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Analysis of Plated Structures by Coupling Techniques

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Summary

In recent years various types of bridge structures have been highly developed and there has been an increasing demand for a new, effective method of analysis. It is often difficult to cope with such problems independently by a single numerical method, and a practically effective method of analysis is required. Many researchers have worked on the hybrid techniques. In those techniques, coupling of two of the well-known numerical methods such as boundary element, finite strip, finite difference, and finite element methods is implemented. Their publications have created controversies over the effectiveness of the coupling technique. The author presents an overview of the past researches including his own in the area of coupling of those numerical methods for the analysis of thin-plated structures, particularly used in highway bridges. The potentiality of hybrid techniques in solving many problems where the distinctive advantages of those methods is effectively utilized.

Keywords: Hybrid techniques; Coupling; Thin plates; Highway bridges; Boundary elements.

1. Abstract

In the last two decades, various types of bridge structures, composed of thin plates such as box-girder and plate-girder bridges, have been highly developed all over the world and there has been an increasing necessity for a new, effective method of analysis. Structural engineers are requested to analyze those large-scale compound structures with stress concentrating parts, cracks, beam and plate-like components, contact parts and so on. In those structures, the stress distributions in the plate elements are most likely to deviate from those predicted by the bending theory or the torsion-bending theory. It is also often difficult to analyze such problems independently by a single numerical technique, and hence a practically effective method of analysis is required. The experience indicates that in the numerical discretization of this problem there are many primary solution techniques. Those techniques are the boundary element method, finite element method, finite difference method, finite strip method, transfer matrix method, and thin walled segment method. Each technique is applicable only within a certain range. Outside this range other technique seems to be more efficient.

If the structure has constant cross section and its end support condition does not change transversely, the finite strip method has proven to be the most efficient method. If the structure has any irregularities, the finite strip method is no longer valid and other method has to be used. However, the major drawback of this method is, no change in material properties of each strip of the bridge along its length is allowed. On the other hand, the finite element has proven to be the most effective numerical tool for analyzing plated structures. However, the efficiency of the method needs to be improved for structures subjected mainly to moving loads. Moreover, under the moving load's condition, the mesh for the bridge deck should be further refined otherwise accuracy of the results tends to decrease significantly. The mesh needs also to be changed as the loads are moved. The boundary element method offers important advantages over domain-type methods. The most interesting features of boundary element are that a much smaller resulting system of equations and a considerable reduction in the data required to solve the problem is obtainable. Another advantage is that, the equations need only be applied to the boundary and the solution is more accurate than those from other methods. It is also effective in simulating local effects of wheel loads. With regard to the finite element, the accuracy of the boundary element, if not better, is equally good. The main disadvantage of the method is, however, the difficulties encountered in non homogeneous problem, i.e., finding the fundamental solutions and defining the interfaces.

In view of these aspects, a considerable expansion in computational power can be obtained if one resorts to hybrid analysis schemes which retain the main advantages of any two of the coupled numerical methods and eliminate their respective disadvantages. The necessity of coupling numerical methods arises from the deficiencies and limitations of each numerical method when it stands alone for analyzing structural problems especially for high way bridge structures. In order to profit from their advantages, a combination between them seems to be ideal. Such a combination should allow for the use of the most appropriate technique over each region of the problem with a reduced number of operations and without compromise in accuracy.

The fundamental difference in the various coupling techniques occurs in the treatment of the interface condition. A linking between the methods is possible in principle simply by applying the appropriate interface conditions between the two regions occupied by the two techniques. A coupling procedure may be performed by simply linking together the two sets of linear algebraic equations obtained from the two numerical techniques.

As shown by many researchers, the boundary element method is introduced as an efficient, simple and more accurate technique when coupled with other numerical methods. It could be used to overcome the deficiencies of applying numerical methods to a certain part of the domain of the problem. Since no method can stand alone for solving most of engineering problems, a structural analysis method based on a combined use of the boundary element method and other numerical method is needed. The coupling techniques ensure the best use and compensate drawbacks of the numerical methods to be coupled. Therefore, this paper presents the hybrid stress analysis procedure that combines the well-known numerical methods with the boundary element method. The basic theory behind the applications and the execution of the coupling technique to different bridge structures is also presented. This work introduces also the coupling of the boundary element method with other numerical methods, especially the finite element method, as an efficient and promising technique. The proposed technique is well-suited for computer aided analysis and to be implemented in many commercial software's. However, much work still needed to be done to streamline the computational process and clarify theoretical and practical aspects of the coupling techniques.