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Evaluation of Compression Member Buckling and Post-Buckling Behavior Using Artificial Neural Network

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Abstract

There are various ways to investigate the buckling phenomenon in a steel compression member. Among these methods experimental formulas, semi-empirical formulas, closed form solutions, classic methods based on differential equations and also numerical methods based on finite element are mostly used. All of the mentioned methods have some complexities with their process. Thus, it is very difficult to perform a comprehensive parametric study on buckling phenomenon of a compression member using these methods. The simplicity of mathematical concepts used in ANN (artificial neural network) and its ability in modeling complex problems made ANN a popular facility. After learning ANN, it is able to introduce a function as a relationship between input variables and output parameters, which is load-displacement relationship in this article. Then it is possible to perform an extensive parametric study on the buckling behavior of the compression member. In this research, this network is also able to extract the critical load-slenderness relationship. Using this network it is possible to conduct an accurate study on the effects of various parameters at critical load, and also evaluate the sensitivity of critical load versus each variable that is used in ANN training.

Keywords: Buckling, Post-Buckling, column, Neural Network, Sensitivity Analysis

1. Introduction

Since the time of Euler, many theories have been developed for understanding the phenomenon of bending and failing of slender columns over the past 239 years (Johnston 1983). Euler was the first to realize that the column strength could also be a problem of stability and not merely a matter of crushing (Tall 1984). Euler investigated the phenomenon of buckling with a mathematical treatment and arrived at the Euler formula for the critical load (i.e., the load at which a slender column fails) of columns. Although Euler's formula has a mathematical basis, it assumes pure elastic buckling. In 1889, Engesser put forward the tangent modulus theory for inelastic buckling by replacing the strength property (E) in the Euler formula by the tangent modulus, E_r. The reduced modulus *(E_r)* or the "double modulus" theory was put forward by Von Karman for understanding the phenomenon of buckling. However, many experimenters found that columns tested in the laboratory with utmost care usually buckled and failed at loads at or slightly above the tangent modulus loads (Johnston 1983; Timoshenko 1953). The theory suggested by Shanley redefined the concept of tangent modulus, suggested by Engesser. The Engesser-Shanley definition of critical load is widely used nowadays for columns that are assumed to be free from residual stresses (Johnston 1983). In practice, however, such an assumption is far from true. The critical load of columns is often affected by many factors such as the slenderness ratio, initial straightness, residual stresses, material imperfections, end restraints, shape of the cross section, etc. Zahn (1992) suggested that the form of the column equation essentially expresses the interaction of two failure modes, namely, crushing and buckling. However, the mode of interaction is difficult to present as the inhomogeneities are located unsymmetrically on various cross sections (Zahn 1992). The mode of interaction, however, is modeled empirically.

The foregoing discussion shows there is still a need to develop tools to model the phenomenon of buckling of columns. In this work, an attempt has been made to model the nonlinear behavior of columns for the prediction of buckling load using an artificial neural network (ANN). In this approach, a neural network is trained with the analytically obtained values for a critical load. This concept can be used for modeling the buckling behavior of a variety of cross sections with different features. The artificial neural network computes through classification. Therefore, it is possible for the network to predict the critical load for