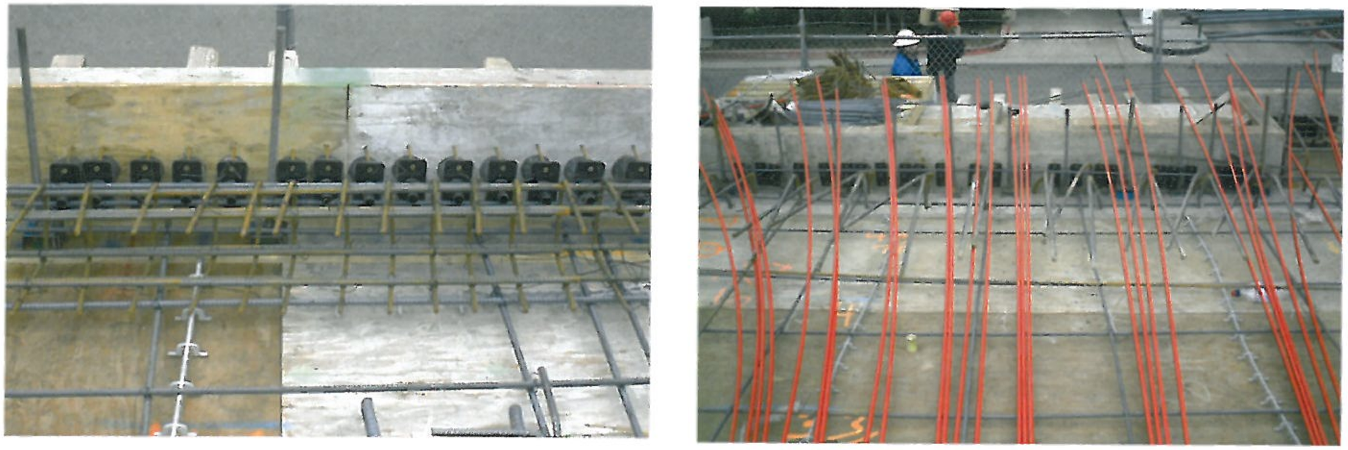


(a) Live ends are secured to the bulkhead and provided with anti-bursting reinforcement (P419)

(b) Tendons are lined up with the anchorage devices, ready to be cut and threaded through (P421)

FIGURE 2.5.1C-4

FIGURE 2.5.1C-5 Tendons are secured in Position and Height to Support Bars (P420)

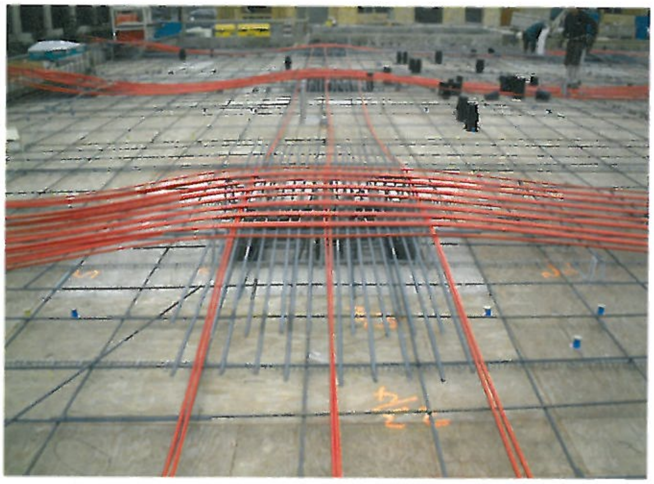


FIGURE 2.5.1C-6 Positioning of Grouped Tendons over the Supports (P422)

(a) Minimum of two tendons over support (P423)

(b) Distributed tendons placed parallel (P424)

FIGURE 2.5.1C-7 Distributed Tendons are Placed, with Minimum of Two Strands over Each Support.

frame as a set of self-equilibrating external actions. Only where all the components of the balanced loading are properly represented and are in static equilibrium, will the calculated hyperstatic actions be in self-equilibrium and correct.

The hyperstatic reactions calculated above are next applied to the member to determine the distribution of the hyperstatic moment and shear along the member (Fig. 4.11.2.2A-3). At any distance Xi, as shown in the figure, the hyperstatic shear is simply the algebraic sum of all reactions, and the hyperstatic moment is the moment of all actions. The relationships are as follows:

$$V_{hyp} = \sum R_i \qquad \text{(Exp. 4.11.2.2A-1)}$$

$$M_{hyp} = \sum [M_{ti} + M_{bi}] + (R_i X_i) \qquad \text{(Exp. 4.11.2.2A-2)}$$

Where,

M_{ti}, M_{bi} and R_i = support reactions due to post-tensioning;

X_i = distance to the section under consideration.

