prescribes the limits on the amount of longitudinal reinforcement for noncomposite compression members. If the use of high reinforcement ratios would involve practical difficulties in the placing of concrete, a lower percentage and hence a larger column, or higher strength concrete or reinforcement (see Commentary Section 9.4) should be considered. The percentage of reinforcement in columns should usually not exceed 4 percent if the column bars are required to be lap spliced.

Minimum reinforcement. Since the design methods for columns incorporate separate terms for the load carried by concrete and by reinforcement, it is necessary to specify some minimum amount of reinforcement to insure that only reinforced concrete columns are designed by these procedures. Reinforcement is necessary to provide resistance to bending, which may exist whether or not computations show that bending exists, and to reduce the effects of creep and shrinkage of the concrete under sustained compressive stresses. Tests have shown that creep and shrinkage tend to transfer load from the concrete to the reinforcement, with a consequent increase in stress in the reinforcement, and that this increase is greater as the ratio of reinforcement decreases. Unless a lower limit is placed on this ratio, the stress in the reinforcement may increase to the yield level under sustained service loads. This phenomenon was emphasized in the report of ACI Committee 105[10.17] and minimum reinforcement ratios of 0.01 and 0.005 were recommended for spiral and tied columns, respectively. However, in all editions of the code since 1936, the minimum ratio has been 0.01 for both types of laterally reinforced columns.

Maximum reinforcement. Extensive tests of the ACI column investigation[10.17] included reinforcement ratios no greater than 0.06. Although other tests with as much as 17 percent reinforcement in the form of bars produced results similar to those obtained previously, it is necessary to note that the loads in these tests were applied through bearing plates on the ends of the columns and the problem of transferring a proportional amount of the load to the bars was thus minimized or avoided. Maximum ratios of 0.08 and 0.03 were recommended by ACI Committee 105[10.17] for spiral and tied columns, respectively. In the 1936 ACI Building Code, these limits were made 0.08 and 0.04, respectively. In the 1956 code, the limit for tied columns with bending was raised to 0.08. Since the 1963 code, it has been required that bending be considered in the design of all columns, and the maximum ratio of 0.08 has been applied to both types of columns. This limit can be considered a practical maximum for reinforcement in terms of economy and requirements for placing.

10.9.2 – This section requires a minimum of six bars for circular compression members and four for rectangular compression members. For other shapes, one bar should be provided at each apex or corner, and proper lateral reinforcement provided. For example, tied triangular columns should contain at least three bars.

10.9.3 – The effect of spiral reinforcement in increasing the load-carrying strength of the concrete within the core is not realized until the column has been subjected to a load and deformation sufficient to cause the concrete shell outside the core to spall off. The amount of spiral reinforcement required by Eq. (10-5) is intended to provide additional load-carrying strength for concentrically loaded columns equal to or slightly greater than the strength lost when the shell spalls off. This principle was recommended by ACI Committee 105[10.17] and has been a part of the code since 1963. The derivation of Eq. (10-5) is given in the ACI Committee 105 report. Tests and experience show that columns containing the amount of spiral reinforcement required by this section exhibit considerable toughness and ductility.

10.10 – Slenderness effects in compression members

The ACI Building Code provisions for slenderness evaluation of reinforced concrete members were entirely rewritten with the 1971 code, based on recommendations of ACI-ASCE Committee 441, Reinforced Concrete Columns.[10.18] This recommendation called for the use of improved structural analysis procedures wherever possible or practical (Section 10.10.1). In lieu of such improved analysis the code provides for an approximate design method (Section 10.11) based on a moment magnifier principle and similar to the procedure used as part of the American Institute of Steel Construction specifications.[10.19] After study of the normal range of variables in column design, limits of applicability were set which eliminate from consideration as slender columns a large percentage of columns in braced frames and substantial numbers of columns in unbraced frames. The accuracy of the approximate design procedure was established through a series of comparisons with analytical and test results. Over the total range of slender compression members, the proposed procedure is more rational, more accurate, and more consistent than the reduction factor method used in earlier ACI Building Codes. Because the moment magnification method calls attention to the basic phenomenon in slender compression members and allows an evaluation of the additional moment requirements in restraining members, a superior and safer design results.

Because results of an extensive series of studies of slender compression members in frames[10.20] indicated that a somewhat modified and carefully limited reduction factor method could give reasonable accuracy in treatment of slenderness effects, such a procedure is included in this Commentary. See "Modified R Method" at end of the commentary discussion for Section 10.11.

10.10.1 – The 1971 ACI Building Code encouraged the use of second-order frame analyses or $P\Delta$ analyses which include the effects of sway deflections on the axial loads and moments in a frame. Since publication of ACI 318-71, this subject has been studied extensively and it is now feasible for a designer to use a second-order analysis in the design of reinforced concrete