EXPERIMENTAL EVALUATION OF STRUCTURAL BEHAVIOR OF GUSSET PLATE CONNECTION IN BRB FRAME SYSTEM

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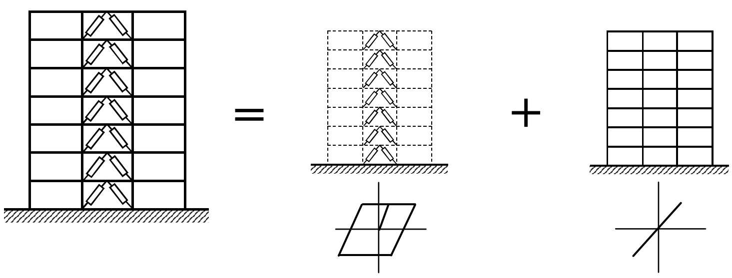
ABSTRACT :

The majority of these studies have tested isolated braces or simple subassemblies which neglect the influence of the framing components and the gusset-plate on the system performance. In this paper, frame subassemblies with the gusset-plate were subjected to cyclic lateral loading. It was found that effective length of the beam shortened by the presence of the gusset-plate connections. It was indicating that critical section of the beam was moved to the toe of the gusset-plate.

KEYWORDS: Steel Structure, Damage-Controlled Design, Beam-Column Connection, Gusset-Plate

1. INTRODUCTION

In the Northridge and Kobe earthquakes, some buildings lost their structural functions, although many buildings avoided collapse as to save human life. The loss caused the termination of social and industrial activities, and severe economic loss. At the design stage of seismic design in urban areas, it is important to consider restoring structures immediately after an earthquake. Most of high-rise buildings are designed according to Damage-Controlled Design (Wada et al., 1992) seen in Figure 1. This system consists of a primary frame and dampers. The primary frame only supports gravity and is able to remain in the elastic range during an earthquake, because dampers absorb the input energy of the earthquake. Therefore, the buildings designed as Damage-Controlled Design can be used continuously by repairing or exchanging dampers after an earthquake. However, the majority of studies on dampers have tested isolated dampers or simple subassemblies which neglect the influence of framing components and gusset-plate on the system performance. Recently, some design-level and beyond design-level cyclic loading tests of frame subassemblies with buckling-restrained braces were carried out. These tests showed good behavior of the braces, and the results indicated a number of important considerations for the design of buckling-restrained braced frames and also of braced frames in general (Mahin et al., 2004). In this paper, four frame subassemblies with the gusset-plate connections were subjected to cyclic loading. The objectives of the tests were to verify structural behavior of the beam affected by the presence of the gusset-plate, removing influences of a brace forces.



(a) (b) (c)

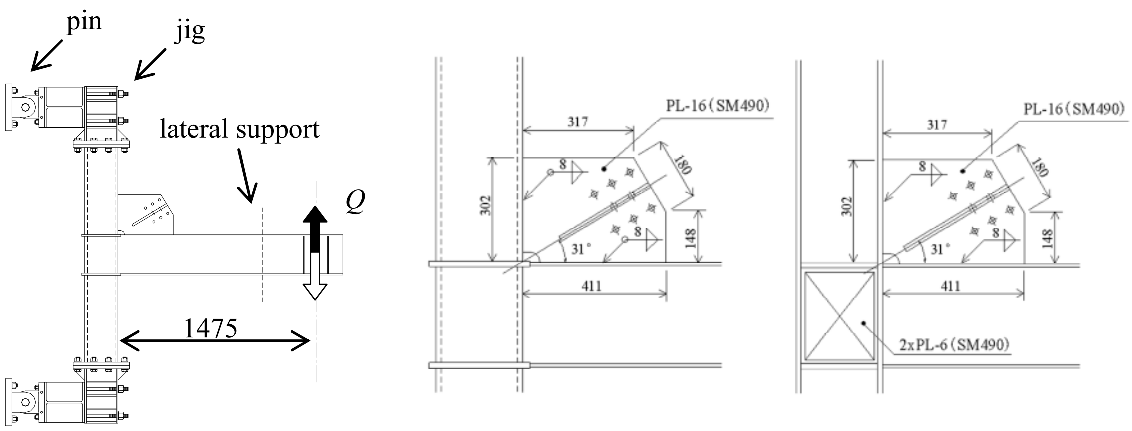
Figure 1 Concept of Damage-Controlled Design (Wada et al., 1992):
(a) Damage-Controlled Structures; (b) primary frame; (c) dampers

