Comparison of calculation method of coupled buckling strength for steel compression members among major design codes

Nagasaki University Student Member ○Xiang CHEN Nagasaki University Member Shozo NAKAMURA
Nagasaki University Member Toshihiro OKUMATSU Nagasaki University Member Takafumi NISHIKAWA

1 INTRODUCTION

Aiming at preventing the coupled buckling on thin-walled structure due to high slenderness and width-thickness ratios, various countries have drawn up codes for the stability design. Among these codes, Chinese code: *Code for Design of Steel Structures* [1] uses the effective width method, Japanese code: *Specifications for Highway Bridges* [2], provides a product for stability design, American code: *Specification for Structural Steel Buildings* [3] adopts the direct strength method (DSM) combined with effective width method. In this study, calculation of coupled buckling strength following those codes were detailed on the box section column under compression. In addition, the ultimate strength based on formulae in these codes was compared with FEA results.

2 CALCULATION METHOD IN EACH CODE

2.1 CODE FOR DESIGN OF STEEL STRUCTURES

The overall buckling stability coefficient is expressed by the normalized slenderness ratio. The potential reduction in capacity due to local buckling, which is considered through effective area as follows;

$$\bar{\sigma}_{cr} = \varphi(\lambda_n) \cdot \frac{A_e}{A_g}$$

where $\bar{\sigma}_{cr}$ is the non-dimensional buckling stress, A_g is the gross area of the cross-section, A_e is the effective area of cross-section, φ is overall buckling stability coefficient, λ_n is the normalized slenderness ratio.

2.2 SPECIFICATIONS FOR HIGHWAY BRIDGES

Design according to Japanese code for the coupled buckling strength can be performed as a product consisting of non-dimensional local buckling stress determined by normalized width-thickness ratio and the non-dimensional overall buckling stress expressed by the normalized slenderness ratio without local buckling as follows;

$$\bar{\sigma}_{cr} = p_{crg} \cdot p_{crl}$$

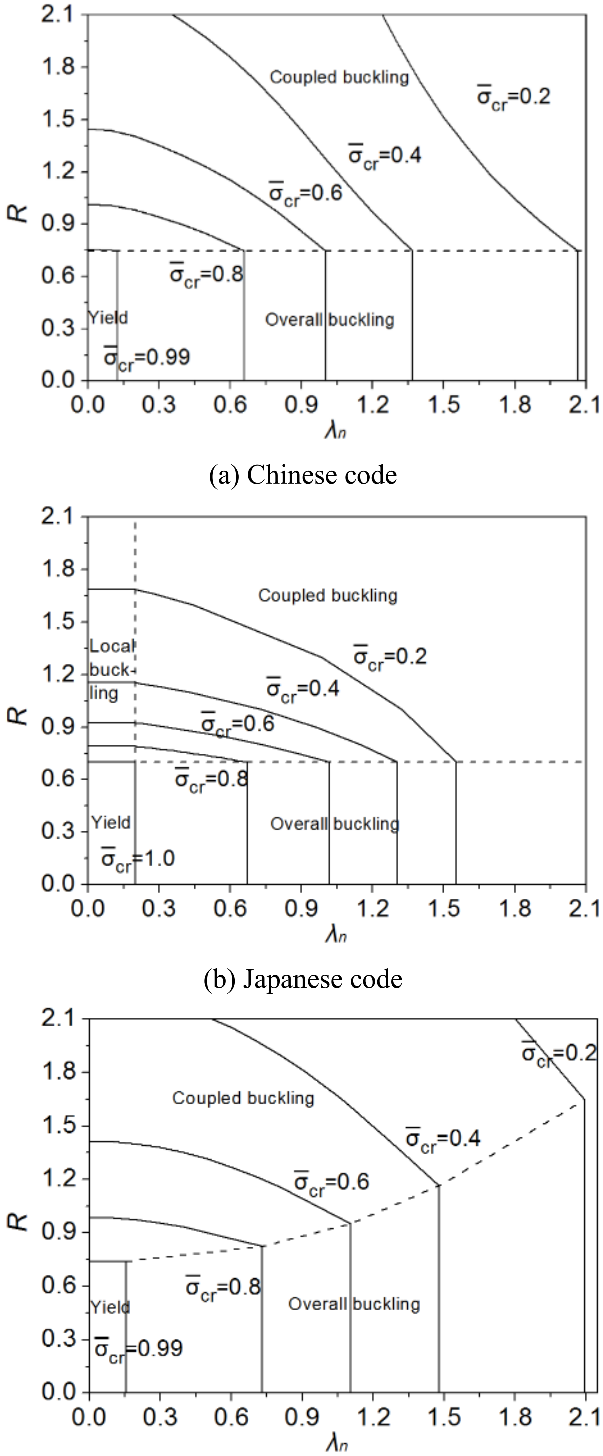
where p_{crg} is non-dimensional buckling stress, p_{crl} is non-dimensional local buckling stress.