B. Indirect Method: The indirect method is a procedure commonly used for the calculation of hyperstatic moments in skeletal structures. It is based on the following relationship:

$$M_{hyp} = M_{bal} - P \times e \qquad \text{(Exp 4.11.2.2B-1)}$$

Where,

e = eccentricity of post-tensioning/prestressing with respect to the neutral axis of the section (positive if CGS is above the neutral axis, otherwise negative);

M_{hyp} = hyperstatic moment;

M_{bal} = balanced moment due to balanced loading; and

P = post-tensioning/prestressing force (positive).

In this relationship, moments causing tension at the bottom fiber are assumed positive. The hyperstatic reactions and shears are then calculated from the hyperstatic moments.

The indirect method (Exp 4.11.2.2B-1) does not apply to members, such as floor systems, where prestressing force can disperse into a structure beyond the strip/section isolated for design. This will be explained in greater detail next.

Consider Fig. 4.11.2.2B-1. It illustrates a post-tensioned member supported on rollers. Following the load balancing procedure, we remove the tendon from its housing and replace it by the forces that the tendon exerted when in place. This is illustrated in Fig. 4.11.2.2B-2a. The loading shown in this diagram is the "balanced loading." In this example, it is comprised of upward and downward forces resulting from tendon segments, as well as a constant compression force P. Part (b) of the figure shows the forces on the extracted tendon. Evidently, the loads shown in part (a) and (b) of the figure are equal and opposite of one another.

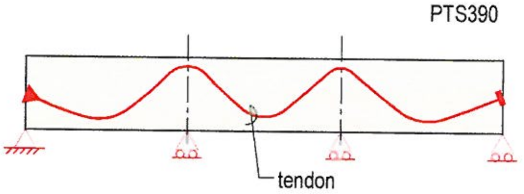
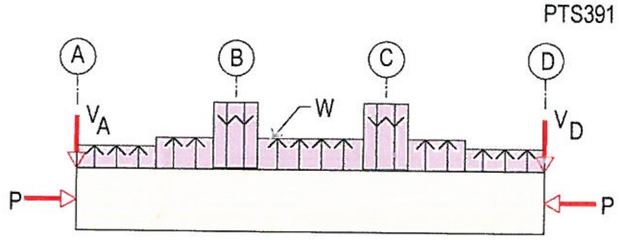
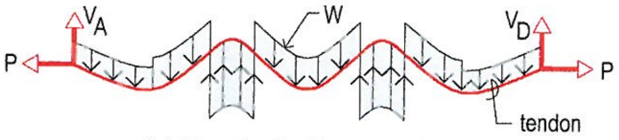


FIGURE 4.11.2.2B-1 Post-Tensioned Member on Supports



(a) Free body diagram of member - tendon removed



(b) Free body diagram of tendon

FIGURE 4.11.2.2B-2 Illustration of Force System Between Tendon and Member

4.10.4 TR43 Crack Control; Stress Check; Non-prestressed Rebar

TR43 [TR43, 2005] is a report generated by the Concrete Society in the UK[58]. It includes practical recommendations for design of post-tensioned floor systems in building construction. Material related to TR43 is included in the International Edition of this book.

4.10.5 Significance of Allowable Stresses and Guidelines for Code Compliance

4.10.5.1 Background: Initiation of cracking and its control is achieved through "computed" tensile stresses at the extreme fiber of a member. For code compliance, the extreme fiber tensile stress is calculated using the gross cross-sectional parameters of the member, even when a section is deemed to have cracked. In common practice, the presence of reinforcement in sharing the actions on the concrete section, and thereby reducing the tensile stresses is generally not accounted for. Simply, the extreme fiber stress is computed, considering the entire cross-sectional area covered by concrete. The following relationship is used.

$$f=\left(\frac{P}{A}+\frac{Mc}{I}\right) \qquad \text{(Exp 4.10.5.1-1)}$$

Where,

f = computed extreme fiber stress;
P = axial force;
A = gross cross-sectional area of concrete section;
M = applied moment;
I = second moment of area; and
c = distance from the centroid of the section to the extreme tension fiber.

The computed stress neither represents the value at the tip of a crack, nor is it the average stress on the section. It is referred to as "hypothetical" stress, used as an indicator for expediency and the type of remedial measure, if any.

4.10.5.2 Extreme Fiber Stress and Cracking: For sections similar to those shown in Fig. 4.10.5.2 -1, cracking initiates when the extreme fiber stress (f_t) exceeds the cracking stress of concrete. Once cracked, the computed crack width is generally determined based on several parameters of the section, such as stress in reinforcement, distance of crack location to the next bar, bar diameter. The relationships commonly used are detailed in Section 4.10.3. A numerical example for crack-width computation is given in Chapter 7. The focus of this Section is the practical significance and application of the hypothetical tensile stresses. Figure 4.10.5.2-1 identifies two of the parameters, namely cover to the reinforcement, and distance of a point on the member soffit to the nearest reinforcing bar.

