Available online at www.sciencedirect.com
SCIENCE DIRECT
Journal of Constructional Steel Research 62 (2006) 950–961
JOURNAL OF CONSTRUCTIONAL STEEL RESEARCH
www.elsevier.com/locate/jcsr

Prediction of rotation capacity of wide flange beams using neural networks

Ibrahim H. Guzelbey[a], Abdulkadir Cevik[b,*], Mehmet Tolga Gögüş[b]

[a] Department of Mechanical Engineering, University of Gaziantep, Turkey
[b] Department of Civil Engineering, University of Gaziantep, Turkey

Received 19 September 2005; accepted 3 January 2006

Abstract

This study proposes Neural Networks (NN) as a new approach for the estimation and explicit formulation of available rotation capacity of wide flange beams. Rotation capacity is an important phenomenon which determines the plastic behaviour of steel structures. Thus the database for the NN training is directly based on extensive experimental results from literature. The results of the NN approach are compared with numerical results obtained by a specialized computer. Available rotation capacity is also introduced in a closed form solution based on the proposed NN model. The proposed NN method is seen to be more accurate than numerical results, practical and fast compared to FE models.

Keywords: Rotation capacity; Plastic behaviour; Neural networks; Explicit solution

1. Introduction

The behaviour of a wide flange beam can be generalized into elastic, inelastic and plastic categories as shown in Fig. 1. In any case the failure of the beam will be due to one of the following: local plate buckling of the compression flange, local plate buckling of the web in flexural compression, or lateral–torsional buckling. The plastic behaviour category is of special concern in this study as it permits moment redistribution in indeterminate structures [1].

Plastic analysis and design enables the full cross sectional capacity of a beam to be used by notionally allowing a *plastic hinge* to form. This hinging occurs when the plastic moment strength, M_p, is reached at a discrete point along the beam (i.e. the entire cross section has yielded). At such a location, the cross section can no longer resist increasing moment and hence large rotations occur, with constant resistance, M_p, being maintained. In the case of an indeterminate structure, such a scenario allows for moment re-distribution to occur. However, it is critical that in addition to the cross section reaching its plastic moment capacity, the beam must also be ductile enough to maintain M_p while continuing to deform (rotate) through a sufficient angle so that moment redistribution can take place. A common structural ductility or deformation capacity measure is termed plastic rotation capacity [2].

The estimation of plastic rotation capacity is of significant importance for plastic and seismic analysis and design of steel structures. Similarly the moment redistribution in a steel structure also depends on the rotation capacity of the section. Thus the determination of rotation capacity of steel structures becomes an important task.

This study focuses on the prediction of available rotation capacity of wide flange steel beams. Theoretical, empirical and approximate methods have been proposed for the determination of available rotation capacity of wide flange steel beams in literature which have been reported by Gioncu et al. [3,4]. In order to find how realistic results are, these studies should be compared with experimental tests. Thus an alternative approach for the prediction of rotation capacity of wide flange steel beams using NNs is presented for the first time in the literature. Backpropagation NNs are used for the training of the NN model. The results of the proposed NN model based on experimental studies are compared with numerical results and are seen to be very accurate. Moreover an explicit solution of rotation capacity for wide flange beams in terms of geometric and mechanical parameters will be introduced by using the well trained NN parameters. The proposed NN approach is quite accurate, fast and practical compared to the FE approach.

* Corresponding author. Tel.: +90 342 3601200x2409; fax: +90 342 3601107.
E-mail address: akcevik@gantep.edu.tr (A. Cevik).

0143-974X/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jcsr.2006.01.003

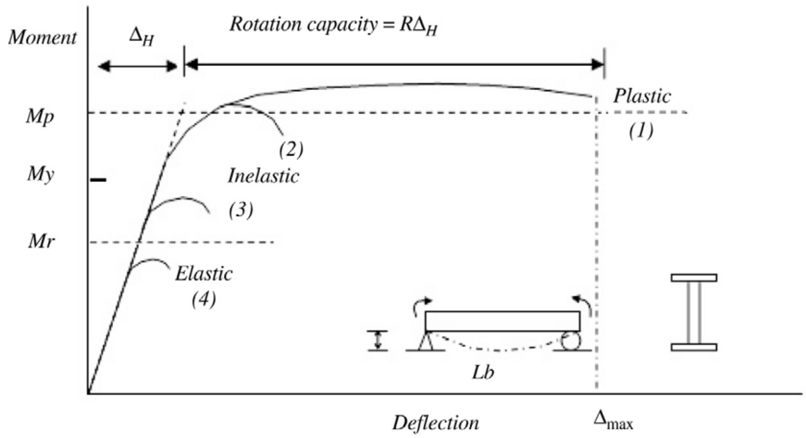

Fig. 1. General beam behaviour [1].

