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Flexural buckling behavior of welded stainless steel box-section columns

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ABSTRACT

Flexural buckling behavior of stainless steel columns has been widely investigated and discussed. However, a barely explored area is that of welded-section members. In this paper, twelve full-scale columns buckling tests have been conducted for both austenitic and duplex welded stainless steel box-section members. Specimen cross-sections and lengths have been selected to cover a wide range of geometries, varying between non-dimensional slenderness of 0.5 and 2.0. Measurements of material properties, residual stress and initial geometric imperfection have been also conducted. Relevant numerical simulation has been performed, accuracy of which is verified by comparing with the test results. The test results have been used to assess the applicability of the EN 1993-1-4, ASCE 8-02 and AS/NZS for stainless steel welded-sections. It shows that current design method predicts the buckling resistance of welded stainless steel box-section generally conservative thus improvement could be anticipated.

1. Introduction

There are numerous grades of stainless steel, characterized by its chemical composition and heat treatment. Stainless steel could be classified into four categories according to its metallurgical properties, namely austenitic, ferritic, duplex (austenitic–ferritic) and martensitic. The austenitic and duplex stainless steel are commonly used in construction. Stainless steel possesses a number of beneficial properties, and thus it is increasingly applied in multiple fields, such as automobile industry, construction, etc.

Stainless steel was initially applied in civil engineering as facades and roofing in 1920s [1]. Worldwide relevant research over the last few decades enables a deeper insight into desirable characteristics of stainless steel, such as corrosion-resistant, long-lasting, more durable and economic. Recent intensive studies of stainless steel mostly focus on its mechanical properties [2–4], compressive behavior [5–7], flexural behavior [8–11], residual stresses [12,13], and connections [14–16].

Throughout the current achievements in terms of understanding the behavior of axial compression members, tests conducted on the bearing capacity of columns subjected to axial compression are limited on cold-formed thin-walled members. Initial researches concentrated on cold-formed rectangular sections, while more afterwards the focus moved to special section types, oval hollow section, through which corresponding design methods, curves and classification for different members were proposed. Studies of welded sections have been performed by Yang and Yuan so far. 28 welded-section stainless steel stub columns fabricated by shielded metal arc wielding (SMAW) were tested in [6]. Comparisons between the test data and current specifications, including EN 1993-1-4 [17], SEI/ASCE8-02 [18] and AS/NZS 4673 [19], were conducted as well. In structural practice, welded-section members meet the bearing capacity requirements much better than cold-formed members do. The inferior post-buckling plastic development on the most stressed section fiber of the cold-formed thin-walled axial column will lead to a quick failure of the member. Therefore, more thorough research aiming at welded sections is anticipated. This paper provides the basis to some degree on the application of welded stainless steel box-section columns.

A total of 12 series of tests are presented in this paper, consisting of six austenitic and six duplex stainless steel specimens. The focus herein is on the flexural buckling behavior of welded stainless steel box-section columns. Further investigations on the strain and displacement developments, as well as the failure mode have been conducted as well. Accuracy of the corresponding numerical analysis

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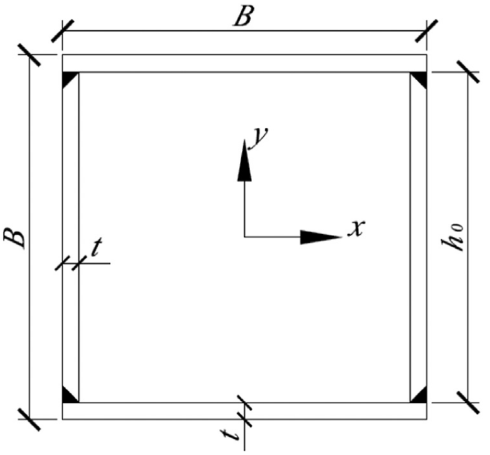

Fig. 1. Cross-section notation.

Table 1
Measured dimensions of specimens.

