MINIMUM PRECOMPRESSION IN POST-TENSIONED MEMBERS

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“Average Minimum Precompression,” as it appears in ACI-318 is a notional value that in today’s Code serves as a guide in selection of prestressing and reinforcement. It is not a required value in absolute terms of the three central Code compliance checks, namely:

- Serviceability Limit State (SLS)
- Ultimate (strength) Limit State (ULS)
- Initial Condition (transfer of prestressing force).

None of the major building codes have a requirement for a minimum average precompression to be provided by prestressed reinforcement, since the intent of the ACI-318’s stipulation in other major codes is accounted for through other provisions.

This Technical Note explains the background, significance, and the application of the “average precompression” in post-tensioned floor systems, when designed according to ACI-318 (IBC).

HISTORICAL BACKGROUND

In early 1970s, the tests that were conducted on flat slabs and were being used as background to ACI-318 had an average precompression of 125 psi (0.84 MPa). This precompression was considered to have had beneficial effects in the punching shear performance of the tests. As a result, for satisfactory punching shear design in two-way slab construction the requirement of 125 psi (0.84 MPa) was introduced in the Code. The provision neither applied to beams, nor one-way slab systems. Today also, it does not apply to either of the two structural systems.

Later, the design for punching shear was refined to account explicitly for the presence or absence of precompression at the columns slab junction, thus rendering the original intent of the minimum precompression redundant.

CURRENT SIGNIFICANCE OF MINIMUM AVERAGE PRECOMPRESSION

Today, the ACI-318 provision for a minimum average precompression in post-tensioned slabs serves the means by which the Code guarantees a minimum amount of reinforcement. Other major building codes, such as European EC2, or British BS8110, do so by stipulating specific values for minimum reinforcement, as opposed to minimum precompression. The minimum reinforcement in the latter

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3 ACI-318 Chapter 18
codes can be provided by prestressing steel, or a combination of prestressing steel and non-prestressed reinforcement.

In principle, a satisfactory design can be achieved for a floor slab containing only a small amount of post-tensioning, if adequate supplemental non-prestressed reinforcement is provided. It is not the level of precompression that guarantees the serviceability and safety of a slab. Rather, it is the entirety of prestressing and non-prestressed reinforcement, in amount and distribution that governs the satisfactory performance of a post-tensioned floor system.

Unlike other major building codes, the provisions for design of post-tensioned slabs in ACI 318 (Chapter 18) are exclusive. There are options that are not permitted for non-prestressed slabs. Contrary to the current trend of thought among leading design engineers, where prestressed and non-prestressed members are viewed and designed in the same manner - as “structural concrete,” ACI-318 in Chapter 18 makes a clear distinction between the design of “prestressed” and “conventionally” reinforced concrete. ACI-318’s distinction is heading to be replaced with design procedures that offer unified transition between non-prestressed and prestressed members, whereby eliminating the explicit requirement of “minimum average precompression.”

As an example, using ACI 318 it is permissible to design a column-supported (two-way) floor slab with no bottom non-prestressed reinforcement. Also, it is permissible to design a slab with a bonded post-tensioning system having neither top nor bottom non-prestressed reinforcement. In order to insure the adequacy of design, ACI 318 imposes a minimum amount of tensioned steel to control cracking. In today’s code, the minimum amount of tensioned steel and its distribution are controlled through the requirement for average precompression. In other words, the requirement of the minimum precompression indirectly addresses a serviceability item that is not spelled out in the Code explicitly. The provision of minimum total reinforcement in the European Code (EC2) or the British BS8110 follow in effect the same concept as “minimum average precompression” in ACI-318, with the difference that the former are explicit and more general.

CODE COMPLIANCE

For compliance with the intent of ACI-318 (IBC) Codes with respect to minimum average precompression and two-way floor systems design, apart from the serviceably, strength and initial condition checks, it is sufficient if:

(i) The total area of prestressed and non-prestressed reinforcement in each “design section” satisfies the shrinkage and temperature requirements. This is expressed as follows:

(a) In the absence of prestressing strands, the reinforcement ratio for each design section shall not be less than 0.0018 for steel Grade 60 (460 MPa) or better. This is expressed as follows:

\[ \frac{A_s}{A_{c}} = > 0.0018 \]

Where;
\[ A_{c} = \text{area of design section (tributary of a design strip)}; \]
\[ A_s = \text{area of non-prestressed steel in design section}; \]

(b) where prestressing strands are used, the reinforcement ratio for each design section shall not be less than

\[ \frac{[A_s + A_{ps} (f_{py}/f_{y})]}{A_{c}} = > 0.0018 \]
Where;

\[ A_{ps} = \text{area of prestressing steel in design section}; \]
\[ f_y = \text{yield stress of non-prestressed steel}; \]
\[ f_{pu} = \text{yield stress of prestressing steel, measured at 0.35 percent elongation}. \]

While the presence of an average precompression not less than 100 psi (0.68 MPa) is deemed adequate for temperature and shrinkage performance of a design section, in practice a design section must be provided with reinforcement to meet other requirements of the Code, such as ultimate limit state. An average precompression of 100 psi (0.68 MPa) is generally not adequate for full Code compliance of a "design section."

(ii) The punching shear design at column slab junction recognizes the presence/absence and level of average precompression over the column region.

**CALCULATION OF AVERAGE PRECOMPRESSION**

For ACI-318 (IBC) Code compliance, the average precompression is associated with a “design section” – not a point. It is important to note that in practical post-tensioned floor systems, the actual value of precompression greatly varies from point to point. At discontinuities and around openings the precompression can drop significantly, and possibly reduce to tension in direction of applied prestressing.

At a design section, the average precompression is calculated using the “effective area” of both non-prestressed and prestressed reinforcement, and the cross-sectional area of the design section \( (A_c) \) according to the relationships (1) or (2). For this purpose, the effective area is defined as the sum of the area of each reinforcement times the cosine of the angle it makes with normal to the design section (Fig. 1). In Fig. 1 the effective area of the prestressing and non-prestressed steel shown are respectively \( A_{ps} \cdot \cos(\theta_{ps}) \) and \( A_s \cdot \cos(\theta_s) \).

![FIGURE 1 PLAN - DESIGN SECTION WITH INTERSECTING TENDON AND REBAR](image-url)