2. Rotation capacity

2.1. Definition of rotation capacity

There are various definitions of rotation capacity in the literature as a non-dimensional parameter. Salmon and Johnson defined rotation capacity as a method of quantifying deformation capacity within a cross-section prior to instability eroding the cross-sectional capacity [5].

According to Lay and Galambos [6] rotation capacity is, $R = \theta_h/\theta_p$, in which θ_p is the elastic rotation at the initial attainment of the plastic moment M_p and θ_h is the plastic rotation at the point when moment drops below M_p.

A widely used definition for rotation capacity is proposed by ASCE [7] (Fig. 2): $R = \theta_2/\theta_1$ where θ_1 refers to the theoretical rotation at which the full plastic capacity is achieved and θ_2 is the rotation when the moment capacity drops below M_p on the unloading portion.

Kemp [8] defined rotation capacity as $R = \theta_{hm}/\theta_p$ in which θ_{hm} is the plastic rotation up to the maximum moment on the moment rotation curve.

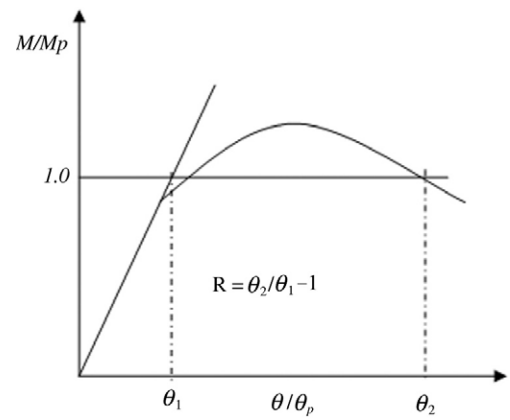

Fig. 2. Definition of rotation capacity [7].

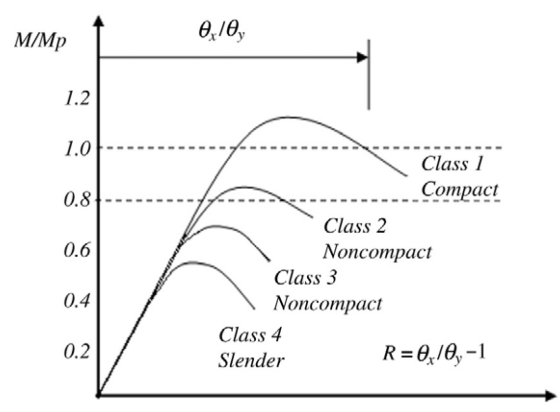

Fig. 3. Classical definition for rotation capacity based on normalised moment–rotation relationship.

2.2. Rotation capacity in design codes

The behaviour of laterally restrained beams is commonly divided into three or four classes of behaviour as illustrated in Fig. 3. The Australian Standard AS 4100 [9] and AISC LRFD [10] have three classes (compact, non-compact, and slender). A compact or Class 1 section is suitable for plastic design, and can sustain the plastic moment (M_p) for a sufficiently large rotation capacity (R) to allow for moment redistribution in a statically indeterminate system [11].

On the other hand Eurocode 3 [12], defines four classes of cross-sections to identify the extent to which the resistance and rotation capacity of cross sections is limited by its local buckling resistance as follows:

– Class 1 cross-sections are those which can form a plastic hinge with the rotation capacity required from plastic analysis without reduction of the resistance.
– Class 2 cross-sections are those which can develop their plastic moment resistance, but have limited rotation capacity because of local buckling.
– Class 3 cross-sections are those in which the stress in the extreme compression fibre of the steel member assuming an elastic distribution of stresses can reach the yield strength, but local buckling is liable to prevent development of the plastic moment resistance.