Ultimate strength of stainless steel columns with welded box section

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Summary

Stainless steels show superior corrosion resistance, making them attractive for structural use owing to the ease of maintenance. This paper presents the ultimate strength of JIS SUS 304 austenitic stainless steel (EN 1.4301, UNS S30400) columns with a welded box cross section using finite element analysis.

Keywords: ultimate strength; stainless steel; column with welded box cross section; finite element analysis; residual stress.

1. Introduction

SUS304 columns are assumed to be axially loaded between two pin-ended supports, and their cross sections consist of stocky plate elements to prevent local buckling. Parametric studies were conducted to investigate effects of the non-dimensional slenderness λ_c, residual stress, and strain hardening exponent of the stress-strain model $n1$ on the ultimate strength. The ultimate compressive behavior of SUS304 columns were compared with those of carbon steel JIS SM400 (EN S235) ones. Furthermore, the ultimate strength of SUS304 columns was discussed in comparison with the design curves specified in several design standards.

2. Parametric studies

In the parametric study, elasto-plastic finite displacement analysis was performed. A modified version of the Ramberg-Osgood material model (MRO curve) [1] was used as a stress-strain model for SUS304. On the other hand, a bilinear curve was employed as the stress-strain model for SM400. Three strain hardening exponent $n1$ values 3, 5, and 10 of SUS304 were considered. Furthermore, the element slenderness of plates consisting of a boxed cross section was assumed as 0.28. In this study, 19 non-dimensional slenderness λ_c values (from 0.2 to 2.0) were considered. Furthermore, the residual stress distribution was modelled according to existing measurement results. The shape of the geometric imperfection was assumed as a sinusoidal half-wave.

3. Analysis results

Fig.1 shows the relationship between the strength ratio $(\sigma/\sigma_F)_R/(\sigma/\sigma_F)$ and the non-dimensional slenderness. Here, $(\sigma/\sigma_F)_R$ and (σ/σ_F) denote the ultimate strength considering and neglecting the residual stress. This figure shows that the reduction in the ultimate strength owing to the residual strength of SM400 columns is greater than that of SUS304 ones. Furthermore, variation in the

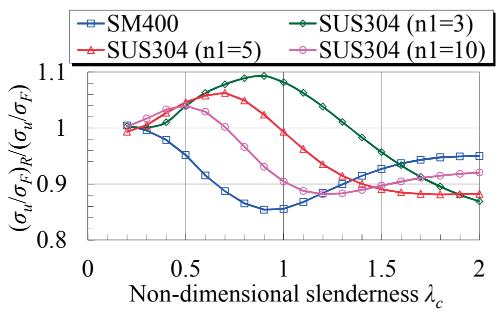

Fig. 1: Influence of residual stress on ultimate strength

ultimate strength of SUS304 columns tends to increase with a decrease in the $n1$ value.

Fig.2 shows the relationships between the strength ratio $(\sigma/\sigma_F)/(\sigma/\sigma_F)_3$ and the non-dimensional slenderness. Where (σ/σ_F) and $(\sigma/\sigma_F)_3$ represent the ultimate strength of SUS304 columns with $n1$ = 5 or 10 and $n1$ = 3, respectively. "R" and "N" denote the case with and without residual stress, respectively. This figure shows that the ultimate strength of SUS304 columns with $\lambda_c \geq 0.7$ increases with the $n1$ value.

Fig. 3 shows a comparison between the design strength curve specified in SSBA [2], curve for square hollow section specified in EC3 [3], curve based on Perry-Robertson's curve specified in AS [4], curves based on tangent modulus method specified in ASCE [5], and Euler curve and ultimate strength of SUS304 columns as obtained from FEA. This figure shows that although the SSBA and AS curves provide conservative estimates of the ultimate strength of SUS304 columns, the EC3 and ASCE curves do not.

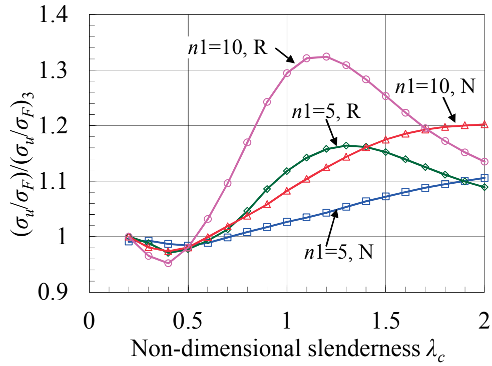

Fig. 2: Influence of strain hardening exponent n1 on ultimate strength

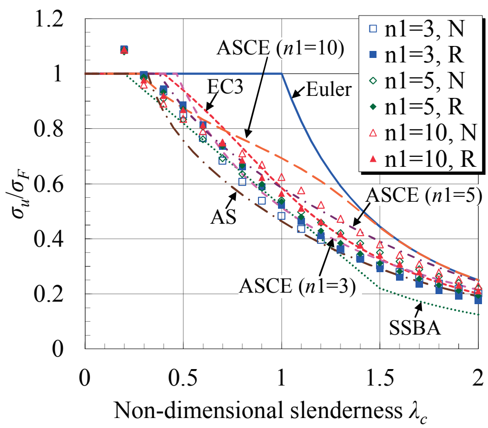

Fig. 3: Comparison of FE results with the EC3, ASCE, AS and SSBA design curves

4. Conclusions

The obtained results can be summarized as follows:

(1) The variation of the ultimate strength owing to the residual stress of SUS304 columns is smaller than that of SM400 ones.

(2) The ultimate strength of SUS304 columns increases with the strain hardening exponent ($n1$).

(3) The design strength curves of columns provided in the SSBA and AS/NZS provide conservative estimates of the ultimate strength of SUS304 columns.

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