Comments by the author of the introductory report

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IIa

Comments by the author of the introductory report
Remarques de l'auteur du rapport introductif
Bemerkungen des Verfassers des Einführungsberichtes

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It is gratifying to note that utilizing the post-buckling strength in thin-walled construction is at last becoming universally accepted. This is reflected in the prepared contributions by Möller and Donat; Reiss and Chilver; and T. R. Graves Smith, and in some of the free discussion.

The writer wishes to correct the re-interpretation of his own work given by Reiss and Chilver because it results in loss of generality and of utility for design use. Post-buckling behavior was first formulated by v. Karman, Marguerre, and later by the writer in terms of an effective width b_e, which is related to the maximum stress σ_{max} at the supported edge or edges. In particular, the writer's equation (see Preliminary Publication, Theme IIa, p. 104) reads

$$b_e/b = (\sigma_{cr}/\sigma_{max})^{\frac{1}{2}}[1 - 0.25(\sigma_{cr}/\sigma_{max})^{\frac{1}{2}}]$$

This equation is valid not only at failure, when $\sigma_{max} = \sigma_y$ (σ_y = yield stress) but also for edge stresses smaller than σ_y. This makes it possible to predict the behavior of thin-walled slender columns where failure occurs at stresses smaller than the yield stress. It also makes it possible to calculate sub-ultimate stresses, deflections and strengths of flexural members whose compression flanges perform in the post-buckling domain. In this case the neutral axis shifts as σ_{max} increases with increasing load, which is properly reflected in the variation of the effective width b_e, and of the corresponding effective cross-section and its properties.

In contrast, Reiss and Chilver re-write the writer's equation in the form

$$\sigma_{ave,f}/\sigma_y = (\sigma_{cr}/\sigma_y)^{\frac{1}{2}}\ [1 - 0.25(\sigma_{cr}/\sigma_y)^{\frac{1}{2}}]$$

where $\sigma_{ave,f}$ is the average stress in the plate when failure starts by yielding at the edges. For isolated plates, or for short compression members which fail in this manner, the two formulations give the same calculated strength. However, any formulation which is in terms of an average stress rather than an effective width, and which holds only at the yield stress σ_y

rather than at any maximum edge stress $\sigma_{max} = \sigma_y$, is incapable of predicting the complete behavior of all types of members. Fundamentally, the effective width is an approximate tool for calculating actual deformations and actual maximum edge stresses at subultimate as well as ultimate loads, neither of which can be computed when only an average stress at yield failure is determined.

The difference is illustrated by the valuable investigation of Graves-Smith, which involves deformational analysis of considerable rigor. His results of the interaction of local and column buckling, as given in his Fig. 7, can be well approximated in design by an effective width approach somewhat similar to the Q-method in current American design codes, but not in terms of an average stress at yield failure.

Modern computing techniques permit deeper theoretical analyses of postcritical behavior than was possible heretofore. The writer agrees with Möller and Donat who emphasize the deviations between theory and test and state that "one must realize that the empirical approximate equations seem better to reflect the actual situations than those derived from theoretical calculations."

The increasing utilization of strength increase obtained through cold-forming is another noticeable development, reflected in the contributions by Marx, Goeben, Schröder, Richter, Bader; and by V. Hlavacek. The writer is intrigued by Hlavacek's manner of analyzing the strain-hardening effect of close-corrugating on the basis of a method first developed by Karren in the writer's department. (Hlavacek's equations 1 through 10 are identical with those used or developed by Karren, Ref. 6, on p. 111 of Preliminary Report). It is gratifying to note that Hlavacek was able to modify Karren's method for this entirely different process of cold-forming.

The paper by the five authors from the DDR further illustrates the possibilities of cold-strengthening. Their critique of the Karren method, to the effect that it leads assymptotically to zero rather than to the original yield strength, is quite correct. However, the Karren method explicitly was limited to a/t-ratios smaller than about 7, for which this problem does not arise. It is clear a priori that the method cannot apply to closed square tubes where the same piece of metal has been bent first in one direction and then in the other. Hence, the authors' Fig. 11 is somewhat misleading in two respects: it plots test results far beyond the a/t-range for which Karren's method was devised, and it includes results from square tubes which have been subjected to a double forming process different from that analyzed by Karren.

This merely illustrates that the cold-forming processes employed in producting many practical shapes are so complex that their effects probably will never become completely calculable. Design methods have to be based on strength calculations where possible, and on test results in more complex situations.