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Determining the deflection of indeterminate beams with nonlinearly tapered cross sections using the GDQ method

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Abstract

This article describes the optimal and distinctive use of the numerical Generalized Differential Quadrature method in analyzing the deflection of indeterminate beams with tapered cross sections. Due to the long time it takes to use analytical methods to solve the fourth order differential equations related to indeterminate beams with different boundary conditions, the use of numerical approaches is unavoidable. One of the relatively new numerical methods that can accurately discretize and solve partial differential equations is the Generalized Differential Quadrature method. This method is based on the idea that the partial derivative of a function is approximated at a specific point of the problem interval as the weighted algebraic sum of function values at all discretized points of the whole region. In this article, the GDQ method and the manner of calculating the weight coefficients by means of this method are explained. The application of this method in the analysis of indeterminate beams with linearly tapered cross sections under different loading conditions and the comparison of the results with those obtained by the SAP2000 software have confirmed the high accuracy of this method in analyzing these types of problems. The other advantage of this numerical method over the other numerical approaches in solving partial equations is that it converges to the solution with fewer mesh points. Therefore, by making a small modification in the analytical program of Generalized Differential Quadrature approach, the deflection of indeterminate beams with nonlinearly tapered cross sections under linear and nonlinear loadings can be obtained; a task which is either impossible to accomplish using the presently available software programs or very difficult and time consuming.

Keywords: Indeterminate beams; GDQ method; Nonlinearly tapered cross section; Partial differential equations; deflection.

1. INTRODUCTION

In a set of structural elements, beams are known as the major members. In fact, the main function of beams is to bear the stresses due to shear loads and the bending moments resulting from the existing forces. The calculation of deflection in beams is an important issue in the analysis and design of structures. Calculating the deflection of beams during loading with aim of controlling the functionality of structures and considering permitted amount of beam deflection in structures helps a great deal in determining type and dimensions of beams.

The most common numerical methods for the analysis of partial differential equations are Finite Element Method (FEM) and Finite Difference Method (FDM). However, in order to achieve acceptable results and the needed accuracy, these methods require a large number of grid points; and as a result, in some cases, the computational expense increases considerably. Since in this research, for the numerical analysis of problems, the Generalized Differential Quadrature (GDQ) method is employed, the characteristics and limitations of this numerical approach will be briefly described.

The Differential Quadrature Method (DQM) was initially used by Bellman and Casti in 1971 as a numerical approach for solving partial differential equations [1]. In this method, the partial derivatives of the function at one point along a specific direction are expressed in terms of the linear weighted sum of function values at all the nodal points along the same direction and throughout the computational domain. This method has gained a growing popularity, since it is based on the idea of integral quadrature, and also because it produces highly-accurate results and is simple to use. The only limitation of this method is in the