Journal of Constructional Steel Research 78 (2012) 144–158

Contents lists available at SciVerse ScienceDirect

Journal of Constructional Steel Research

Ultimate behavior of steel beams under non-uniform bending

Mario D'Aniello [a], Raffaele Landolfo [a,*], Vincenzo Piluso [b], Gianvittorio Rizzano [b]

[a] Department of Constructions and Mathematical Methods in Architecture, University of Naples "Federico II", Italy
[b] Department of Civil Engineering, University of Salerno, Italy

ARTICLE INFO

Article history:
Received 29 February 2012
Accepted 3 July 2012
Available online 31 July 2012

Keywords:
Steel beam
Ductility
Moment resisting frames
Overstrength
Rotation capacity

ABSTRACT

The ultimate behavior of steel beams deeply influences the overall performance of steel frames. The main response parameters are the rotation capacity and the flexural ultimate resistance. The former is the source of the local ductility supply needed to achieve a global dissipative behavior of structures under seismic actions, whereas the latter governs the flexural overstrength whose knowledge is needed for an appropriate application of hierarchy criteria in seismic design of structures. Therefore, a twofold classification of steel members according to their ductility and overstrength is the most appropriate approach for seismic design applications. Currently, modern international design codes are based on the classification of steel sections for both plastic and seismic designs of structures, providing misleading emphasis mainly on local buckling as the primary strain-weakening effect. Even though different methods are available in the technical literature for predicting the ultimate behavior of steel members under non-uniform bending, the problem still deserves further investigations, because of the high number of parameters affecting the ultimate response and the variety of cross-sectional shapes. Therefore, a new experimental program dealing with a wide range of cross section typologies (I and H sections, Square and Rectangular Hollow sections) under monotonic and cyclic loading has been carried out by testing specimens with different local slenderness ratios properly selected to integrate the data already available in the technical literature. The obtained results are herein presented and discussed.

1. Introduction

The development of adequate plastic rotation capacity is a fundamental requirement both for plastic design and for seismic design of building structures. Indeed, plastic design can be carried out provided that members are able to develop plastic hinges rotating until the collapse mechanism is completely developed, without dropping their moment capacity, thus assuring the required redistribution of bending moments. The rotation of plastic hinges required to fully develop the collapse mechanism and/or to achieve needed displacement levels provides the plastic rotation demand, which varies for different structural configurations, loading arrangements, geometry, material strengths and levels of the seismic intensity measure. It has been widely investigated in the literature, particularly for continuous beams and frames [1–4].

In particular, in earthquake-resistant design, rotation capacity is essential to assure that a determined portion of the input seismic energy is dissipated by plastic behavior. Therefore, steel beams need to develop a ductile behavior with high rotation capacity. To this scope appropriate geometrical limitations to the geometry of the plate elements constituting the cross-section and to the laterally unrestrained length need to be considered, because the flexural behavior of steel beams can be undermined by the occurrence of plastic local buckling of compressed elements and/or by inelastic flexural–torsional buckling. Therefore, in order to perform a reliable structural analysis, it is essential to quantify clearly the meaning of "sufficient rotation capacity" or "sufficient local ductility".

Nowadays, Eurocode 3 [5] provides the subdivisions of cross-sections into four classes, depending on the properties of compression elements (Fig. 1). For plastic global analysis, it is required that all members containing plastic hinges shall belong to class 1, i.e. to be made of ductile sections. According to Eurocode 8 [6], the cross section classes defined in Eurocode 3 provide a limitation to the selected behavior factor requiring class 1 for $q>4$, class 2 for $2<q\leq 4$, and class 3 for $q\leq 2$ (as shown in Table 1). However, the main criticism to Eurocode classification is the small number of parameters considered to characterize the beam performance. In fact, they relate rotation capacity to material and cross-section factors only, neglecting very important behavioral issues, such as the flange–web interaction, the overall member slenderness, the moment gradient, the lateral restraints, and the loading conditions (monotonic or cyclic).

These considerations led several authors to develop other classification criteria. In the recent past, classification criteria accounting for both cross-section slenderness and member slenderness were early proposed by [7–10] for I and H shaped members.

Furthermore, regarding seismic applications it is important to note that it is not possible to directly extend the criteria developed for

* Corresponding author. Tel.: +39 0812538987; fax: +39 0812538989.
E-mail address: landolfo@unina.it (R. Landolfo).

0143-974X/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jcsr.2012.07.003