THE EFFECT OF THE LOADING PATTERN ON THE ELASTOPLASTIC BEHAVIOR OF STAINLESS STEEL LONG COLUMNS WITH GUSSET PLATES

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1. INTRODUCTION

The life-cycle costs of steel bridges have become increasingly important in recent years because of the rise in maintenance costs of these structures. Stainless steel, with its high corrosion resistive properties, offers the possibility for lowering such life-cycle costs. Several cases in particular have been reported for severe corrosion damage in sway bracings and lateral bracings. Prior to applying stainless steel to these members, however, it is necessary to resolve several problems. For example, although sway bracings and lateral bracings can be designed according to its buckling strength using the ultimate strength curve specified in the "*Specifications for Highway Bridges*" (Japan Road Association 2017), this design method is based on the experimental studies on conventional steel (Usami, T. and Fukumoto, Y. 1972, Usami, T. and Galambos, T. V. 1971) and the experimental studies on stainless steel are still limited. As a part of a joint research between several organizations, the purpose of this investigation is to grasp the load carrying capacity of lateral bracings made from stainless steel. In particular, in order to reflect the actual design in construction, the lateral bracing with a T-section was prepared and bolt-connected to gusset plates on both ends.

Moreover, due to the high occurrence probability of earthquakes like the Nankai Trough Earthquake, it is also necessary to consider the effect of dynamic loading. For this reason, the focus of this paper will be to examine the effect of cyclic loading on the load carrying capacity of such members, in order to determine whether these members can be design based on the results of previous studies.

2. EXPERIMENTAL METHOD

The geometric configuration of the test specimen under the monotonic loading is shown in **Figure 1**. The test specimen for the cyclic loading is prepared under a similar design. The slenderness ratio parameter of the column, calculated by **Equation 1**, governs the overall buckling behavior of the column, while the $a/2t$ ratio governs the local buckling behavior of the gusset plates. Both parameters are determined by using the most frequently recorded values in existing bridges in Japan. The column and gusset plate specifications are summarized in **Table 1** and **Table 2**.

For the monotonic loading, the axial compression test was conducted with repetitions of loading and unloading at various intervals to simulate repeated loading under seismic activity. For the cyclic loading, the specimen was loaded in compression and tension with similar repetitions. The reference points for the intervals were based on the yield and maximum load and displacement. Four displacement transducers were placed in the vertical direction to measure the average vertical displacement, and horizontal displacement transducers were placed at three cross-sections along the length of the column to measure the column's out-of-plane deflection. Strain gauges were attached to the column and gusset plates, and clip-on gauges were attached at the end of the column to measure the bolt-connection slippage.

3. RESULTS AND DISCUSSION

The load-vertical displacement relationships for both loading types, as shown in **Figure 2**, show a negligible difference. In addition, the results in both cases were unaffected by the repeated loading and unloading.

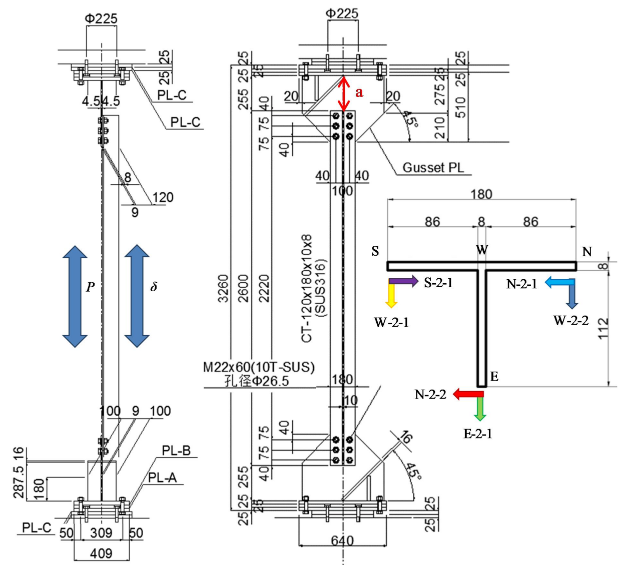

Figure 1: Test specimen geometric configuration (cyclic)

Table 1: Column specification (material: SUS316)

Cross sectional area	A	(mm^2)	2597
Length	L	(mm)	2600
Slenderness ratio parameter	$\bar{\lambda}$	-	0.861
Radius of gyration over x axis	R_x	(mm)	35.7
Yield strength	σ_y	(MPa)	251

Table 2: Gusset plate specification (material: SM400A)

Fixed point distance	a	(mm)	295
Thickness	t	(mm)	9
Yield strength	σ_y	(MPa)	293

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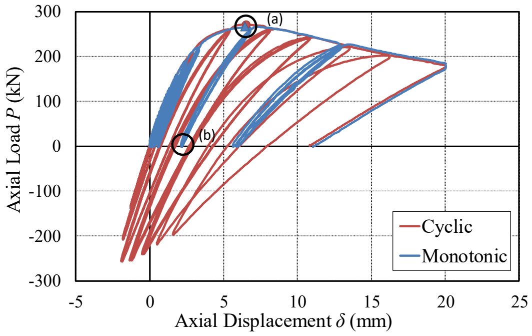

