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Combining Integrated Force Method and Basic Displacement Functions to Solve Nonprismatic Beams

R.Allahvirdizadeh[1], R.Attarnejad[2], R.Rashetnia[3], A.Mehdipanah[4]

1- Student of Structural Engineering, School of Civil Engineering, University of Tehran
2- Associate Professor, School of Civil Engineering, University of Tehran
3- Student of Structural Engineering, School of Civil Engineering, University of Tehran
4- Student of Structural Engineering, School of Civil Engineering, University of Tehran

allahvirdizadeh@ut.ac.ir

Abstract

Almost all engineering problems are indeterminate, so equilibrium equations are not sufficient to solve them and additional conditions called compatibility conditions should be satisfied. Aim of solving a problem is gaining internal forces and stresses, but because of need for compatibility conditions, direct methods of analyzing structure are abandoned. Thus indirect methods such as FEM have been developed. In such methods internal forces are back-calculated from displacements. In integrated force method (IFM) which is developed by Patnaik, compatibility conditions are formulated, so obstacle of direct method's developing is passed. IFM does not use the idea of shape functions to calculate internal forces in domain of problem, and results are obtained at nodes. It has been shown that IFM's results are more accurate than FEM's, especially when stresses are needed, but since there was no flexibility based shape functions, using of this method is not so popular. Through introducing the concept of basic displacement functions (BDF) developed by R.Attarnejad, it is shown that exact shape functions are derived in terms of BDFs. They are obtained via application of flexibility method. The flexibility basis of the method ensures the true satisfaction of equilibrium equations at any interior point of element. Analysis of nonprismatic members has received a great deal attention from designers due to their wide use in practice. In this study basic displacement functions (BDF) and IFM are combined to solve nonprismatic beams. Using BDF's shape functions help to gain stresses in all domain of problem. To show applicability of this method and exact problem is solved by combined method, FEM and analytical method. Stresses and deflection are calculated and compared. Results show that combined method is competitive especially for forces.

Keywords: Structural analysis, Nonprismatic beams, IFM, FEM.

1. INTRODUCTION

Analysis of nonprismatic members has received great attention from designers and engineers due to their ability in satisfaction of architectural and aesthetic necessities. Using these structural members in complex structures such as aircrafts, turbine blades and space vehicles, exact static and dynamic analyses of these members become more significant.

Most of the literature on nonprismatic beams revolves around the application of displacement-based formulations. Displacement-based formulations are established on an assumed or prescribed displacement field within the whole domain (e.g. Rayleigh Ritz) and weighted residual methods or a discrete part of it (e.g. FEM); an extra hypothesis on the displacement field is usually imposed in addition to three essential relations, namely equilibrium of forces, compatibility of displacements and/or strains and the constitutional law of the material behavior. Due to this extra hypothesis, one of the three essential relations, generally the equilibrium equations, is satisfied only in certain interior points such as integration points; thus, the formulation is approximate in nature. However, the generality of the stiffness method seems to be a considerable advantage such that the majority of formulations and programs are based on this method. Unlike the stiffness method, application of the flexibility-based method ensures the exact satisfaction of the equilibrium equations at any interior point of the element; nevertheless its application has mostly been limited to simple engineering problems as it generally involves tedious mathematical/numerical procedures. Beside of tedious procedure of solving problems using common flexibility methods, these methods were dependent to who is solving, this disadvantages cause flexibility methods not to be expanded in practical engineering methods [1].