Specimen	B (mm)	t (mm)	L (mm)	L_t (mm)
S304-1500	129.9	6.00	1542.7	1882.7
S304-2000	130.0	6.00	2036.8	2376.8
S304-3000	129.9	6.00	3034.3	3374.3
S304-3500	130.1	6.00	3537.6	3877.6
S304-4000	129.8	6.00	4038.6	4378.6
S304-4000-B	99.8	6.00	4031.5	4371.5
S2205-1500	130.5	6.00	1538.2	1878.2
S2205-2000	130.5	6.00	2037	2377
S2205-3000	130.8	6.00	3037.3	3377.3
S2205-3500	130.7	6.00	3536.1	3876.1
S2205-4000	130.1	6.00	4036.1	4376.1
S2205-4000-B	100.1	6.00	4033.1	4373.1
S304-130	130.3	6.00	1120	–
S2205-130	130.5	6.00	1120	–

Table 2
Material properties along rolling direction.

Grade	t (mm)	E_0 (MPa)	f_u (MPa)	f_y (MPa)	Elongation at fracture (%)	n
Austenitic	6.00	182,300	660	282	58.1	6.5
Duplex	6.00	191,900	798	553	35.0	7.4

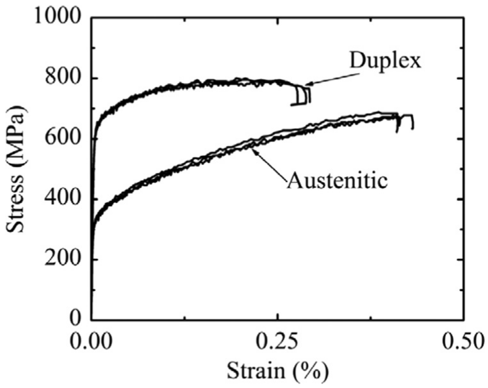

Fig. 2. Stress-strain curves of material coupon tests.

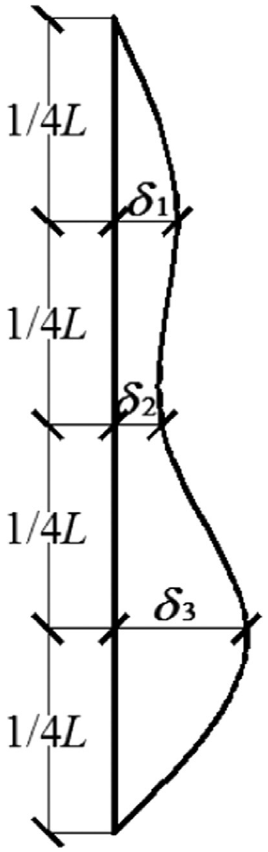

Fig. 3. Illustration of initial bending measurement.

have been verified by experimental results. This paper also presents a comparison of the results obtained from the tests and those predicted by EN 1993-1-4, SEI/ASCE 8-02 and AS/NZS 4673.

2. Experimental program

2.1. Specimens

A total of 12 tests on columns fabricated by SMAW from hot-rolled plates were conducted. The adopted labeling convention of the cross-section geometry for both austenitic and duplex specimens is shown in Fig. 1. Measured dimensions of each specimen, including the two samples for the residual stress measurements (S304-130 and S2205-130), are reported in Table 1 with the nomenclature defined in Fig. 1, where L is the geometric length, L_t is the distance between rotation centers of two single pole hinges, and $L_t=L+340$, considering the dimensions of the hinges. Besides, distinct cross-sections were adopted to cover a wider range of slenderness ratio (S304-4000-B and S2205-4000-B). Due to the anisotropy of stainless steel, the consistency between the longitudinal direction of the specimens and the rolling direction of the plate was ensured in the fabrication process.

Tensile coupon tests were carried out in accordance with ISO 6892-1 [20] to evaluate the material properties. For each material grade, three coupons, along the rolling direction, were machined from each parent stainless steel plate. The average measured 0.2% proof stress f_y, ultimate stress f_u, modulus of elasticity E_0 and percentage of elongation at fracture and the strain-hardening exponent n are summarized in Table 2. Fig. 2 displays all the measured stress-strain relationships.