CRACKING MOMENT AND DESIGN STRENGTH OF POST-TENSIONED MEMBERS

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This Technical Note reviews the calculation of cracking moment of post-tensioned members and its relation to the associated design capacity. The calculation is applied to a rectangular section and the midspan of a single cell box girder bridge. It is concluded that for the conditions investigated, the design capacity of a post-tensioned member exceeds its cracking moment for practical ranges of prestressing. More cases should be analyzed, in order to arrive at a comprehensive conclusion on the relationship between the cracking moment and the design strength of a post-tensioned section.

CRACKING MOMENT

Figure 1 shows the schematic of a section reinforced with a post-tensioned tendon. The stress due to post-tensioning at the bottom fiber is fp (compression). The externally applied moment that would initiate cracking of the section (Mcr) must eliminate the initial compressive stress fp (decompression) and cause a tensile stress ft (cracking stress).

\[ M_{cr} = S*(f_p + f_t) \]

Where, S = section modulus

(i) Generic section with post-tensioning tendons at distance “e” from centroid
(ii) Distribution of stress due to post-tensioning only
(iii) Distribution of stress at initiation of crack

FIGURE 1 POST-TENSIONED SECTION AND DISTRIBUTION OF STRESS

The stress due to post-tensioning is given by:

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fp = P*(1/A + e*c/I)

Where,

P = force due to post-tensioning;
A = area of section;
c = distance of farthest compression fiber from the centroid; and
I = second moment of area of the section.

The cracking stress is ft = 7.5 * f_c^{0.5}

Once the geometry, concrete strength (f'_c), the location and amount of prestressing is known, the cracking moment can be readily calculated.

ASSUMPTIONS OF THIS TECHNICAL NOTE

Concrete strength f'_c = 5000 psi
Hence, cracking stress ft = 7.5*5000^{0.5} = 530 psi

Prestressing system = grouted
Effective stress in prestressing tendon = 175 ksi

The investigation is performed for three values of average precompression, namely 300, 500 and 700 psi. The range of practical interest is around 600 psi.

The distance of tendon from the centroid is another parameter governing the ratio of the design capacity to the cracking moment. Three distances are considered: (i) tendon as close to the compression fiber as practical (largest e/h), (ii) tendon halfway between the centroid of the section and farthest distance to the compression fiber, and (iii) tendon at centroid. Condition (i) with highest e/h is more representative of practical scenarios, where design (demand) moment (Mu) is likely to be highest.

DESIGN CAPACITY (ΦMn)

The design capacity moment is determined from the geometry of the section, its material properties, and the amount and location of prestressing using strain compatibility of the section. Details of the calculation are given in a companion Technical Note1.

RECTANGULAR SECTION

A rectangular section is selected to illustrate the concept, procedure and the characteristics of the results. The section is 12 inch wide and 36 inch deep. For the maximum e/h the distance of tendon centroid from the compression fiber is 1.8 in. The results are shown in Fig. 2.

1 Strain compatibility for design of prestressed sections – ADAPT TN178
Note that in the range of practical interest (e/h = 0.45) and precompression (P/A = 500 psi) the design capacity of the section is well above its cracking moment.

BOX GIRDER

The cross-sectional geometry of the box girder analyzed is shown in Fig. 3. The position of the tendon is varied from its lowest point to the centroid of the cross-section. The results of the analysis are shown in Fig. 4.

The range of practical interest is the when tendon is at its lowest point (high value of e/h) and an average precompression between 600 to 700 psi. For this range, the ratio of the design capacity to cracking moment is well above 1.
FIGURE 3 SECTION OF BOX GIRDER AT MIDSPAN

Mu/Mcr vs e/h curve

- P/A=300 psi
- P/A=500 psi
- P/A=700 psi

SINGLE CELL BOX GIRDER

FIGURE 4 VARIATION OF ΦMn/Mu WITH TENDON ECCENTRICITY

Note: Mu in the diagram represents ΦMn