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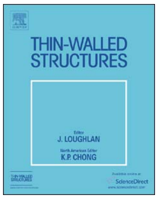

Full length article

Ultimate behaviour of RHS temper T6 aluminium alloy beams subjected to non-uniform bending: Parametric analysis

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ABSTRACT

The aim of this work is the numerical assessment of the ultimate behaviour of temper T6 aluminium alloy beams subjected to non-uniform bending. An extensive numerical analysis has been performed by means of FE code ABAQUS with reference to RHS sections considering the typical range of variation of the geometrical parameters governing the ultimate behaviour of RHS beams under non-uniform bending. In particular, a wide parametric analysis has been carried out by varying the flange slenderness, the flange-to-web slenderness ratio and the non-dimensional shear length accounting for the moment gradient. The ultimate behaviour of such beams has been investigated with reference to the material constitutive law proposed by Eurocode 9, based on the Ramberg-Osgood model. Particular attention has been devoted to the interaction between the different non-dimensional parameters governing the ultimate behaviour. The importance of the investigated parameters on the non-dimensional ultimate flexural strength and on the rotation capacity of aluminium alloy beams is clearly pointed out.

Successively, by means of multivariate non linear regression analyses, empirical relationships are provided in order to predict both the non-dimensional ultimate flexural resistance and the rotation capacity of RHS temper T6 aluminium alloy beams, starting from their geometrical and mechanical properties.

1. Introduction

The ability of a material, a section, a single structural member or a structural scheme of withstanding plastic deformations, maintaining their load carrying capacity is a general property usually referred to as ductility. Ductility is always measured as the ratio between the ultimate value of a deformation parameter and the value that the same parameter attains at first yielding. In case of beams subjected to non-uniform bending the deformation parameter is the rotation in a properly selected section. Therefore, in case of members subjected to bending, the term “rotation capacity” is adopted.

The rotation capacity of metal members has been investigated in several studies over last three decades, mainly with reference to steel members [1–5]. The main focus is related to the evaluation of the redistribution capacity of internal actions and to the prediction of the global ductility of structures. In particular, an adequate rotation capacity is of paramount importance for plastic design as well as to assure high-energy dissipation capability of seismic resistant structures [6–9]. For these reasons, the rotation capacity is one of the most important behavioural parameters usually adopted to characterize the ultimate behaviour of members.

Rotation capacity is conventionally defined as a non-dimensional measure of the inelastic rotation that the member is able to withstand before the bending moment falls below a certain level, usually fixed as the full plastic bending moment. In particular, modern codes, such as Eurocode 3 (EC3) [10], divide cross sections into different behavioural classes. First-class corresponds to ductile sections which are able to develop their whole plastic resistance and high plastic deformation capacity. The whole plastic resistance can be also attained by compact sections belonging to the second class, but with a limited plastic deformation capacity. Semi-compact sections are able to develop the flexural resistance corresponding to the elastic limit stress, but locally buckle before the complete development of the full plastic moment; therefore, their plastic deformation capacity is very limited. Finally, fourth-class sections are subjected to local buckling in elastic range and, therefore, are referred as slender sections.

With reference to aluminium alloy structures, Eurocode 9 (EC9) [11] provides a classification system mainly based on the results of stub column tests. In particular, the width-to-thickness ratio b/t and the conventional elastic stress limit $f_{0.2}$ are adopted as the main parameters

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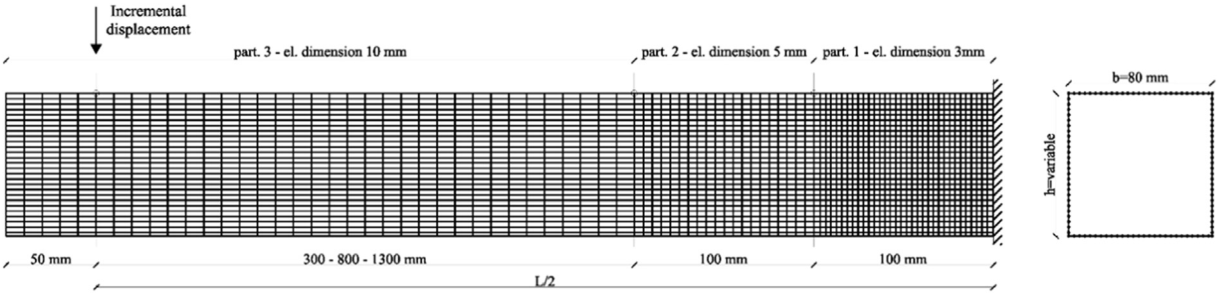

Fig. 1. Finite Element Model with geometry, mesh discretization, incremental displacement location and restraints.

