A PROFESSOR'S PERSPECTIVE

SECONDARY MOMENT EFFECTS

in Continuous Prestressed Concrete Beams

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The topic of secondary moment effects in continuous prestressed concrete beams is one that can be tough to understand at first (or so it seems, based on the looks I get when I first introduce the topic in class). Perhaps we need some solid, practical understanding of how prestressed concrete beams behave before we can really have a feel for how these moments are induced. In this column, I will do my best to give a short introduction to the topic for those familiar with prestressed concrete. Most prestressed concrete textbooks and post-tensioned multispan design examples cover the topic in more detail.

What are secondary moments, and why do I have to deal with them in continuous beams but not simply supported beams?

To answer this question, consider a simply supported prestressed concrete beam such as the one shown in Fig. 1 (top). You can visualize the deflected shape due to prestressing directly or think of the prestress force as a uniform load acting upward on the beam. Either way, this beam is determinant, which means the reaction forces can be calculated by equilibrium alone, and when the prestressing force (load) is applied without external loads, the reactions remain zero.

However, the case is different for an indeterminate structure such as a continuous beam. Figure 1 (bottom) shows the same beam with an intermediate support added. Now, the reactions are affected and the center support keeps the beam from taking its preferred deflected shape. This hold-down reaction induces a moment—specifically, a secondary moment.

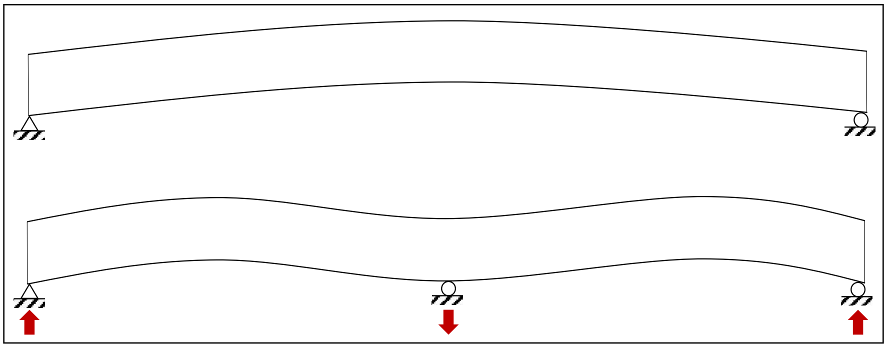
So, what does a secondary moment mean for my calculations?

The secondary moment M_2 can be found by subtracting the primary prestressing moment M_1 (the moment due to the prestressing force applied at an eccentricity) from the total moment due to the prestressing force $M_{total\ PS}$:

$$M_2 = M_{total\ PS} - M_1$$

Figure 2 shows a generic illustration of each of the components of moment due to the prestressing force. The top beam shows a typical tendon profile for a multispan, post-tensioned concrete beam. A uniform load representing this profile can be developed, but a simplified tendon profile is used in this case. We can find the total moment due to the prestressing force directly by applying the equivalent uniform load due to the tendon profile and constructing the moment diagram.

Figure 1. Deflected shapes of determinate and indeterminate beams under prestress. The top figure shows the curvature due to prestress for a simply supported member. The bottom figure shows the curvature and induced reaction due to prestress for a continuous beam. All Figures: Dr. Andrea Schokker.



The primary moment M_1 is simply the prestressing force multiplied by the eccentricity, or:

$$M_1 = Pe$$

where

P = prestressing force

e = eccentricity of the tendon relative to the center of gravity of the cross section

For the example shown in Fig. 2, the ends of the tendon are located at the center of gravity of the section. As expected, the secondary moment diagram has the shape of a moment diagram from a point load (the reaction). The moment diagrams can be taken from an analysis program, but the moment-distribution method can be a useful tool for hand calculations (this is when my students groan, but hand calculations really are a quick method for continuous beams).

For stress calculations, the total moment due to prestressing force is all we need. However, when we consider the required capacity of the section, $øM_n$, we need to consider the effect of the secondary moment separated out because this will influence the factored moment M_u:

$$øM_n \geq M_u - M_2$$

The secondary moment can reduce the required capacity of the section if its effect is the opposite of the effect due to the external loads (such as live and dead loads). As with any calculation, do not use the equations blindly without considering the effect of signs.

