Evaluation of Critical Loads of Steel Frames using Iterative Buckling Analysis

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Summary

This paper proposes a new method of inelastic buckling analysis to determine the critical load of steel frames. The inelastic analysis includes a modified bifurcation stability using the tangent modulus theory and a column strength curve. The inelastic buckling analysis can consider geometric imperfections or residual stresses in a steel frame by using the column strength curve. Criteria for inelastic buckling analysis are suggested in order to account for the effect of the primary moment as well as the axial force of members by using beam-column interaction equations. Conventional elastic buckling analysis and refined plastic hinge analysis were carried out to validate the proposed inelastic buckling analysis for simple columns with geometric imperfections and a four-story plane frame.

Keywords: Elastic buckling analysis; Inelastic buckling analysis; Refined plastic hinge analysis; Critical load; Steel frame

1. Introduction

The main purpose of this paper is to propose a new and simple alternative to evaluate the critical load of steel frames. We present a method of modified bifurcation stability using the tangent modulus theory and a column strength curve instead of the conventional plastic hinge method. In real situations, the method based on bifurcation stability is inadequate to determine the critical load of steel frames that have geometric imperfections or transverse loadings. However, inelastic buckling analysis, which is presented in this paper, can consider geometric imperfections or residual stresses in a steel frame by using the column strength curve. In addition, we suggest the criteria for inelastic buckling analysis in order to account for the effect of the primary moment as well as the axial force of members in steel frames. Simple columns with geometric imperfections and a four-bay plane frame were analyzed as benchmark examples. Conventional elastic buckling analysis and refined plastic hinge analysis with these models were also performed to validate the proposed inelastic buckling analysis method.

2. Methods of Analysis

2.1 Procedures of inelastic buckling analysis

The proposed inelastic buckling analysis is based on the concept of bifurcation stability. The basic equation of inelastic buckling analysis is described as a similar form of conventional elastic buckling analysis except for the elastic stiffness matrix of the structure.

$$([K_e(E_t)] + \kappa[K_g])\{\phi\} = \{0\} \tag{1}$$

where $[K_e(E_t)]$ is the modified stiffness matrix, which is a function of tangent modulus E_t.

The first step of inelastic buckling analysis is linear stress analysis to determine the section force and moments of members in steel frames. Eigenvalue analysis is carried out with the elastic stiffness and the geometric stiffness of the structure by general finite element procedures. The eigenvalue analysis at the first iteration step of inelastic buckling analysis is equivalent to the eigenvalue analysis of elastic buckling analysis, since the members in a structure have the elastic modulus at this step. The next step is to calculate the axial and flexural resistances of members. The

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