Journal of Constructional Steel Research 72 (2012) 1–11

Contents lists available at SciVerse ScienceDirect

Journal of Constructional Steel Research

Resistance of steel I-sections under axial force and biaxial bending

A.M. Baptista *

Departamento de Estruturas, LNEC, Av. do Brasil 101, 1700-066 Lisboa Codex, Portugal

ARTICLE INFO

Article history:
Received 30 June 2011
Accepted 28 July 2011
Available online 2 October 2011

Keywords:
Steel structures
I-section
Biaxial bending
Deviated bending
Axial force
Elastic limit state
Plastic limit state
Interaction criteria
Neutral axis

ABSTRACT

The plastic criteria for the verification of steel cross-sections resistance are usually based on some basic hypotheses such as the development of plastic hinges, which depend on the interaction between the internal forces and the cross-section shape; therefore, specific equations are required for each type of cross-section.

This paper presents new alternative interaction criteria for the analysis of steel I-sections subjected to an axial force and biaxial bending moments, at the elastic or the plastic limit states (as long as buckling phenomena are not involved).

The plastic interaction criteria are presented, in a first step, for some particular combinations of the internal forces, such as axial loading with bending about a main axis, and biaxial bending without axial loading. In these cases, they are given by exact equations (within the frame of the hypotheses adopted in this study). All these plastic interaction criteria are compared with the corresponding plastic criteria adopted in the Eurocode 3 (EC3).

Afterwards, a simplified global criterion is proposed for the simultaneous combination of an axial force and bending moments about both the main axes of inertia. This new simplified plastic criterion and the corresponding plastic criterion adopted in the EC3 are compared with the exact solution, obtained by a mixed numerical and analytical integration procedure. This comparison shows that this simplified criterion usually leads to results closer to the exact solutions. Some suggestions are then presented to improve the results given by the EC3.

1. Introduction

The analysis of the behaviour and limit carrying capacity of a cross-section under biaxial bending is usually a complex problem, which has been studied by many researchers for a long time. A large number of publications may be found, covering the study of structural cross-sections made of different materials (such as reinforced concrete sections [14,29], composite steel-concrete sections [25,26], steel sections [31], or aluminium sections [13], for instance). A review of different methods used for the evaluation of the cross-sections plastic resistance may be found in [27]; most of them essentially consider only axial stresses due to axial loading and biaxial bending for the determination of the plastic section capacity. Warping normal stresses due to bimoments, as well as shear stresses from bending, uniform torsion and warping are either disregarded or considered only approximately in some of those approaches [27].

In the case of steel sections, a considerable amount of research has been done concerning the study of different types of cross-sections, such as H and I shapes [20], solid and hollow rectangular sections [18,31], or angle sections [33,34]. Some extensive reviews of these research works may be found in several publications, such as [15] or [20] for instance.

The elastic–plastic methods are currently adopted in modern standard codes of design to estimate the ultimate resistance of some steel structures, since they allow the beneficial effects of yielding in the redistribution of stresses to be taken into account. The analysis of the limit carrying capacity of a cross-section under biaxial bending is simpler than the analysis of its behaviour along the elastic–plastic range, [6,9], and hence the earliest papers were restricted to that problem [35].

The research works carried out with this purpose have been based on analytical studies [16,19], experimental investigations [13,28,32], and numerical models [12,21,22]. A large number of these studies took in account other aspects than the elastic or plastic carrying capacity of the cross-sections, such as the possible occurrence of local or overall buckling phenomena of the structural elements in biaxial bending [28,33,34].

Although the results of some numerical models evidence a very good agreement with test results, their practical use for design purposes is limited, since most of them are not currently available and the labour required by the numerical calculations is quite important [22]. Therefore, their applications usually remain within the limits of research studies, and the designers often rely on simple interaction equations, between the cross-section internal forces, which may be found in bridge and building specifications such as [1–5,17], for instance.

The interaction criteria between the cross-section internal forces at its plastic limit state depend on the cross-section shape. Consequently, specific analytical expressions are required for each type of cross-sections. However, these analytical expressions are not currently available for some cross-section shapes, or they are defined by

* Tel.: +351 21 844 3252; fax: +351 21 844 3025.
E-mail address: ambaptista@lnec.pt.

0143-974X/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jcsr.2011.07.013