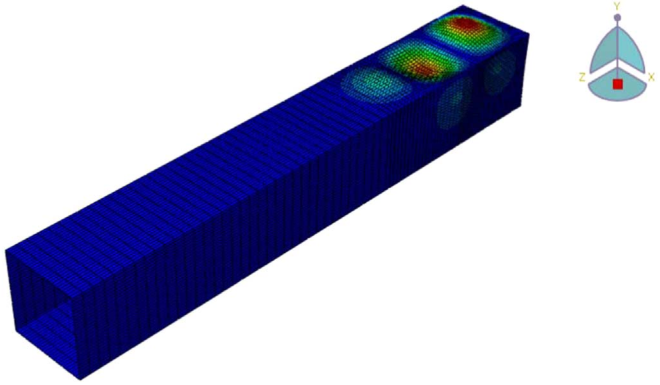

Fig. 2. Buckling mode adopted for modelling initial geometrical imperfections.

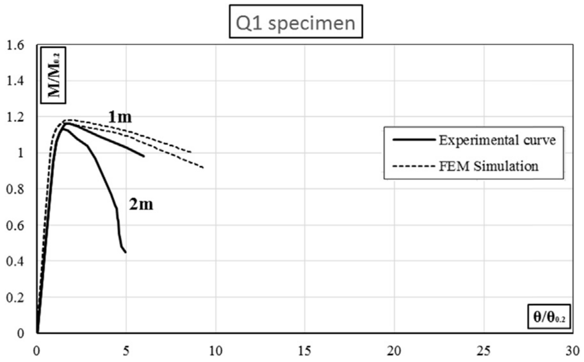

Fig. 4. Comparison between FE numerical results and experimental test results: SHS 100 × 6 section, temper T6.

governing the classification, starting from the behaviour observed in numerous experimental tests recently carried out. In particular, an experimental investigation concerning extruded aluminium profiles subjected to local buckling under moment gradient has been carried out at Norwegian University of Science and Technology [12] while, a wide experimental research devoted to heat-treated aluminium alloy RHS sections subjected to local buckling under uniform compression, i.e. stub column tests, has been carried out at University of Salerno [13]. Although these experimental tests do not consider neither the strain gradient along the section, nor the longitudinal stress gradient along the compressed plate elements, which occur under non-uniform bending, they have constituted the background for the classification rules reported in Eurocode 9 [11,13]. This is justified because, unfortunately, very few experimental results are available for aluminium alloy beams [12] compared with the large number of experimental studies reported in the technical literature for the rotation capacity of steel members [14,15]. For this reason, wider and more exhaustive investigations for the prediction of the plastic rotation capacity of aluminium members have been mainly performed by means of FE models [16,17]. In fact, the behaviour of extruded aluminium thin-walled RHS members subjected either to a uniform moment loading [18] or to moment gradient loading has been investigated [19–21]. Also the behaviour of tubular continuous aluminium alloy beams has been analysed [22,23]. In particular, De Matteis et al. [24] performed a numerical study to assess the rotation capacity of aluminium alloy members taking into account the influence of the flange slenderness ratio, of a parameter related to the web restraining action, of the section shape factor and of the moment gradient along the member. However, relationships for a quick prediction of rotation capacity have not been proposed.

With reference to EN-AW 6082 aluminium alloy temper T6 [11], this work aims to further advance previous studies [24] by developing a wider and exhaustive parametric analysis taking into account initial geometrical imperfections, the influence of the moment gradient along the member and the typical range of variation of the flange slenderness and of the flange-to-web slenderness ratio. The results herein presented can be useful for the setting up of approaches for estimating the rotation capacity [25–27]. Indeed, in the final part of the present paper empirical relationships for evaluating the rotation capacity of RHS temper T6 aluminium alloy beams have been provided. The proposed relationships are derived from the numerical results obtained by means

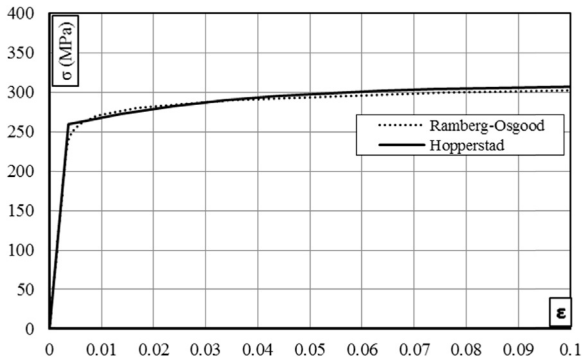

Fig. 3. Comparison between the Ramberg-Osgood and Hopperstad constitutive model.

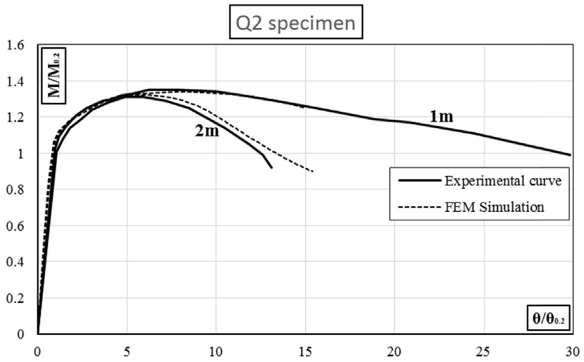

Fig. 5. Comparison between FE numerical results and experimental test results: SHS 100 × 6 section, temper T4.