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Experimental investigation on local buckling behaviors of stiffened closed-section thin-walled aluminum alloy columns under compression

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A B S T R A C T

Six aluminum alloy tensile coupon tests were carried out and stress–strain curves obtained from tests were compared with a Ramberg–Osgood model. Comparison showed that the Ramberg–Osgood model can precisely describe stress–strain relationship of 6063-T5 aluminum alloy. Totally, 10 axial compression tests on thin-walled aluminum alloy members with four stiffened closed-section were carried out. Local buckling occurred in all specimens eventually. The axial displacement, lateral deflection, strain development and failure modes of the tested specimens were recorded. A finite element method (FEM) model was presented to simulate local buckling behaviors of the tested columns under axial load. The ultimate strength, strain development and failure modes obtained from FEM agreed well with the test results. Current design codes on aluminum alloy structures, such as the American aluminum design manual (AA), the European code (EC9), Chinese design specifications for aluminum structures (GB50429), the North American Specification for the design of cold-formed steel structural members (AISI) and the direct strength method (DSM), were used to calculate the ultimate strength of the tested columns. Comparison showed that current design codes overestimated the ultimate strength of stiffened closed-section thin-walled aluminum alloy columns under axial compression loads.

1. Introduction

For its high strength-to-weight ratio, lightness, better corrosion resistance and simple procedure of fabrication, aluminum alloy members are used increasingly in structural applications. Many works have been carried out to investigate the buckling behaviors of aluminum alloy members both with and without transverse welds. Zhu and Young studied the behaviors of aluminum alloy tubular and circular hollow section columns through tests and numerical simulations [1–4]. Proposed design equations for aluminum tubular sections subjected to web crippling were provided [5,6]. Rasmussen and Rondal [7] proposed a column curve capable of predicting the strengths of extruded aluminum alloys failed at flexural buckling. The column curve used a simple extension of the Perry curve and was verified to be valid for large range of alloys in practice. Based on a parametric study with FEM on buckling behaviors of fire exposed aluminum alloy column, Maljaars et al. [8] found that the simple calculation model for flexural buckling of fire exposed aluminum columns in EN 1999-1-2 did not give an accurate prediction. They proposed an alternative design model that took into account the stress–strain relationships of aluminum alloys at elevated temperatures.

At present, researches on aluminum alloy members are mainly focused on global buckling and traditional cross-sections such as circular, square, rectangular and angle sections. Local buckling behaviors of aluminum alloy members with irregular sections should be studied further. Aluminum alloy members can be produced through extrusion. The cross-sections of an aluminum alloy member can be very complex to integrate both structural and service function. At the same time, plates in the section are relatively thin in order to make full use of materials, while thin plates are more vulnerable to local buckling.

The current design rules for aluminum alloy compression members follow effective section approach that separates the cross-section into elements. This approach appears to be much tedious for members having complex cross-sections. Instead of the traditional effective width method [9] which is widely applied in cold formed steel members, design codes for aluminum alloy members use effective thickness method [10]. Both the effective width method and the effective thickness method need iterations to determine the final effective section. The direct strength method (DSM) based on the gross section effectively can take global buckling, local buckling, distortional buckling and interactions of different buckling modes into consideration [11,12]. The

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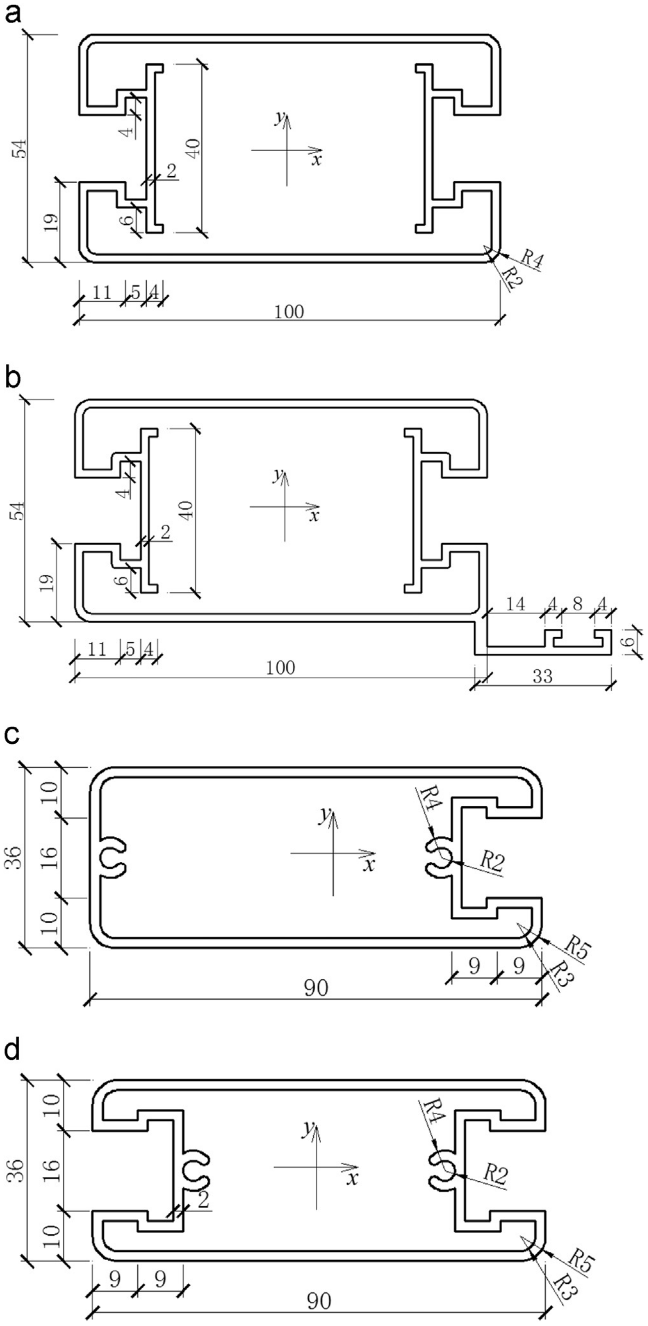

