Reader's Comment

A Technique to Gain Extra Capacity in Double Tees

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Comments by John Tanner, Kurtz Precast Corporation, Denver, Pennsylvania; closure by authors.

John Tanner. As the authors pointed out, using the transformed section properties for double-tee calculations can make a significant difference over the gross section properties. However, the full extent of these differences were not shown in their calculations because of an error in the loss computations. The initial prestress loss, as calculated, was due primarily to the elastic shortening of the concrete. In using the transformed section properties, the elastic shortening is automatically taken into account (a mathematical proof of this was illustrated in an article by Ti Huang in the January/February 1972 PCI JOURNAL).

Thus, according to the calculations presented, the initial losses, when using the transformed section properties, should be zero (in most cases some additional initial loss will occur due to steel relaxation, shrinkage, and anchorage slip). Since the initial loss of 8.1 percent should not be applied to the transformed section example, the final losses should be the 21.84 percent used minus the 8.1 percent initial loss which did not exist. Table A shows the final stresses which would have occurred.

The final loss ratios after all losses are:

$f_2 = 0.7816$ (gross section)
$f_2 = 0.8625$ (transformed section)

The significant change in Table A is the final bottom fiber stress of 143 psi tension, which is well within the 1971 ACI Code of $6\sqrt{f'_c}$. This is a remarkable change from the 700 psi tensile stresses obtained with the gross section properties.

These calculations show that using the gross section properties with eccentric members can lead to large errors. Fortunately, in the single and double-tee cases they result in a conservative design. In the case of inverted tee beams the eccentricity of the strands and the member add to each other

Table A. Final stress, psi

Location	At ends with gross section properties $P/A + Pe/Z$	At midspan					
		Gross section			Ttransformed section		
		$P/A + Pe/Z$	M_t/Z	Combined	$P/A + Pe/Z$	M_t/Z	Combined
Top	234	−940	2760	1820	−795	2506	1711
Bottom	2947	5648	−6348	−700	4925	−5068	−143

which would actually decrease the working stress capacity of the member. It should be noted that the type of section properties used in the working stress design, does not effect the ultimate strength capacity of the member. Therefore, large errors in the working stress calculations have not shown up in the form of a total member failure.

I was also impressed by the small initial cambers measured on the test specimens. For similar members that we have prestressed, we have almost always obtained 2 to 4 in. initial camber. This range of initial camber was indicated by the calculations and would seem to be more typical of members of this length and prestressing.

Authors' closure. The point presented by Mr. Tanner raises some interesting questions concerning loss calculation when using mild steel in highly prestressed members. To refine our calculations for elastic shortening loss in accordance with the basic procedure as outlined by Ti Huang, certain terminology must be defined.

1. *Gross section*—Will be as defined by Ti Huang and as we determined in the original article.
2. *Net section*—Since the mild steel reinforcement (two No. 6 bars plus welded wire fabric) is unstressed prior to the application of the prestressing force, we feel that their transformed area should be included in the net section properties.
3. *Transformed section*—Will be as defined by Ti Huang and as we determined in the original article.

Since the mild steel is under compression for basically the entire range of stresses when subjected to service loads, we have included section properties when both n and $2n$ are used to transform the steel. Calculated section properties and stresses using these properties are presented in Table B. Using the "exact" and proposed procedures as outlined by Ti Huang, and defining η as per the formula below, losses and stresses are calculated and presented in Table C.

$$\eta = (f_{si} - \text{losses})/f_{si}$$

where f_{si} denotes the initial stress in the prestressing steel.

$$\text{Losses} = 5.60 + 2.5\,n \times \left(f_1 f_{ct} - M_{sw}\frac{e}{I}\right) + 0.02\,f_{si}$$

where

5.60 represents the shrinkage.
2.5 denotes the creep factor.
n is the modular ratio.
$\left(f_1 f_{ct} - M_{sw}\frac{e}{I}\right)$ is an expression for finding the initial stress at the center of gravity of the section.
0.02 f_{si} represents the steel relaxation.

As can be seen from Tables B and C, a wide variation in stress values may be computed depending on the calculation method used. Method A would decrease the allowable service load while Methods B and C would increase the allowable service load as compared to our previous analysis. Method B would give the greatest increase of approximately 8 percent in allowable service load to achieve the same −605 psi tension previously allowed.

However, this method of computation would require a release strength of 5252 psi, but no adverse affect was observed with a 3800 psi release strength. Camber computations with any method using the net I for prestress uplift and

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Table B. Calculated section properties and stresses

Item	Gross concrete	Net section		Transformed section	
		n	$2n$	n	$2n$
A, sq. in.	213.9	217.9	224.6	227.1	243.0
I, in.^{4}	4809.6	5165.3	5707.1	5783.8	6839.8
Y_t, in.	5.00	5.33	5.33	5.46	5.95
Y_b, in.	11.50	11.38	11.17	11.04	10.55
Z_t, in.^{3}	962.1	1008.8	1070.7	1059.3	1149.5
Z_b, in.^{3}	418.2	453.9	510.9	523.9	648.3
e, in.	8.50	8.38	8.17	8.04	7.55
Stresses due to prestressing only (no losses), psi					
f_t	—1203	—1075	—919	—921	—709
f_{cgs}	5694	5257	4468	4504	3599
f_b	7227	6664	5910	5710	4556
Stresses due to self weight only, psi					
f_t	1607	1532	1443	1459	1344
f_{cgs}	—2731	—2507	—2212	—2148	—1706
f_b	—3695	—3405	—3025	—2950	—2384
Stresses due to full service design load, psi					
f_t	2760	2632	2480	2506	2310
f_{cgs}	—4692	—4308	—3801	—3691	—2931
f_b	—6348	—5850	—5197	—5068	—4095

