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Strength of cold formed battened columns subjected to eccentric axial compressive force

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ABSTRACT

The strength of a battened beam-column composed of four slender cold formed angles is mainly governed by the local buckling of its elements as well as the overall buckling of the column. The local buckling mode is mainly affected by local slenderness ratio of one angle (between batten plates). Overall buckling mode is mainly affected by overall member slenderness ratio as well as angle legs width to thickness ratio. Members' failure modes occur by local buckling and yielding at short lengths, and by local flexural buckling at intermediate and flexural at long lengths. In the present study, the behavior of bi-axially loaded battened beam-columns composed of four equal cold formed slender angles is investigated. A nonlinear finite element model was developed to study the effect of the aforementioned factors on the ultimate capacity of members. Geometrical and material nonlinearities were considered in the model. A parametric study was performed on a group of battened beam-columns with variable angle legs having different outstanding leg width–thickness ratios, angle local slenderness ratios, and column overall slenderness ratios. The axial–bending interaction curves are presented for short, medium and long beam-columns having two different square cross sections. These interaction curves were compared with different code rules. These design rules have been shown to be reliable using reliability analysis.

1. Introduction

The current trends in steel construction are to use high yield steels and slender cross-sections. There are advantages to be achieved in terms of lighter weight although the combination of high yield strength and high plate slenderness leads to local instability with reduced section capacities in compression and bending. Built-up (combined section) columns are widely used in steel construction especially for relatively long columns; since these sections often provide sufficient flexural stiffness to resist buckling without increasing the area of such sections. However, built-up (combined section) columns are more flexible than solid columns having the same moment of inertia due to the additional effect of shear deformation, which must be taken into account in the design. The ultimate capacity of battened columns mainly depends on the local behavior of the components, the global behavior of the column as well as the internal forces in the connecting elements. The overall behavior is influenced by deformations due to bending and shear. Bending deformation is related to the moment of inertia of the whole cross section, while shear deformation is related to the deformability of the batten plates. In addition, the ultimate strength and behavior are affected by the shear deformation as well as the flexural deformation. The effect of shear in opened battened columns is included by adding the curvature due to shear deformation to the buckling curvature, which means that the total curvature of open battened columns equals the summation of the shear, and buckling deformations. The shear deformation in solid closed cross-section columns is restricted by a continuous web thus the distortion caused by shear is relatively small. Structures formed from thin-walled members and subjected to compression are highly affected by local buckling. Nevertheless, post-buckling strength of thin walled sections is often considered in the design to provide economic design either by using the effective width approach or direct strength method [1].

M. A. El Aghoury et al., [2,3], investigated experimentally the behavior of axially loaded battened columns composed of four cold formed angles. Moreover, M. A. El Aghoury et al., [4], developed a three dimensional nonlinear finite element model using thin shell element to investigate theoretically the flexural behavior and resistance of battened beams composed of four equal cold formed angles subjected to uniform bending moment. The developed finite element model included the effect of angle leg outstand width to thickness ratio, single angle slenderness ratio, and the overall member slenderness ratio. Failure modes are governed by local buckling of the compression angles between battens. Moreover, the flexural strength depends on the interaction of the mentioned factors. Also, the ultimate strength goes down with increasing angle leg width–thickness ratios, λ_b, In addition, the

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Table 1
Comparison between experimental [2] and F.E.M results.

Specimen	Specimen properties					Load eccentricity			Failure mode		
	Column length (mm)	Cross section outer dimension D (mm)	λ_b	λ_z	λ_c	ex (mm)	ey (mm)	$P_{Exp.}$ kN		P_{FEM} kN	$\frac{P_{Exp.}}{P_{FEM}}$
1000B80L30B2	1000	80 × 80	20	50	30	30	–	28	FT	33	0.85
1000B80L30B6	1000	80 × 80	20	20	30	30	–	53	T	54	0.98
1940B80L30B5	1940	80 × 80	20	50	58	30	–	20	FT	26	0.77
1250B100L40B2	1250	100 × 100	26	20	30	30	–	28	FT	30	0.93
1250B100L40B7	1250	100 × 100	26	50	30	30	–	55	T	57.6	0.95
2460B100L40B5	2460	100 × 100	26	50	58	30	–	18	FT	18.7	0.96
1000B80L30B2	1000	80 × 80	20	50	30	30	30	67	FT	68	0.99
1000B80L30B6	1000	80 × 80	20	20	30	30	30	27	T	27.6	0.98
1940B80L30B5	1940	80 × 80	20	50	58	30	30	16	FT	19.6	0.82
1250B100L40B2	1250	100 × 100	26	20	30	30	30	22	FT	25.1	0.88
1250B100L40B7	1250	100 × 100	26	50	30	30	30	24	T	29.9	0.81
2460B100L40B5	2460	100 × 100	26	50	58	30	30	12	FT	12.5	0.96

T = torsional (local).
FT = flexural (overall)–torsional (local).

section possesses a substation post-local buckling capacity although single cold formed angles subjected to compressive force do not have significant post-local buckling capacity. This is due to the contribution of the part of the section in tension. Murray C. Temple and Ghada Elmahdy [5] carried out an experimental and theoretical study to investigate the behavior of battened columns made of standard steel channel sections. A combination of equivalent slenderness ratios and limitations to the slenderness ratios of the main members between batten plates (interconnectors) was provided.