2. TEST PLAN

A constant comparison was used for all specimens to investigate structural behaviors of beam-column frame subassemblies affected by the presence of the gusset-plate. Capacity limitations of the testing equipment, as well as constraints on the overall size of the test specimen, dictated that the specimen were approximately half of the actual building bay width and story height. The specimen was cut out from the frame with a bay width of 3.0m and a story height of 2.2m. The tests were cantilever beam, cyclic-load tests with a stiff, strong column as seen in Figure 2. A lateral support was applied to the beam during cyclic loading.

Two pairs of specimen were tested. Each pair consisted of the conventional moment-resisting beam (B) and the beam with the gusset-plate attachment to the beam and column flanges (G). In the first pair, a rectangular hollow section (RHS) was chosen for the column. On the other hand, a wide flange H-shaped section was chosen for the column in the second pair. Overall details are complied in Table 1.

Beam was made of section (depth × flange width × web thickness × flange thickness) of 300×150×6.5×9. Steel grades JIS SS400 were chosen for flange and web of the beam. As shown in Table 2, mechanical properties were obtained from tensile coupon tests according to JIS-1A. Cold-formed RHS columns with 250mm depth, 12mm thickness, and BCR295 steel grade were used for specimen BOX_G and BOX_B. Columns for specimen H_G and H_B were made of section of 250×250×9×14 with JIS SS400 steel grade.



(a) (b) (c)

Figure 2 Test set-up and details of beam-column-gusset plate connection:
(a) test set-up; (b) specimen Box_G; (c) specimen H_G (unit:mm)

Table 1 List of test specimens

Specimen	Shapes of Columns	Gusset-plate
Box_G	RHS-Roll	Attached
Box_B	RHS-Roll	Nothing (bare)
H_G	Wide Flange	Attached
H_B	Wide Flange	Nothing (bare)

A detail of the gusset-plate installed at the beam-column connections is shown in Figure 2. The gusset-plate was attached to the beam and column flange by using shop-welding of filet welds. Gusset-plates are fabricated in many different configurations. The most common configuration in Japan, rectangular non-compact type, was used for the specimen BOX_G and H_G. Steel grades JIS SM490, stronger than the beam and column, were chosen for the gusset-plate.

Quasi-static loading was carried out following to a simple loading program shown in Figure 3. The loading programs were based on rotation angles of the specimen, which were 1/200, 1/100, 1/50, 1/33, 1/25, and 1/20 radian. The cantilever beams had a length L from the face of the column to the center of the load. The total tip deflection was due to elastic and plastic flexural deformation of the beam and connection. A rotation angle of the specimen can be found out by dividing the total tip deflection by L. Note that length L from the face of the column to the center of the load was used regardless of the presence of the gusset-plate.

Table 2 Mechanical properties of steel plate used for specimens

Sample plate	Grade	σ_y [MPa]	σ_u [MPa]	ε [%]
Beam-flange	SS400	342	461	29
Beam-web	SS400	406	490	22
Gusset-plate	SM490	400	536	27

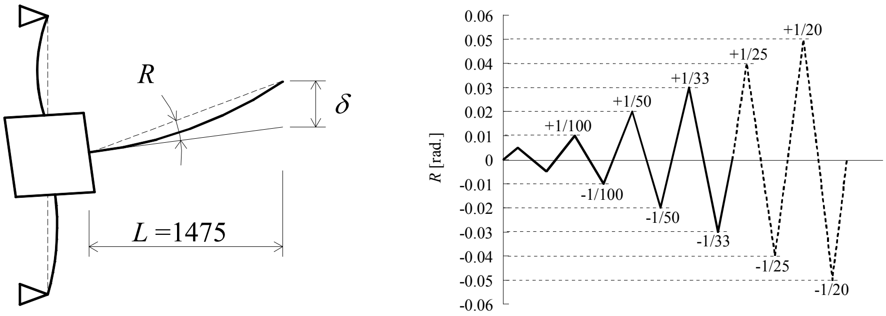


Figure 3 Loading program

3. TEST RESULTS AND CONSIDERATION

3.1. Specimen performance

A shear force versus a rotation angle of the beam is plotted for all specimens in Figure 4. As observed in Figure 4, all specimens exhibited stable hysteretic behavior during 1/50 radian rotation angle cycles. Locally buckled beam flange led to degrading hysteretic characteristics over 1/50 radian rotation angle cycles. Locally buckled beam flanges grew up shown in Fig. 5. As compared in place of the locally buckled beam flanges, those of test specimen BOX_G and H_G were observed at the toe of the gusset-plate.