Table C. Summary of losses and stresses by various methods

Item	Method A (proposed procedure)	Method B ("exact" procedure)	Method C ("exact" procedure)	Method D (authors' analysis)
Properties for prestress	Gross	n net	$2n$ net	n transformed
Properties for gravity loads	Gross	n transformed	n transformed	n transformed
f_1, initial loss ratio	0.8824	0.8980	0.9156	0.9190
f_b, initial bottom stress at drape point	2839 psi	3159 psi	2623 psi	2422* (2760)
η, time dependent loss ratio	0.7608	0.7377	0.7875	Equals f_2
f_2, final loss ratio	0.7727	0.7315	0.7932	0.7816
f_b, final bottom stress at midspan	—764 psi (tension)	—193 psi (tension)	—380 psi (tension)	—605 psi (tension)

* The 2422 psi was previously calculated, while the 2760 psi is in accordance with the "automatic" provision of Ti Huang's procedure as pointed out by Mr. Tanner.

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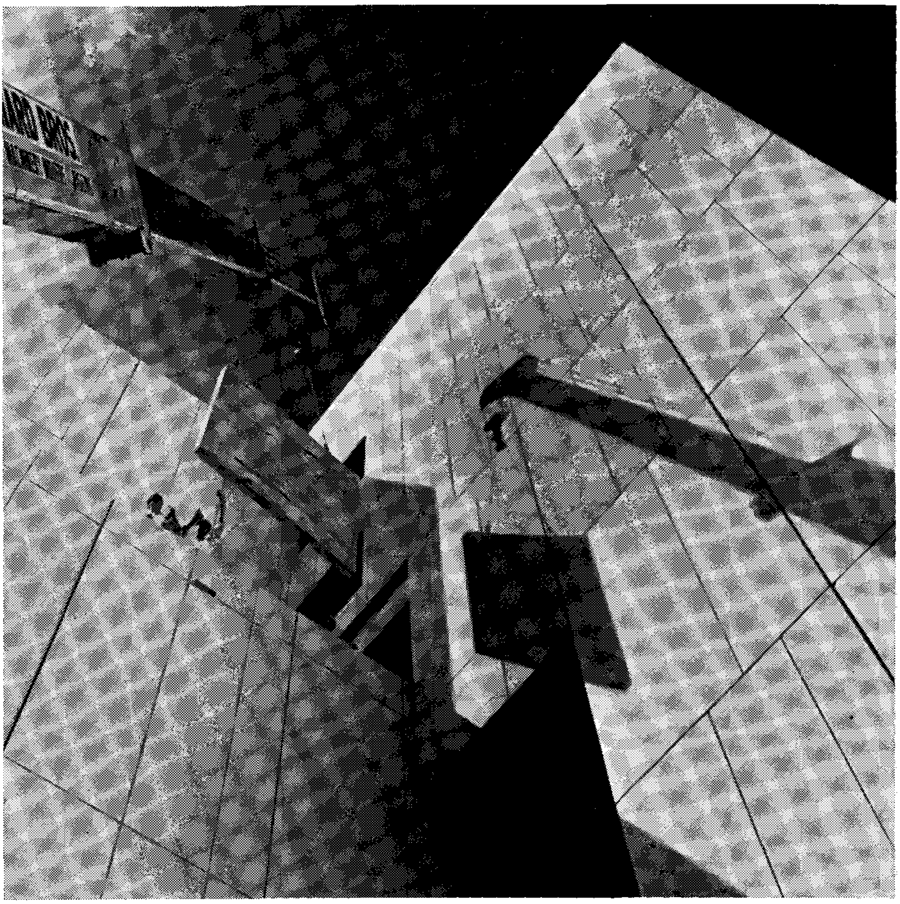
the transformed I for gravity load will only increase the already too high value previously calculated. Here Method C will give the lower camber value since this method has the highest value of net I.

In conclusion, we would like to thank Mr. Tanner for his comments and observations. We also believe the method of computation as originally presented will give satisfactory results for predicting the increased capacity in double tees when using mild steel. Should one desire to use the more accurate procedure involving net section properties for prestress and transformed section properties for gravitational loads, we believe consideration should be given for using $2n$ for transposing the mild steel in computing the net section properties.



Light and shadows are major design elements in the angular building that will house the downtown campus of Miami-Dade Junior College. The outer walls of the six-story building are clad in 800 sandblasted precast concrete panels manufactured by Stresscon Division of Maule Industries. The 193,000 sq ft structure is being built by Frank J. Rooney, Inc. for opening in August 1973.