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Continuous Unbonded Post-Tensioned Concrete
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published in PTI JOURNAL, December 2018, pp. 5-16**

BY KENNETH B. BONDY



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Discussion of “Monitoring Secondary Moments of Continuous Unbonded Post-Tensioned Concrete Beams,” Kyungmin Kim and Thomas H.-K. Kang, published in *PTI JOURNAL*, December 2018, pp. 5-16

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This paper conflicts with the entire history of American post-tensioned concrete building construction, including field experience, research, and engineering logic. Surely if secondary moments were roughly 10 times larger than normally calculated (as the authors allege), that would have been noticed in the last 60 years of indeterminate post-tensioned beam behavior. It never was. Secondary moments were first required to be included in strength calculations by ACI 318-77. Since then, over 40 years ago, they have been calculated for many thousands of indeterminate post-tensioned beams using the authors’ Eq. (10), which is fully detailed and explained in the PTI Post-Tensioning Manual.¹ These existing beams would obviously have exhibited serious deficiencies if the actual secondary moments were in fact 10 times larger than predicted by Eq. (10). Because secondary moments are typically additive to positive (field) moments caused by external dead and live loads, there would be severe cracking problems, deflection problems, and flexural failures in virtually every indeterminate post-tensioned beam ever built. If the authors were correct in their allegations about secondary moments, joint moments in virtually all multi-span post-tensioned beams would reverse and negative moments would no longer exist. In fact, of course, no such pervasive problems related to secondary moments have ever been observed. Considering these facts, one must trust the decades of behavioral observations and not the bizarre allegations of the authors.

As an example, consider a very typical 14 in. (360 mm) wide x 36 in. (910 mm) deep parking structure beam designed in accordance with the International Building Code, with 5000 psi (34 MPa) normalweight concrete,

two equal 65 ft (20 m) spans, spaced at 20 ft (6.1 m) on center with a 5 in. (130 mm) slab between beams, and 18 in. (460 mm) square columns 12 ft (3.7 m) long above and below. The final design of the beam requires eleven 1/2 in. (13 mm) diameter 270 ksi (1860 MPa) unbonded tendons with a parabolic drape and high- and low-point CGS dimensions of 4 in. (103 mm) each. The factored dead and live load moments (1.2DL and 1.6LL) acting at the face of the interior column are -955 and -526 ft-kip

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(-1290 and -710 kN-m), respectively, and the unfactored secondary moment calculated by Eq. (10) is +309 ft-kip (+420 kN-m). This results in a factored design moment at the center support of $-955 - 526 + 309 = -1172$ ft-kip (-1580 kN-m). If the secondary moment were in fact 10 times larger, as the authors claim, the resulting moment at the center support would be $-955 - 526 + 3090$ or a POSITIVE +1609 ft-kip (+2180 kN-m)—much larger in magnitude than the normally calculated factored design moment of -1172 ft-kip (-1580 kN-m) and in the opposite direction. For this beam, the conventional design at the center support would require four No. 9 bars—fully developed, at the top of the beam, along with the 11 tendons—to resist the design negative moment. No compression reinforcement is required at the bottom of the beam, so the bottom bars would consist of just two No. 8 bars, which are required to resist the positive moment at midspan. The two No. 8 bottom bars would typically be lapped over the support. Obviously, the beam would fail in flexure in positive moment at the support, because the bottom beam reinforcement is grossly inadequate. The fact that this behavior has never been observed raises serious doubts about the accuracy and credibility of the authors' results and conclusions.

The authors point out that few researchers have measured secondary effects in their testing. However, one highly credible researcher, Alan Mattock, did in fact measure them in his classic work on indeterminate post-tensioned beams in 1969.² In this work, the researchers measured the center reaction in three two-span beams caused by dead load and prestress forces (including significant secondary effects) and found that the measured value ranged between 1.006 and 1.02% of the calculated value (using the normal method for calculating secondary moments—the authors' Eq. (10)). That is strikingly good agreement and differs wildly from the results presented by the authors of this paper. So the authors' conclusion that their measured secondary moments were 10 times larger than the calculated values is seriously at odds with not just the observable behavior of existing post-tensioned beams, but at least one highly respected and influential research publication.

This discussor performed independent calculations for secondary moments in the test beam 4L, using commercially available software which has been calculating secondary moments in more than 700 structural design offices worldwide since 1983. These calculations indicate a secondary moment at the interior support of 17 ft-kip (22.9 kN-m) approximately 57% higher than that calculated by the authors in Table 3 (11 ft-kip [14.6 kN-m]) and still only one-sixth of their "measured" value for that beam (103 ft-kip [139.6 kN-m]). In these calculations,

a compound-parabola tendon profile was used with four parabolas in each span, two concave downward at the supports and two concave upward between them, with inflection points at one-tenth of the beam span from each support (the "Type 3" tendon profile in the commercial software). This was done because the authors seem to be critical of the commonly used single-parabola "ω-shaped profile with kink," as they describe it in the second paragraph under "OBSERVATION AND DISCUSSION". Using this tendon profile slightly reduced the calculated values of the secondary effects from those calculated with a single-parabola "kinked" profile. This means that both the authors' calculated and measured values of secondary moments, as presented in Table 3, are highly suspect.

Two other less significant points should be mentioned. In "SUMMARY AND CONCLUSIONS," Item No. 2, the authors suggest, without evidence, that secondary moments are different if the tendons are bonded or unbonded (presumably with all else equal). To the discussor's knowledge, no one in the history of prestressed concrete has ever suggested this. In a bonded tendon, the bond is obviously applied after the tendons are stressed and the secondary moments have already been generated. While it is true that secondary moments are a function of tendon force, and the tendon force varies differently with loading for bonded and unbonded tendons, this is a minor effect and has been historically ignored in practice and not recognized by Codes. Finally, the first sentence under "STATICS ANALYSIS" is puzzling. If the magnitudes of the applied loads are known, as the authors acknowledge they are, the three reactions (L , R_E , and R_W) are easily calculated with standard indeterminate methods. Perhaps the authors meant something else here, but as it reads, it is grossly incorrect.

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