Stability Condition of Pin-Ended Buckling-Restrained Brace

Tomohiro KINOSHITA
Senior Researcher
JFE Steel corp.
Kanagawa, Japan
to-kinoshita@jfe-steel.co.jp

Yosuke KANESHIRO
Researcher
JFE Steel corp.
Kanagawa, Japan
y-kaneshiro@jfe-steel.co.jp

Yuji KOETAKA
Associate Professor
Kyoto University.
Kyoto, Japan
koetaka@archi.kyoto-u.ac.jp

Keiichiro SUITA
Professor
Kyoto University.
Kyoto, Japan
suita@archi.kyoto-u.ac.jp

Kazuaki MIYAGAWA
General Manager
JFE Civil Engineering & Construction corp.
Tokyo, Japan
miyagawa@jfe-civil.com

Summary

This paper presents conditions to prevent global buckling of pin-ended buckling-restrained braces. The both end joints of pin-ended buckling-restrained braces are supported by mechanical pins (not welded or bolted). When one end of the buckling restraining member is rigidly connected to the pin joint and the sliding joint is adopted at the other end, the deflection of the brace makes an asymmetric curve and the local deformation of the restraining member may occur at the sliding joint. In this paper, theoretical method to calculate deflection of the core member and bending moment of the restraining member is derived, and design criteria to prevent global buckling is proposed. In order to verify the validity of proposed methods, cyclic loading tests and FEM analysis are conducted.

Keywords: Pin-ended buckling-restrained brace, Deflection curve, Condition to prevent global buckling, One-sided sliding type, Loading test, FEM analysis

1. Introduction

Pin-ended buckling-restrained braces have to be designed to restrain the excessive rotation at joints by buckling restraining member (hereinafter, referred to restraining member). In order to carry the bending moment adequately from joint part to restraining member. Therefore, the one end of the restraining member is rigidly connected to the pin joint and rigid member is inserted into the other end of the restraining member (called as sliding joint), as shown in Fig.1(a). In this case, the deflection of the brace makes an asymmetric curve, and the local deformation of restraining member (δ_B) which causes the global buckling of the brace may occur at the sliding joint. In the previous research[1]-[3], the asymmetric deflection curve and the influence of local deformation δ_B has not been considered in the evaluation of global buckling.

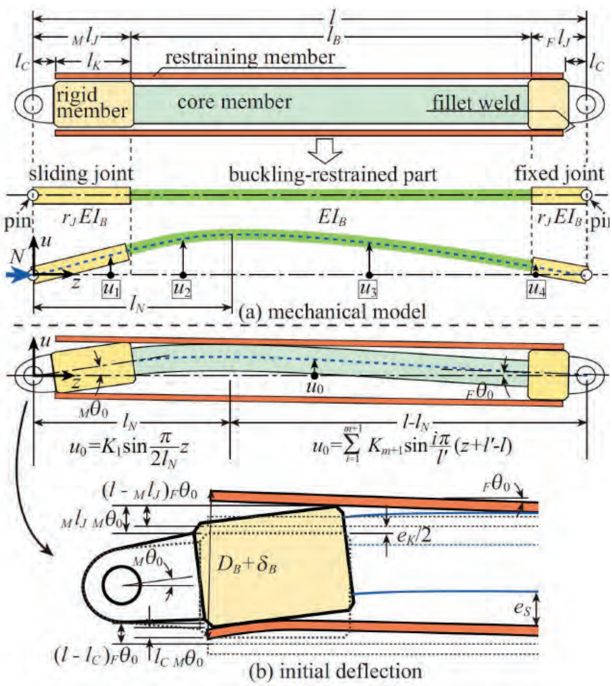

Fig.1 : Pin-ended buckling-restrained brace (one-sided sliding type) and mechanical model

In this paper, a method to calculate deflection of the core member and bending moment of the restraining member considering the local deformation of the restraining member is led theoretically, and conditions to prevent global buckling of pin-ended buckling-restrained braces are proposed. Also, validity of proposed method and condition are examined through parametric study by cyclic loading tests and FEM analysis.

2. Condition to prevent the global buckling

When a core member is plasticized by axial compression force, the sliding joint will rotate and contact with the restraining member at two points and the core member will contact with the restraining member at *m* points as shown in Fig.1(b). This state is defined as the initial deflection of the brace u_0, and the calculation formula is derived by referring Fig.1(b). The deflection of the core member u is derived by substituting u_0 for the following equation.

$$EI \cdot \frac{d^4(u-u_0)}{dz^4} + N \cdot \frac{d^2u}{dz^2} = 0 \tag{1}$$

Where, N : axial compression force, EI : flexural rigidity.

Supposing that only the restraining member is subjected to bending moment at buckling restrained part, the bending moment of the restraining member M_B is calculated by multiplying N by u. Then, the condition to prevent global buckling is presented as follows.

$$M_B = N \cdot u < {}_BM_y \tag{2}$$

Where, ${}_BM_y$: yield bending moment of the restraining member.

Cyclic loading tests and FEM analysis are conducted to verify accuracy of calculated deflection u and bending moment M_B and the validity of the condition to prevent global buckling Eq.2. At the first several loading cycles, calculated bending moment are larger than test results caused by the out-of-plane deflection. However, as loading cycles go on and the deflection become larger, calculation results become closer to experimental results, and both results well corresponded at the cycle when M_B reaches to ${}_BM_y$ for the first time. Furthermore, when M_B became larger than ${}_BM_y$, the deflection increased rapidly, and then global buckling of the brace occurred.

In FEM analyses which simulate monotonic compressive loading tests, it is able to remove the out-of-plane deflection and evaluate the deflection of the core member directly. As a result, calculated values well agreed with FEM results for any parameters.

3. Conclusion

The validity of proposed methods to calculate deflection of the core member and bending moment of the buckling restraining member are verified. Global buckling of pin-ended buckling-restrained braces (one-sided sliding type shown in Fig.1) can be prevent by designing the details (i.e. thickness of restraining member, length of rigid member, gap between rigid member and restraining member) to satisfy the condition Eq.(2). However, the theoretical estimation of the local deformation δ_B remains as a problem to be solved and we are researching about this problem.

References

[1] Fujimoto, M., Wada, A., Saeki, E., Watanabe, A., Hitomi, Y., "A study on the unbonded brace encased in buckling-restraining concrete and steel tube", *Journal of Structural Engineering B*, vol.34B, 1988, pp.249-258 (in Japanese)

[2] Takeuchi, T., Ozaki, H., Matsui, R., "Out-of-plane stability assessment of buckling restrained braces including moment transfer capacity at restrainer-end", *Journal of Structural and Construction Engineering*, No.691, 2013, pp.1621-1630 (in Japanese)

[3] Fujii, S., Tagawa, H., "Behaviour characteristics of buckling-restrained braces using round steel bar cores and double steel tubes", *Journal of Structural and Construction Engineering*, No.659, 2011, pp.167-174 (in Japanese)