DETERMINATION OF CRACKING MOMENT
IN ADAPT-PT AND FLOOR PRO

This explains the method used in ADPAT-PT and FLOOR-Pro to determine the initiation of cracking in a member.

There are two ways to determine the initiation of cracking in a prestressed concrete member. One assumes the prestressing to be an integral part of the member - like its geometry, concrete material and reinforcement. The other assumes prestressing to be external to a member, such as dead and live loads. Both can yield the right results when followed through consistently. ADAPT software follows the first scheme, in which prestressing is considered as a part of the member being investigated. The following explains the details

BACKGROUND

Refer to Fig. 1. It shows a concrete member subjected to an external moment. The member will crack under an applied moment Mcr, when tension stress at the farthest fiber reaches the cracking limit (ft). The cracking stress ft is viewed to be a property of concrete. It is independent from the amount and location of reinforcement, be it prestressed or otherwise. The moment (Mcr) that initiates crack in the member is given by:

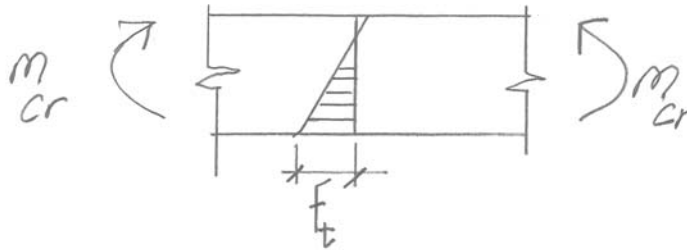$$Mcr = S*ft$$

Where, S is the section modulus of the member

FIGURE 1 MEMBER WITH CRACKING STRESS ft

Next, as an example, the impact of temperature on cracking is reviewed, in order to make it easier to follow the influence of prestressing. Figure 2 shows the same member restrained at the ends and subjected to rise of temperature at the bottom. Temperature rise at the soffit of the member results in a compressive stress (fo) at the farthest fiber. To initiate crack at the bottom fiber of this member the compressive stress fo must first be eliminated, before tension can develop. The moment that causes cracking for this condition is:
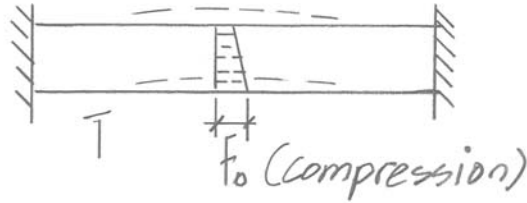
$$M = S (ft + fo)$$

FIGURE 2 RESTRAINED MEMBER WITH RISE OF TEMPERATURE AT BOTTOM

Prestressed members can be viewed in a similar manner, where fo is substituted by fpt from prestressing. Hence the cracking moment of a prestressed member becomes:

$$Mcr = S (ft + fpt)$$

The stress due to prestressing (fpt) is expressed as follows:

$$fpt = Mpt + P/A$$

Where, Mpt is the moment from prestressing. It consists of the primary moment (prestressing force times its eccentricity with respect to the centroid of the section) and the hyperstatic moment caused from the reactions of the member from prestressing.

Once cracking is initiated, its width (w) and depth (a) (Fig. 3) depend, among other parameters, on the amount and location of the reinforcement. The reinforcement generally consists of non-stressed and stressed steel. The contribution of the reinforcement in crack width and depth depends on the location, area and the modulus of elasticity of the reinforcement. The force in prestressing steel does not impact the computations at this stage, using the method described herein.
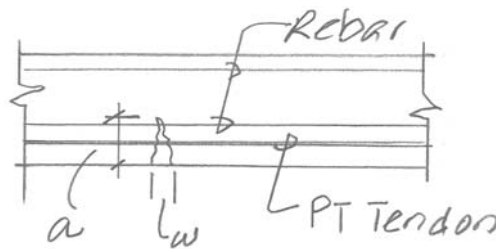

FIGURE 3 CRACKED MEMBER SHOWING WIDTH AND DEPTH OF CRACK

LOAD COMBINATIONS

In this method of calculation, the load combinations for which the initiation of crack is being investigated should include only the externally applied forces. As an example, the load combination for the serviceability limit state of "sustained load" of a prestressed member will be:

1.0DL + 0.3LL

Where DL and LL are dead and live loads. Prestressing is not included . To investigate the cracking of a member under selfweight and its deflection the load combination will be simply:

1.0*(selfweight)

REDUCTION IN STIFFNESS DUE TO CRACKING

The reduction in flexural stiffness due to cracking is implemented through substitution of the original second moment of area of the section (Ig) by a reduced value (Ie). The following relationship is used:

$$Ie = (Mcr/Ma)^3 Ig + [\ 1 - (Mcr/Ma)^3\ ]Icr\ <=\ Ig$$

Where:

Icr = second moment of area of cracked section;
Ie = effective second moment of area;
Ma = applied moment at the section, where cracking occurs; and
Mcr = moment that initiates cracking in the section.

In the calculation of Icr the presence of post-tensioning is accounted for. This is detailed in ADAPT-TN310[1]

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[1] TN310 Implementation of Deflection with Allowance for Flexural Cracking in ADAPT-PT