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Elasto-Plastic Analysis of Structures Using Adaptive Gaussian Springs Based Applied Element Method

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Abstract : Applied Element Method (AEM) is a method that was developed to aid in the analysis of the collapse of structures. Current available methods cannot deal with structural collapse accurately; however, AEM can simulate the behavior of a structure from an initial state of no loading until collapse of the structure. The elements in AEM are connected with sets of normal and shear springs along the edges of the elements, that represent the stresses and strains of the element in that region. The elements are rigid, and the material properties are introduced through the spring stiffness. Nonlinear dynamic analysis has been widely modelled using the finite element method for analysis of progressive collapse of structures; however, difficulties in the analysis were found at the presence of excessively deformed elements with cracking or crushing, as well as having a high computational cost, and difficulties on choosing the appropriate material models for analysis. The Applied Element method is developed and coded to significantly improve the accuracy and also reduce the computational costs of the method. The scheme works for both linear elastic, and nonlinear cases, including elasto-plastic materials. This paper will focus on elastic and elasto-plastic material behaviour, where the number of springs required for an accurate analysis is tested. A steel cantilever beam is used as the structural element for the analysis. The first modification of the method is based on the Gaussian Quadrature to distribute the springs. Usually, the springs are equally distributed along the face of the element, but it was found that using Gaussian springs, only up to 2 springs were required for perfectly elastic cases, while with equal springs at least 5 springs were required. The method runs on a Newton-Raphson iteration scheme, and quadratic convergence was obtained. The second modification is based on adapting the number of springs required depending on the elasticity of the material. After the first Newton Raphson iteration, Von Mises stress conditions were used to calculate the stresses in the springs, and the springs are classified as elastic or plastic. Then transition springs, springs located exactly between the elastic and plastic region, are interpolated between regions to strictly identify the elastic and plastic regions in the cross section. Since a rectangular cross-section was analyzed, there were two plastic regions (top and bottom), and one elastic region (middle). The results of the present study show that elasto-plastic cases require only 2 springs for the elastic region, and 2 springs for the plastic region. This showed to improve the computational cost, reducing the minimum number of springs in elasto-plastic cases to only 6 springs. All the work is done using MATLAB and the results will be compared to models of structural elements using the finite element method in ANSYS.

Keywords : applied element method, elasto-plastic, Gaussian springs, nonlinear
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