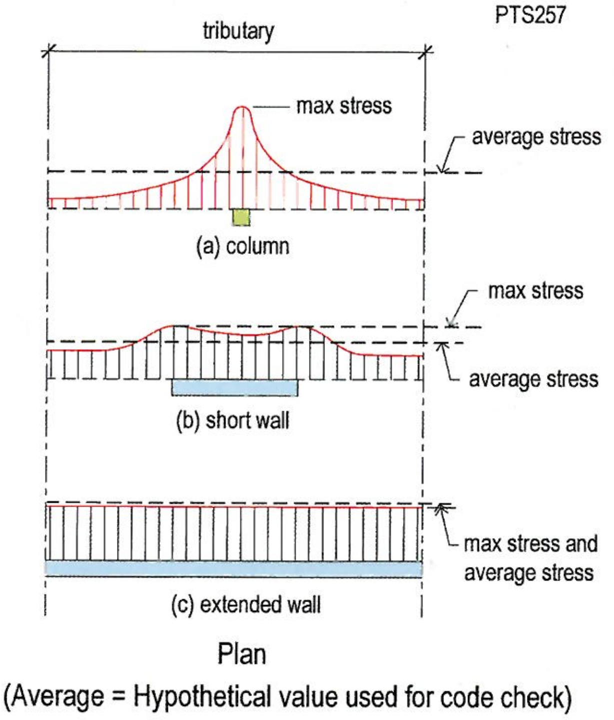


FIGURE 4.10.5.3A-2 Distribution of Maximum Bending Stress in a Design Strip

4.10.5.3 Significance of Computed Crack Width: The reliability of computed crack width depends on (i) the accuracy with which the tensile stress (f_t) at the "point" of interest is estimated, and (ii) among other parameters, the "distance" between the point selected for evaluation and the nearest reinforcement (Fig.4.10.5.2-1).

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[58] The Concrete Society, Post-Tensioned Concrete Floors: Design Handbook, No. 43; pp. 110; 2005

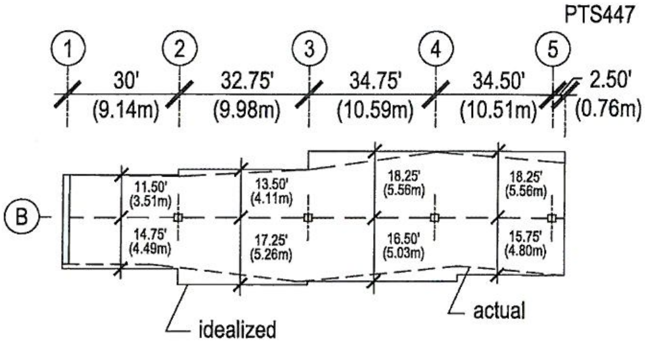
the extracted design strip are adjusted to the maximum width of the respective span on each side of the support line. The dimensions of the final design strip are shown in Figs. 1.4-1.

For gravity design of the structure, the practice in selection of boundary conditions of the extracted design strip is verbalized in ACI/IBC as follows. The strip is modeled with one level of supports immediately above and below the level under consideration. The far ends of the supports are assumed fixed against rotation.

The elevation of the idealized design strip and a three dimensional view of it are shown in Figs. 1.4-2 and 1.4-3

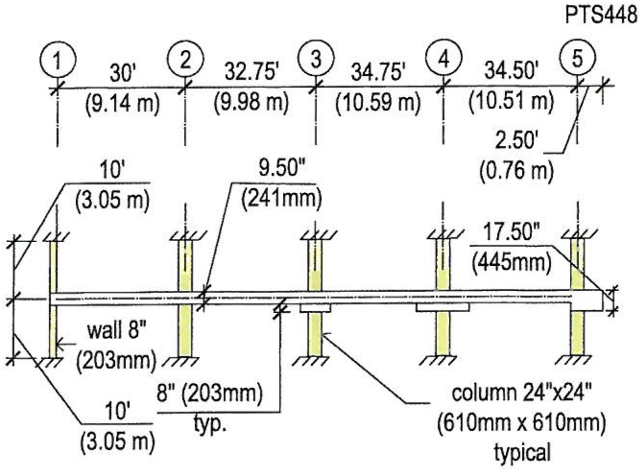
❖ Section properties:

The section properties of each span are calculated using the gross cross-sectional area of the idealized design strip as shown in Figs. 1.4-1 and 1.4-2. The values of the controlling locations are summarized in Table 1.4-1.