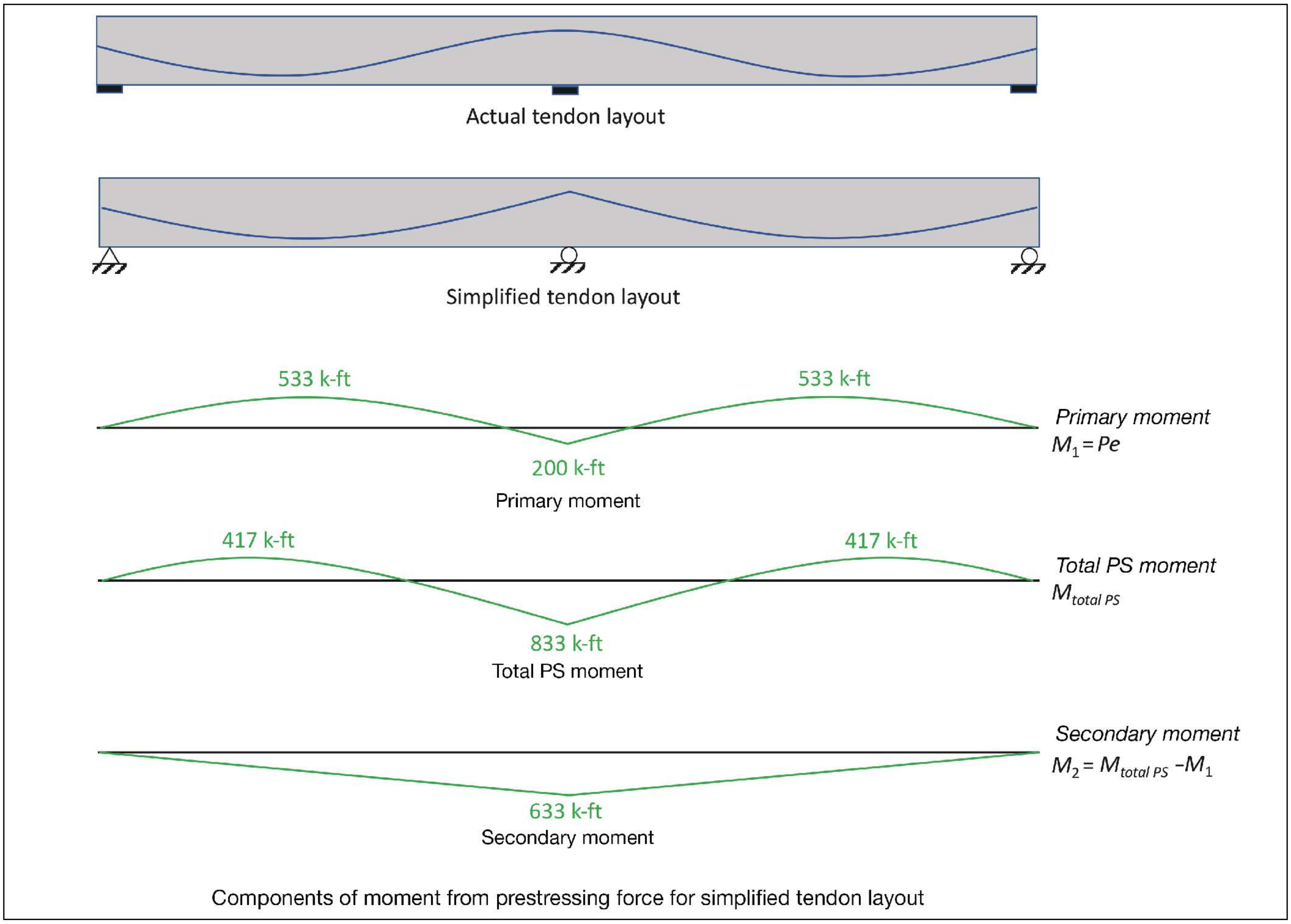


Figure 2. Example of a two-span post-tensioned beam to demonstrate secondary moment. Moments are plotted on tension side, and figures are not to scale.