Finite element method for buckling analysis of plate structures

Finite Element Method for Buckling Analysis of Plate Structures[a]

Discussion by C. M. Menken[4]

The finite element method presented by the authors in the paper performs well; however, the following comments are relevant:

1. In their introduction, the authors state that in general the structural stiffness matrix of the spline finite-strip method (SFSM) lacks sparsity. It is agreed that the bandwidth in the SFSM does increase due to the splines overlap; however, they do not mention that in the SFSM calculation with a certain number of spline sections fewer degrees of freedom are involved than in a full finite element (FE) calculation, with the same number of elements. For instance, in the example of the plate strip loaded in pure shear, the element presented by the authors would require 582 degrees of freedom, whereas, with the SFSM it would require 312 degrees of freedom. That more or less eliminates the influence of an increased bandwidth (Kouhia and Menken 1992).

2. The authors state that neither the (semi-analytical) finite strip method (FSM) nor the SFSM can be applied to complex structures easily; likewise, when the loading and boundary conditions become more complicated. That is true, but in the discusser's opinion, each method has its own merits in different fields:

   a. The FSM is very fast for end-loaded prismatic structural members that show sinusoidal buckling; moreover, it guarantees the C^1 continuity over a fold line, which is required by the potential energy formulation, and both in-plane displacements are interpolated in the same way.
   b. The SFSM can handle transverse loading and shear too, whereas the buckling modes may have an arbitrary shape.

The method proposed by the authors lies somewhere between the SFSM and the full FEM, the latter of which would enable any structures under arbitrary loading to be analyzed.

3. The prebuckling stresses σ_{xx}, σ_{yy}, and τ_{xy} are simply related to the nodal forces; however, their distribution has a lower order than the membrane stresses derived from the assumed buckling displacements. The paper does not mention if the prebuckling nodal forces pertain to the same displacement distribution as was used for the in-plane buckling displacements. If they do, the discussers question is: Have the prebuckling membrane stresses been simplified in order to facilitate symbolic manipulation?

4. In Table 3, the authors compared the first buckling loads of a simply supported T-beam, obtained with their element method, with those obtained by van Erp and Menken (1990). Using seven elements in the cross section they obtained approximately the same result as van Erp and Menken, who used 15 strips in the cross section. However, the discusser would remark that this was not a valid comparison for the two methods, because 15 was

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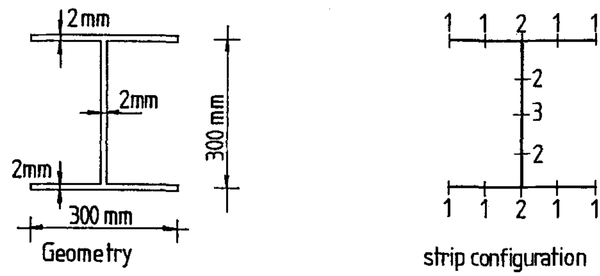
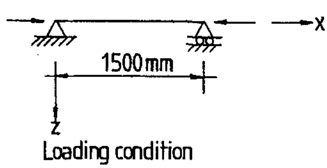
TABLE 5. Buckling Coefficients of Uniformly Compressed I-Column for Varying Numbers of Strips

Strips in flange (1)	Strips in web (2)	Section (3)	Numerical buckling coefficient (4)	Analytical buckling coefficient (5)
2	2	10	2.66	2.64
4	4	10	2.64	2.64
6	6	10	2.64	2.64





1. $W(0) = W(L) = \theta_x(0) = \theta_x(L) = 0$

2. $V(0) = V(L) = W(0) = W(L) = \theta_x(0) = \theta_x(L) = 0$

3. $U(0) = V(0) = V(L) = W(0) = W(L) = \theta_x(0) = \theta_x(L) = 0$

FIG. 11. Geometry, Loading Condition, and Strip Configuration of I-Column

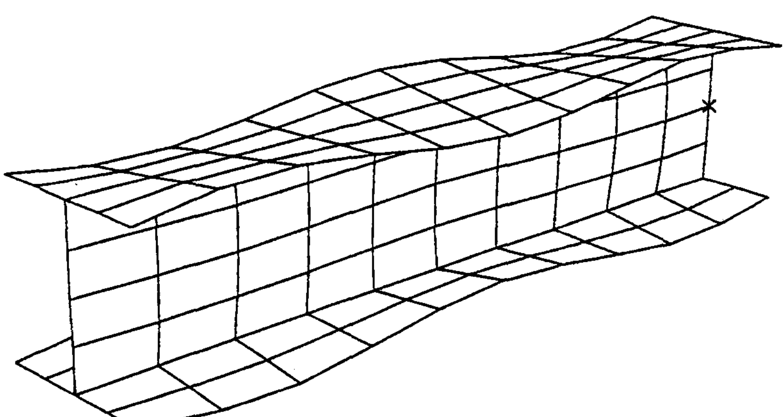


FIG. 12. Buckling Mode of Uniformly Compressed I-Column

not the least number of strips needed for calculating just the first critical load in pure lateral-torsional buckling. The example presented by van Erp and Menken was one of a series of calculations that also involved the second buckling load, as well as the second-order postbuckling fields (van Erp 1989; van Erp and Menken 1991). All those calculations were performed with the same mesh. The second buckling mode involves local buckling, whereas in the second-order fields, the deformations are still more localized (e.g., a doubling of the periodicity); therefore, it can be seen that 15 strips were adequate for those calculations, although too many for simple lateral torsional buckling. Another example presented by van Erp (1989) proves that point and it is reproduced next. Table 5 shows the first buckling loads calculated for a uniformly compressed I-column (Figs. 11 and 12); four strips in each flange were sufficient for calculating the first buckling load accurately.

5. Finally, only the buckling coefficients of the plate strip in pure shear suggest that the element method proposed by the authors is more accurate than the SFSM. Perhaps the modified material matrix ($D_{12} = D_{21} = 0$) contributes to the difference. To the discusser it seems that the main advantage of the element method is that it can be incorporated into a general FE program.

APPENDIX I. REFERENCES

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Closure by Chee-Kiong Chin,[5] Faris G. A. Al-Bermani,[6] and Sritawat Kitipornchai[7]

The writers would like to thank Menken for his interest in the paper and for bringing to their attention the conference paper by Kouhia and Menken (1992). The writers would like to point out that the aim of this paper was to present a new plate element for the analysis of general thin-walled structures using symbolic manipulation. The paper was not intended to demonstrate the relative merits between the finite element method (FEM), the finite strip method (FSM) and the spline finite strip method (SFSM). However, in order to validate the new element formulation, it was necessary to compare results with available analytical, numerical, and experimental solutions.

The writers agree with Menken that each of the methods (FEM, FSM, SFSM) has its own merits and fields of applications. The writers' choice of

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