TN501_EC2_min_rebar_1

MINIMUM REINFORCEMENT IN PRESTRESSED SLABS

Using EC2

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EC2[2] has two provisions for the minimum reinforcement of concrete slabs. One covers the adverse effects of concrete shrinkage[3] . The other is for the satisfactory distribution of applied load[4]. This Technical Note explains the background and application of the former.

Concrete slabs shrink. If slab supports restrain the shrinkage shortening, tensile stresses develop. when tensile stress exceeds the axial tension capacity of the slab, shrinkage cracks form.

Shrinkage cracks convey the sense of inadequacy; they can be unsightly; expose the reinforcement to the elements of corrosion; and possibly lead to ingress of water.

The two common schemes to control shrinkage cracking are:

(i) addition of a minimum amount of nonprestressed reinforcement distributed throughout the slab; or
(ii) provision of precompression not less than the amount of the force that the first option is deemed to generate.

Application of both options, and their combinations, as a third option (iii) are detailed in ACI 318[5].

EC2 does not cover the design of post-tensioned slabs in detail. Many design and detailing scenarios are left to the judgment of the design engineer. Minimum shrinkage reinforcement for “post-tensioned floors” is one such example. This leaves the engineers to refer to other building codes, or specialist literature to handle the scenario.

The EC2 provision of minimum rebar for shrinkage control is[i]:

$$A_{s\,min} = 0.0013 b_t d \qquad \text{(Exp. 1)}$$

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[2] EC2 EN 1992 -1-1 2004 (E)
[3] EC2 EN 1992 -1-1 2004 (E); 9.2.1.1
[4] EC2 EN 1992 -1-1 2004 (E); 9.3.1.1
[5] ACI 318-11 (§7.12.2)

where,
b_t = width of the section; and
d = distance of compression fiber to farthest reinforcement.

ACI-318 covers the scenario of precompression providing, or supplementing, the intended function of nonprestressed shrinkage reinforcement.

ACI 318[6] provision is expressed by the graph shown in Fig. 1.

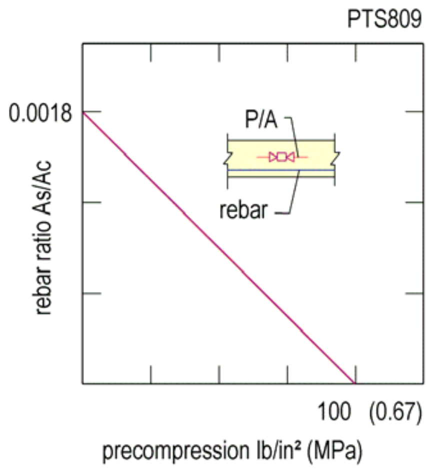

FIGURE 1 Minimum Shrinkage and Temperature Reinforcement for Concrete Members
Nonprestressed reinforcement, prestressing, or a combination of the two can be used to meet the minimum requirements
ACI 318-11 (§7.12.2)

The graph of Fig. 1 is based on the following relationship:

$$(P/A)/0.67 + (A_s/A_c)/0.0018 \geq 1 \qquad \text{(Exp 2)}$$

P/A = average precompression in MPa;
A_s = cross-sectional area of nonprestressed steel; and
A_c = cross-sectional area of concrete.

The direct application of Exp 2 in EC2 designs is feasible, but cumbersome. The following is the reason.

In ACI 318-based designs, at the “minimum reinforcement” design step, the value of the precompression (*P/A*) is a known quantity. Hence, it can readily be checked.

In EC2-based designs (*P/A*) is not a design parameter. Its explicit calculation will pose additional computational effort. However, in EC2-based-designs, the amount of post-tensioning, hence its cross-sectional

6 ACI 318-11 (§7.12.2)

area (A_{ps}) is known. It is more expedient to account for the contribution of precompression in terms of the known parameter A_{ps} , as opposed to *P/A* when using EC2.

The contribution of precompression associated with A_{ps} can conservatively be accounted for in EC2 deigns as follows

The contribution of nonprestressed reinforcement in service condition to counteract cracking is generally considered at stress level equivalent to 0.5 of its yield stress[7].

The yield stress of common nonprestressed reinforcement used in building construction has range of:

f_y = 400 to 500 MPa

Hence, the upper value at which the contribution of nonprestressed reinforcement for shrinkage control is accounted for is of the order of

Design stress at crack for nonprestressed rebar: 0.5x500 = 250 MPa

At service condition, the effective stress in prestressing steel is generally given by[8]:

Unbonded tendons *fse* = 1,100 MPa
Bonded tendons *fse* = 1,000 MPa

The ratio of stress that bonded tendons provide in service condition compared to nonprestressed reinforcement for shrinkage control is:

f_{se}/f_s =1000/250 = 4

For unbonded tendons, the contribution will be slightly higher

Ratio of yield stress of prestressing tendons to nonprestressed reinforcement is approximately[9]

f_{pk}/f_{yk} = 1860/450 = 4.1

It is concluded that the ratio of the yield stress of prestressing to nonprestressed reinforcement can approximate the contribution of prestressing steel in providing precompression in the amount that nonprestressed reinforcement is rated to provide for shrinkage control.

From the preceding, it is concluded that the contribution of prestressing to minimum reinforcement of concrete slabs can be conservatively approximated by the following relationship.

$$A_{s,\min} = A_s + \left(\frac{f_{pk}}{f_{yk}}\right)A_{ps} \geq 0.0013 b_t d \qquad \text{(Exp 3)}$$

[7] ACI 318-11 318-11 18.9.3.2
[8] Book “Post-Tensioned Buildings; Design and Construction,” by Bijan Aalami; www.PT-Structures.com
[9] The actual values vary. The above is an approximation to arrive at a simplified safe relationship

Where,

A_{ps} = area of prestressed steel.