Since the strength of battened beam columns composed of four slender angles depends on the behavior of single angle between the batten plates; as such the literature review of single angle should be considered in this introduction. Trahair N. S. [6] used single angle steel sections as beams to support distributed loads which caused biaxial bending and

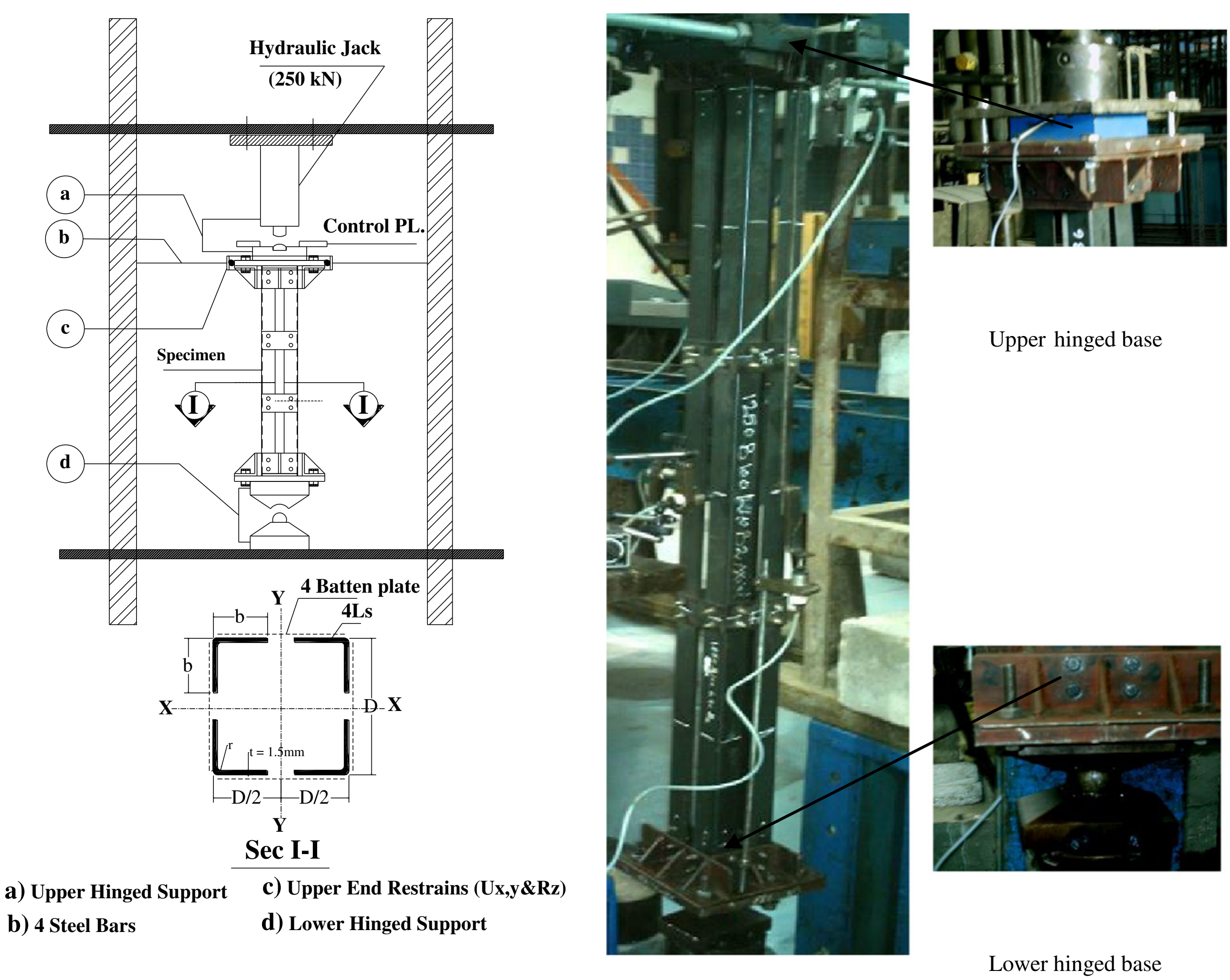

Fig. 1. Test setup. a) Upper hinged support. b) 4 Steel bars. c) Upper end restrains (Ux, y & Rz). d) Lower hinged support.