2.3 SPECIFICATION FOR STRUCTURAL STEEL BUILDINGS

The non-dimensional overall buckling stress is calculated on the basis of DSM with related to the normalized slenderness ratio. On the other hand, the reduction factor caused by the local buckling is considered through the ratio of effective area to gross area.

$$\bar{\sigma}_{cr} = \frac{F_{cr}}{F_y} \cdot \frac{A_e}{A_g}$$

Where F_y is nominal yield stress, F_{cr} is critical stress.



(a) Chinese code

(b) Japanese code

(c) American code

Fig.1 Ultimate strength against buckling parameters

Key words: Compression members, Coupled buckling strength, FE analysis, Comparative study.
Contact address: 1-14, Bunkyo-machi, Nagasaki 852-8521, Japan. Tel:095-819-2613

3 COMPARISON OF COUPLED BUCKLING STRENGTH

The ultimate strength against buckling parameters is plotted in Fig.1. To provide a definitive comparison among those codes, formulae are detailed into the case of a steel column with square cross-section. The non-dimensional buckling strength from FE analysis as well as the results calculated according to each code are plotted with the normalized slenderness as shown in Fig.2.

3.1 COMPARISON AMONG THE CODES

It can be seen that when normalized width-thickness ratio $R \leq 0.7$, buckling strength based on the formula shows good agreement with each other. When $R \geq 0.9$, buckling strength results start to be different. American code provides the highest prediction on the coupled buckling strength, while the coupled buckling strength based on the Japanese code shows to be rather conservative.

3.2 COMPARISON WITH FEA RESULTS

From the comparison between the FEA results and design codes, it can be seen that for the stage that local buckling is not supposed to occur (i.e. R=0.5), formula results show good agreement with the FEA results. At the critical point whether or not the local buckling will occur (i.e. R=0.7), the formula results provide higher prediction on the buckling strength than the FEA results. With $R > 0.7$ and $\lambda \geq 0.2$, formula results based on American code are at the dangerous side than the FEA results. Japanese code, on the other hand, offers a relatively safer prediction than the FE analysis. With respect to Chinese code, it provides higher prediction than FE analysis when the normalized slenderness ratio $\lambda < 1.0$, while it will give conservative results when the structure is controlled by overall buckling (i.e. $\lambda \geq 1.0$). In addition, the results based on Chinese code corresponds well with the FEA results.

4 CONCLUSIONS

Main conclusions of this study can be summarized as follows.

(1) Among the three codes, American code provide relatively high prediction on the coupled buckling strength, while Japanese code offers a more conservative result than others.

(2) Among the three methods, design value based on the effective width method shows good agreement with the FEA results.

