Nonlinear Bending and Collapse of Long, Thin, Open Section Beams and Corrugated Panels

F. A. Emmerling. The basic assumptions in this work raise some doubts. In particular, the longitudinal stress is assumed “proportional to the vertical distance from the neutral axis” and the bending moment is found “from the classical beam-equilibrium equation $M_r = E_I dx$” where the area moment of inertia $I$ is calculated for deformed section. But redistribution of longitudinal stress in the cross section constitutes the main effect of the initial curvature. This has been known since the linear analysis of Th. V. Karman [1]. (But the work is clearly intended to encompass initially curved beams.) This fact has been confirmed in the nonlinear theory of tubes and open-section beams (initially straight or curved). Regrettably, most of the relevant literature has been overlooked. The review paper by E. L. Axelrad mentioned by the author refers to work [23, 35, 37, 39] treating the problems in question. There are also more recent publications [2].

References

1 Karman, Th., V., Uber die Formanderung dünnewandiger Rohre, insbesondere federnder Ausgleichsrohre,” Zeitschr, VDI, Vol. 55, 1911, pp. 1889-1895.

Author’s Closure

Professor Emmerling raises a valid point about the effect of initial curvature on the form of the longitudinal moment-curvature relationship, and I will try to address the issue as best I can in this short space. The neglected terms give rise to two manifestations of error: one associated with the cross section as a whole, and another associated with the deformation of the cross section. Compared to terms retained, the former effect is of order of magnitude $y(\kappa + \kappa_0)$, and the latter is of the order of magnitude $(\Delta y_0)/y_0$. Here $\dot{y}$, $\kappa$, and $\kappa_0$ are as defined (dimensionally) in the paper under discussion, and $\Delta y$ is the displacement of the neutral axis from its original location. In the limit as $\kappa$ and $\Delta y$ approach zero, the first effect is the source of greater possible error, and as $\kappa$ and $\Delta y$ become larger, the second effect is of greater importance. Neither of these would I label as the “main effect of the initial curvature.” That I would reserve for the importance of $\kappa_0$ in the equation $\rho = (\kappa_0 + \kappa) N$, which relates the longitudinal load, $N$, to the distort load of the cross section, $\rho$.

Nevertheless, the neglected effects can be important if $\kappa_0$ is too great, and some stricures are needed to judge the appropriateness of the model. I had supposed that when classical beam theory was invoked, the reader would take, as one of the implications, that the depth of the cross section was very much smaller that the radius of curvature of the bend (i.e., that $\dot{y} \ll \kappa_0 + \kappa$). Such would directly address the first source of error described in the foregoing, and is important whether or not $\kappa_0 = 0$. Since the second source of error is tied to the deformation of the cross section, the test for its significance (i.e., the ratio given previously) must be made a posteriori. Of course, if $\kappa_0$ is identically zero then the ratio will also be identically zero. In retrospect, I see that it would have been helpful to have incorporated the elements of this Discussion in the original paper. I thank Prof. Emmerling and the Journal for providing the present opportunity for discussion.

On the subject of “relevant literature,” there is no reason to assume that because a particular article was unused it was “overlooked.” As clearly stated in the paper, the primary purpose was to put forth a versatile solution scheme that was not tied to a particular cross-sectional geometry. The point of comparison to Ashwell [7], Rimrott [9], and Mech [10] was to demonstrate the ability to regenerate trusted and independently obtained results. Other sources could well have been used, including some of the German and Russian articles that Prof. Emmerling cites. My purposes being otherwise served, I chose not to. This in no way casts aspersions on these other fine papers or makes my selection “regrettable.” The reader seeking additional publications was well served by the reference to Axelrad [11]—the one entry on the reference list without substitute.

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