Figure 2: Load-vertical displacement

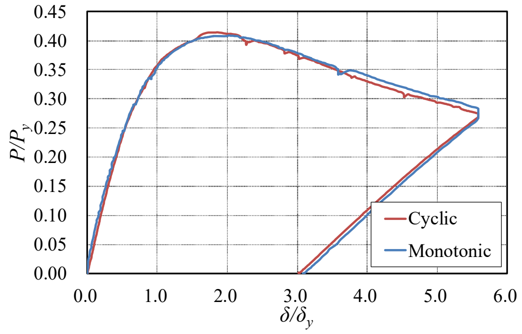

Figure 3: Envelope load-vertical displacement

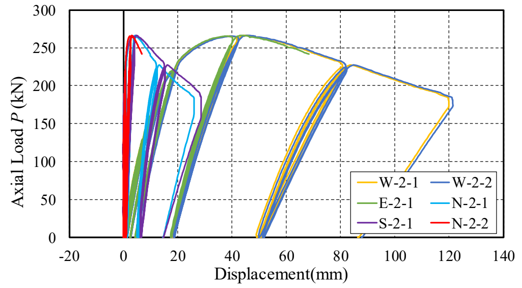

Figure 4: Load-lateral displacement (monotonic)

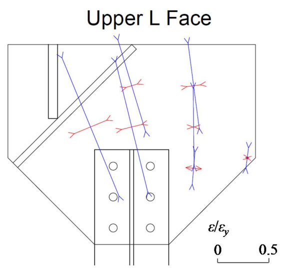

Figure 5: Principle stress (a)

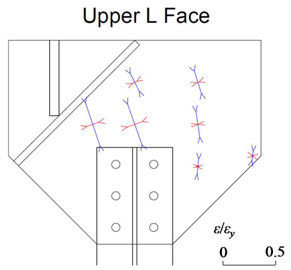

Figure 6: Principle stress (b)

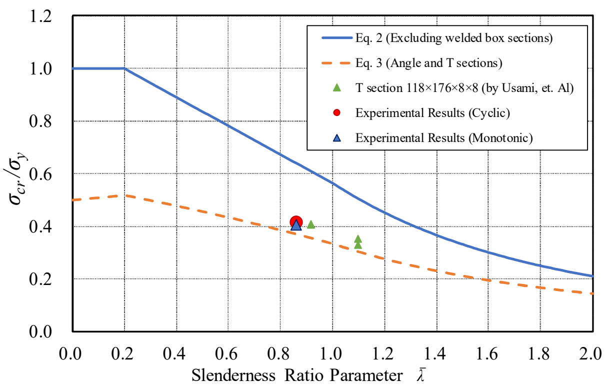

Figure 5: Ultimate strength curve

$$\bar{\lambda} = \frac{L}{r_x} \cdot \frac{1}{\pi} \cdot \sqrt{\frac{\sigma_y}{E}} \tag{1}$$

$$\frac{\sigma_{cr}}{\sigma_y} = \begin{cases} 1.00 & (\bar{\lambda} \le 0.2) \\ 1.109\text{-}0.545\bar{\lambda} & (0.2 < \bar{\lambda} \le 1.0) \\ 1/(0.733+\bar{\lambda}^2) & (1.0 < \bar{\lambda}) \end{cases} \tag{2}$$

$$\frac{\sigma_{cud}}{\sigma_y} = \frac{\sigma_{cr}}{\sigma_y}\left(0.5 + \frac{L/r_x}{1000}\right) \tag{3}$$

A similar result can be observed through the envelope curves, as shown in **Figure 3**. With a similar maximum load and elastoplastic behavior, it can be concluded that the loading type in this experiment has negligible effect on the load carrying capacity.

Figure 4 shows the out-of-plane and in-plane deflections at the column's longitudinal center during monotonic loading, where the dominant deflection occurs over the strong-axis. Overall buckling was observed in the column for both cases, and neither local buckling in the gusset plates nor slippage in the bolt connections were observed. The strains on the gusset plates at the maximum load (a) and at the point after unloading from the maximum load (b) were compared, as shown in **Figure 5** and **Figure 6**. The low magnitude of residual strains on the gusset plates after the unloading from P_{max} was observed

The experimental results were compared with the ultimate strength curves specified in the "*Specifications for Highway Bridges*" (Japan Road Association 2017). The ultimate strength curves for columns excluding welded box sections and that for angle sections and T sections considering eccentricity are shown in **Equation 2** and **Equation 3**, respectively. The experimental results are plotted against the ultimate strength curves, as shown in **Figure 5**. The results show that the ultimate strength curves from previous studies can be used to evaluate the ultimate strength of T section long columns made of stainless steel, regardless of the loading type as for the two test specimens.

4. CONCLUSIONS

In this experiment, the loading pattern had little effect on the load-vertical displacement relationship, load carrying capacity, and buckling mode. For both specimens, it is possible to evaluate the ultimate strength of the members based on previous studies with conventional steel.

ACKNOWLEDGEMENTS

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