Plan of Design Strip B

FIGURE 1.4-1



Design Strip in Elevation

FIGURE 1.4-2

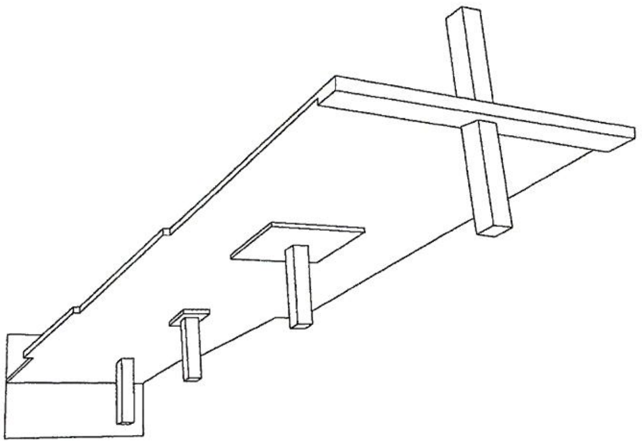


FIGURE 1.4-3 View of Design Strip (P473)

The stiffening of the slab due to the added thickness of the column drops and drop panels are accounted for in the calculation through their section properties. In SFM adopted in this example, the added stiffness in the slab immediately over the support is not included in the analysis. However, the EFM of analysis acounts for the aforementioned increase in stiffness.

2 - MATERIAL PROPERTIES

2.1 Concrete

f'c, fck (28 day cylinder strength)[6] = 5000 psi (34.47 MPa)

Weight = 150 pcf

Elastic Modulus = $57000\sqrt{f'c}$ = 4,030.50 ksi [ACI]

= $22 * 10^{3*} [(f_{ck} + 8)/ 10]^{0.3}$ [7] [EC2]

= 33,950.59 MPa [4,924 ksi]

Creep/shrinkage coefficient = 2

Material factor, γc = 1 for ACI; 1.50 for EC2

The creep/shrinkage coefficient is used to estimate the long-term deflection of the slab.

2.2 Nonprestressed (Passive) Reinforcement:

f_y = 60 ksi

Elastic Modulus = 29,000 ksi

Material factor, γc = 1 for ACI; 1.15 for EC2

Strength reduction factor, φ = 0.9 for ACI; 1 for EC2

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[6] fck is the European (EC2) symbol for f'c

[7] EN 1992-1-1:2004(E) Table 3.1

FIGURE 2.5.2C-3 Row of Stressing Pans Next to Wall (P181)

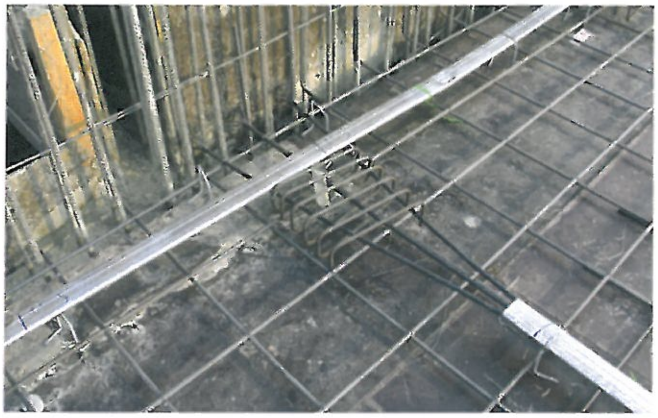

FIGURE 2.5.2C-4 Anti-Bursting Reinforcement behind Anchorage Device (P183)

the author's experience, in most countries it is not common to have an independent agency for quality control. A visit by a representative of the building department prior to placing concrete may be required, but it is often a formality rather than a detailed checking and approving of the reinforcement layout. Inadequate quality control means that problems

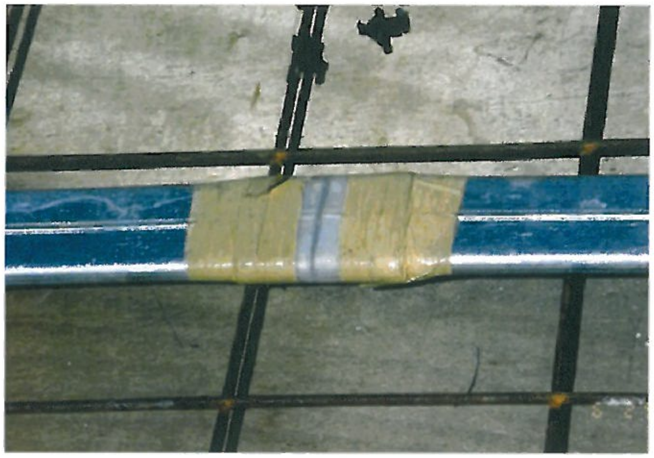

FIGURE 2.5.2C-5 Taped Duct Splice (P184)

FIGURE 2.5.2C-6 Pocket Former for Stressing using Tape Over Styrofoam (MEPS; P185c)

FIGURE 2.5.2C-7 Required Chair Heights are Marked along the Length of Each Tendon (P186)