REFERENCES

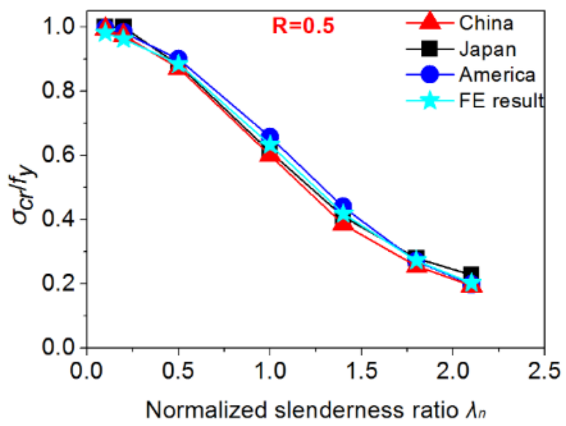
[1] GB 50017-2017, Code for Design of Steel Structures, China, 2017.

[2] Japan Road Association, Specifications for Highway Bridges, Part II Steel Bridges and Members, Japan, 2017.

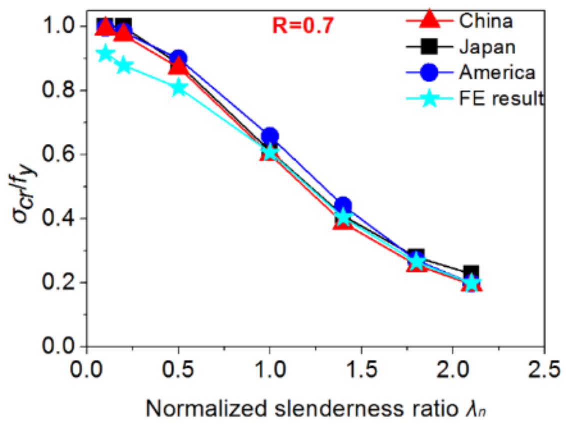
[3] AISC, ANSI/AISC 360-16, Specification for Structural Steel Buildings, AISC, Chicago, 2016.

ACKNOLEDGEMENTS

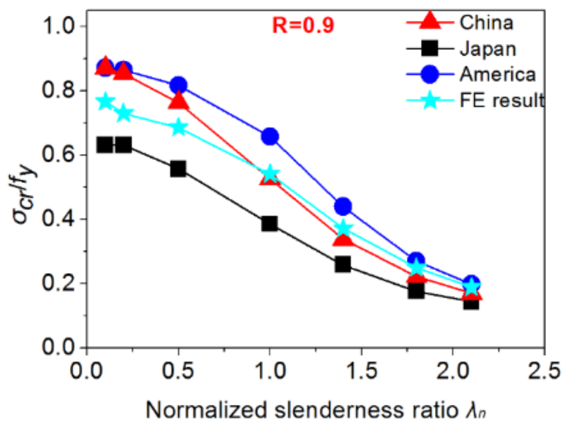
This study has been carried out as a part of the collaborative research among Tokyo Metropolitan University, Yokogawa Bridge Corporation, Nippon Engineering Consultants Co., Ltd. and Nagasaki University.



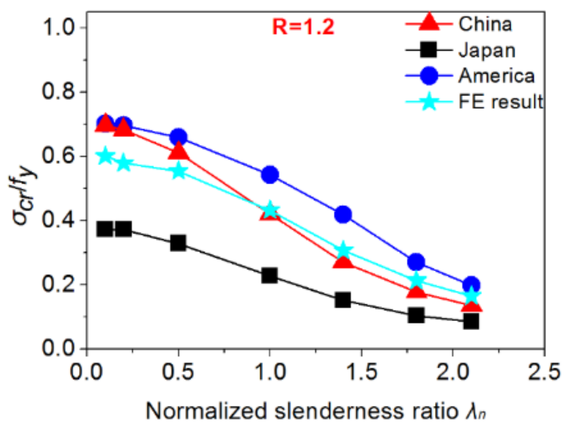
(a) R=0.5



(b) R=0.7



(c) R=0.9



(d) R=1.2

Fig.2 Comparison coupled buckling strength