Fig. 1. Cross section of the test members. (a) Section A, (b) Section B, (c) Section C, and (d) Section D.

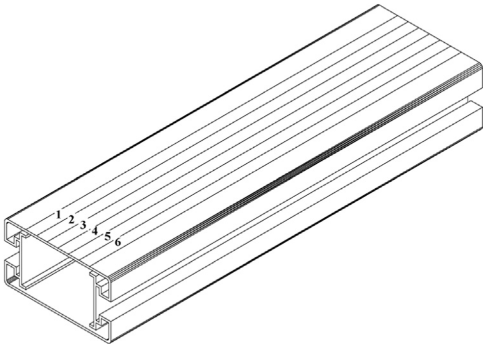

Fig. 2. Samples of test coupon.

equations of DSM are obtained by numerical analysis based on the test data of axial compression columns with open sections such as simple lipped channel, lipped channel with web stiffeners, Zed section, hat section and rack upright section. The feasibility of DSM for the aluminum alloy members with complex cross-sections should be calibrated.

This paper presents an experimental investigation on behaviors of stiffened closed-section thin-walled aluminum alloy columns experiencing local buckling under axial compression. At first, six tensile coupon tests were carried out. Stress–strain curves obtained from the tests were compared with the Ramberg–Osgood model. Second, 10 axial compression tests were carried out. Four types of cross-section were studied, as shown in Fig. 1. The axial displacement, lateral deflection, strain development and failure modes of the specimens were recorded. Then, a Finite Element Method (FEM) model was presented to simulate the local buckling behaviors of the tested components under axial load. The ultimate strength, strain development and failure modes obtained from

Table 1
Results of tensile tests.

Specimens	$f_{0.1}$ (MPa)	$f_{0.2}$ (MPa)	f_u (MPa)	Elastic modulus E (GPa)	n	Ultimate strain ε_u (%)
L1	179.89	184.85	206.40	69.1	25.5	1.78
L2	184.57	192.80	211.20	68.9	15.9	2.60
L3	171.71	178.65	200.77	68.4	17.5	1.47
L4	197.82	203.78	222.40	68.7	23.4	2.61
L5	196.13	200.22	219.20	67.0	33.6	2.61
L6	173.46	178.32	194.40	70.0	25.1	1.73
Mean	**183.93**	**189.77**	**209.06**	**68.7**	**23.5**	**2.13**
COV	**0.060**	**0.057**	**0.051**	**0.014**	**0.271**	**0.249**

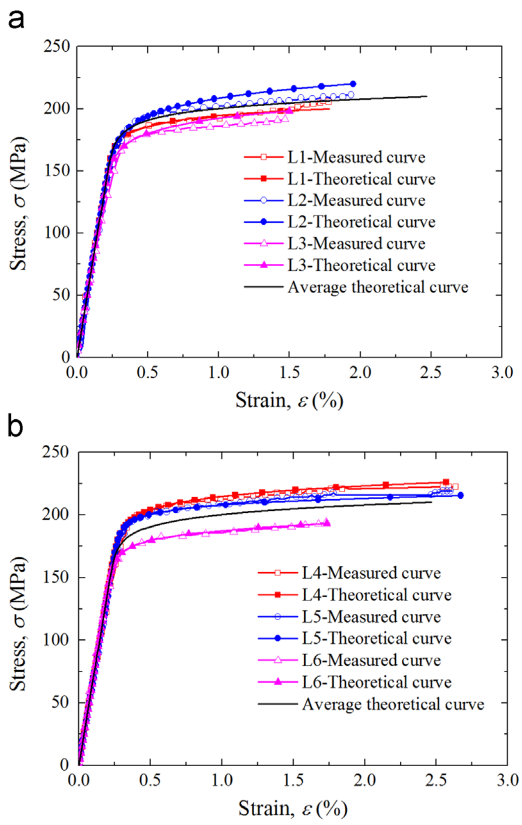

Fig. 3. Comparison between test σ–ε curve and theoretical σ–ε curve. (a) Specimen L1, L2 and L3, and (b) specimen L4, L5 and L6.