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DISCUSSION

The automatic non-linear analysis of stiffened plates and shallow shells using finite elements

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In structural mechanics, one is fortunate in often having access to several solution techniques for a problem. It becomes possible to compare the results obtained by using the different techniques available to solve the same problem, and hence to obtain some feel for the performance of these techniques with their various assumptions.

52. The problem of the imperfect square or rectangular plate under uniaxial compression has acquired the status of a standard problem, and it is interesting to compare the results in §§ 30-37 with work I reviewed in reference 14. One feature is found in all the methods which use full-section yield criteria. The earlier methods are those of Frieze *et al.*²⁸ using the original Ilyushin criterion and of the Author using his modification of the Ilyushin criterion. In these, and the Author's present work, the load shortening curve, particularly around $b/t = 55$, shows a more rapid unloading beyond the maximum load, than do methods which represent plasticity using the von Mises criterion applied at several layers through the plate thickness.

53. The practical significance of this is twofold. First, for an unwelded plate in a larger structure, this unloading slope can affect the ability for loads to be redistributed within the structure. Second, combining edge strips and the centre zone to represent a plate with longitudinal edge welds, using the Author's or other approximate treatments of welded plates, can significantly vary the shortening at which maximum load on the welded plate occurs. Experimental results²⁹ suggest that the unloading slopes of load shortening curves for structural steel plates are closer to those predicted using a von Mises criterion.

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Dr Bradfield reiterates his earlier observation¹⁴ that 'stress resultant yield criteria' tend to overestimate the rate of reduction of load following collapse. It was partly as a result of this observation that I strove to derive a more accurate full-section yield criterion. The resulting modified Ivanov yield criterion is described in the Paper. At least for plates subject to uniaxial compression, the

accuracy of this new stress resultant yield criterion can be judged by the comparisons given in Fig. 4, with alternative solutions obtained using a layered von Mises yield criterion. Although the most significant differences occur for the critical plate with $b/t = 55$ and $\Delta_0 = 0.001b$, even in this case the differences are small. Even with the very crudest unmodified Ilyushin yield criterion, the error in the collapse load is only of the order of 5%.

55. Although a layered von Mises solution is the most accurate (provided enough layers or integration stations are taken), the use of full-section yield criteria clearly allows reasonable approximate solutions to be obtained.

56. Even with today's powerful computers, the demands of a full layered solution can be prohibitive for a complex structure especially when, for reasons of economy, large load increments are adopted. In such cases it would be unreasonable to maintain fixed material properties during the load increment and the iterations will adjust simultaneously for both material and geometric non-linearities. With more stresses moving on the yield surfaces during the iterations, the layered solution will tend to require more iterations. The resulting extra computer time will be augmented by the larger number of disc accesses required as a result of the larger storage requirements.

57. The ideal solution probably involves a computer program allowing both options. The full-section yield criteria can then be used for preliminary analyses while the von Mises layered procedure can be used for the final solution. Many such preliminary analyses may be required for a complex non-linear problem.

References

28. FRIEZE P. A. *et al.* *Steel box girder bridges—parametric study of plates in compression*. Imperial College of Science and Technology, London, 1975, Report BG 39.
29. BRADFIELD C. D. Tests on plates loaded in in-plane compression. *J. Constructional Steel Res.*, 1980, 1, 27–37.

Corrigendum

Reference 14 is dated 1979, not 1974.