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Nonlinear instability of angle section beams subjected to static and dynamic sudden step loads

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ABSTRACT

This paper presents a study on the flattening behaviour of angle section beams subjected to pure bending. Analytical solutions for both static and dynamic instabilities of angle section beams subjected to pure bending about its weak axis are derived using energy methods. The results show that the dynamic instability of angle section beams under the action of a sudden step moment occurs at a moment about 71% of the corresponding critical static moment, but the deformations of the longitudinal curvature and flattening at the critical dynamic state are almost twice of those corresponding to the static instability case.

1. Introduction

Steel angle sections are widely used as columns and beams to carry axial and bending loads. Despite the apparent simplicity of the section geometry, the behaviour of angle section beams is often complicated and their strengths are difficult to predict. When an angle section beam is bent about its weak axis, Brazier's flattening deformation would occur in the section, which can lead the beam to have nonlinear snap-through instability.

From the literature review it is shown that most of existing studies focused on the linear buckling of angle section beams subjected to axial and/or bending loads. For example, Meck presented analytical solutions for buckling of a thin-walled symmetrical angle section beams loaded by a bending moment in the plane of symmetry [1]. Instability occurring either by deformation of the section or by torsional buckling was considered. Simple formulae were derived, which can be used to predict the buckling load. Wilhoit et al. [2] and Popovic et al. [3] conducted compression tests on equal angles with slender legs. The angles tested by Wilhoit et al. [2] were brake-pressed from high strength steel plates, which produced a yield strength of 465 MPa, whereas the angles tested by Popovic et al. [3] were cold-rolled and in-line galvanised, which produced a nominal yield strength of 350 MPa. A series of investigations on the performance of angle section beams subjected to various loading conditions was carried out by Earls using analytical, numerical and experimental methods [4–7]. Design recommendations were also provided by Earls [8] and by Earls and Galambos [9] for single angle flexural members. Trahair studied the behaviour of single angle steel beams. In his series of papers [10–16], the general case of unrestrained biaxial bending and torsion was simplified successively into restrained biaxial bending, lateral buckling, unrestrained biaxial bending, and buckling and torsion. Rasmussen presented an application of the direct strength method to equal angle section beam-columns with locally unstable legs [17]. In contrast to existing design methods, which independently determine the compression and bending capacities and use an interaction equation to combine these, the direct strength method determines the elastic local buckling stress for the actual stress distribution resulting from the combined action of compression and bending, and incorporates the elastic buckling stress into a direct strength equation for beam-columns. Aydin and Dogan investigated the elastic, full plastic and lateral torsional buckling problems of steel single-angle section beams subjected to biaxial bending [18]. Lately, Aydin further investigated the first yield, full plastic and critical lateral torsional buckling moments of single-angle section beams subjected to combined axial compression and biaxial bending [19]. The influence of the section flattening on the bending of the angle section beam was investigated by Kuwamura [20]. By assuming the neutral axis remains unchanged during the flattening of the section, Kuwamura managed to obtain an analytical solution for predicting the flattening behaviour of the long angle section beam under pure bending.

In this paper, the Brazier's flattening behaviour [21] of angle section beams subject to pure bending is investigated. The present

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