Folded plate approach to analysis of shear wall systems and frame structures

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The technique presented in the Paper is potentially very useful for extending the conventional folded plate approach, in conjunction with the continuous medium approach to include the influence of connecting lintel beams, to deal with tall three-dimensional shear wall systems.

38. The addition of a mirror image of the structure to create an equivalent system with alternative simpler boundary conditions is a powerful one when allied to the continuum technique, because the solution is independent of the number of storeys of the structure. However, it can deal only with rigidly built-in base conditions. This would be a serious deficiency if it were wished to incorporate the soil–structure interactive behaviour, which is now realized as being of considerable importance in many practical situations.

39. Mirror image techniques have been used previously for other problems such as the testing of a physical model of a shear wall structure⁵ and to overcome the difficult tip boundary conditions associated with cantilever plates,⁶ a folded plate approach has been used for the solution of shear-core structures.^{7,8} The latter, however, have considered only in-plane stress conditions for the core wall panels, and the Author's solution has the merit that out of plane behaviour, and the influence of the real stiffness of floor slab diaphragms, can be included simply in the analysis.

40. Most analyses of tall building structures have assumed that, because of the high in-plane stiffness of the floor slabs, out of plane effects in shear walls and box cores can be neglected. The truth of this assumption has not been properly established, and it would be useful if the Author were to employ his technique to examine this problem. The power of the method would have been more clearly demonstrated if it had been applied to a more realistic three-dimensional structure, rather than to the somewhat idealized multiple plane wall system considered in the Paper, which can be readily treated by existing techniques.

Professor Křístek

The folded plate approach to analysis of shear wall systems presented in the Paper can easily be generalized to be capable of incorporating the base flexibility. The stiffness method can be used for such an analysis.

DISCUSSION

42. The rigidly built-in base conditions are assumed in the first stage of the stiffness method. The method in the Paper may be used to evaluate both the stresses in the structure and the distribution of reactions at the rigidly built-in base cross-section due to given external loads (Fig. 8(a)).

43. In accordance with the principles of the stiffness method, unit deformation impulses are to be enforced to the base cross-section of the structure (Fig. 8(b)) and the flexible foundation (Fig. 8(c)), using for example the elastic foundation concept and the elastic half-space concept.

44. Bearing in mind that the rigid body motion of the structure (due to a vertical displacement and rotations of the base cross-section about two axes) does not induce any changes of internal forces, the number of the independent deformation impulses equals the number of degrees of freedom in the vertical

Fig. 8

direction of the base cross-section, reduced by three. To simplify the calculation, the unit deformation impulses can be orthogonalized and thus a set of independent deformation patterns introduced into the analysis (Fig. 8(b)–(d)).

45. The behaviour of the structure (the stress distribution and deformations) subjected to the deformation impulses applied at the base cross-section (Fig. 8(b)) can be analysed by the folded plate method presented in the Paper, based on the introduction of the substitute structure (with a mirror image, Fig. 2(b)). Orthogonalized sets of vertical forces are applied to the cross-section at the mid-height of the substitute structure (Fig. 8(d)) as further loading cases. As all the force and moment resultants of such a loading are zero, the substitute structural system as a whole is in a state of equilibrium, no reactions appear at the ends of the substitute structure, and so the folded plate solution again fulfils the boundary conditions at the free top cross-section.

46. Although the sum of the vertical loading for the entire substitute structure is zero, it is not self-balancing on each joint of the folded plate system. The analysis must respect this (see, e.g., the approach presented on page 99 of reference 2).

47. It follows from symmetry of the substitute structure (with regard to its mid-height) and from antisymmetry of the loading represented by a set of vertical forces (Fig. 8(d)), that the stresses as well as the deformations of the actual structure and those of its mirror image are identical (but with the opposite signs). It is therefore evident that the vertical forces necessary for the deformation impulses at the base cross-section of the actual structure equal half the mid-height forces causing the same impulses on the substitute structure (Fig. 8(d)).

48. Force factors corresponding to the individual unit deformation impulses on both the base cross-section of the structure (Fig. 8(b)) and the flexible foundation (Fig. 8(c)) together represent the stiffness of the structure–foundation against the deformation pattern considered. Thus the stiffness matrix of the system can be assembled, taking full advantage of band nature due to the orthogonalized deformation patterns; the size of the stiffness matrix corresponds to the number of deformation impulses.

49. Using the stiffness matrix it is possible to write the relationship between the desired values of base deformation impulses and components of reactions at the rigidly built-in base cross-section assumed in the first stage of the stiffness method (Fig. 8(a)). This relationship, representing the equilibrium conditions of the base cross-section, has the form of a system of linear algebraic equations for the unknown values of deformation impulses.

50. The analysis is almost complete when the required values of base deformation impulses have been determined; it remains only to evaluate stresses in the structure due to these impulses (Fig. 8(d)) and to add them to the stresses of the state when the structure has a rigidly built-in base cross-section (Fig. 8(a)).

51. The analysis of the influence of prescribed settlement of the structure base can be carried out using the second stage of the method only (Fig. 8(d)).

52. The method can be further generalized to take account of the time-dependent soil–structure interaction.

References

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DISCUSSION

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