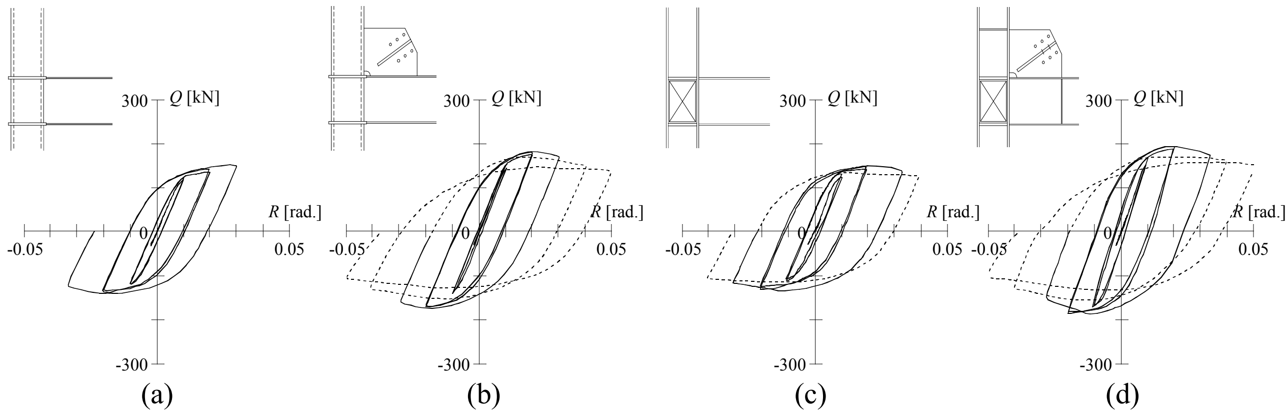


Figure 4 Test set-up and details of beam-column-gusset plate connection:
(a) test set-up; (b) specimen Box_G; (c) specimen H_G (unit:mm)

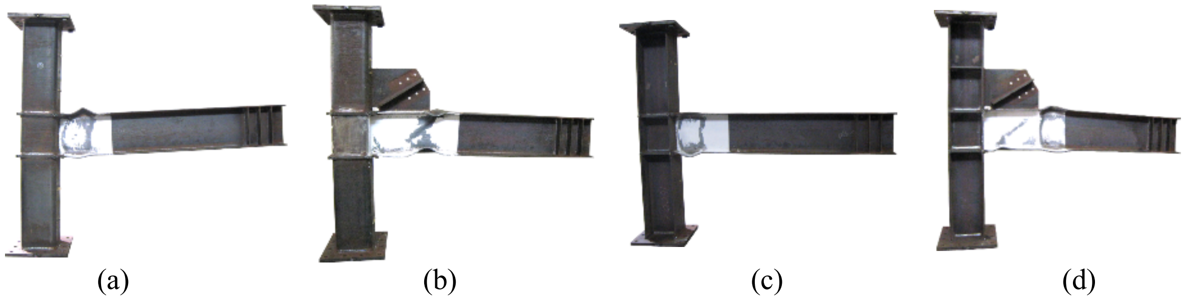


Figure 5 Photographs of locally buckled beam flange of test specimen
(a) Box_B; (b) Box_G; (c) H_B; (d) H_G

"Skelton curves", which are cut out from overall behaviors of the beam, are plotted for all specimens in Figure 6. The gusset-plate attached led to a roughly 35% increase in the yield strength. It was indicating that the critical section of the beam was moved to the toe of the gusset-plate. And a roughly 25% increase in initial elastic stiffness was caused by the gusset-plate in specimen H_G. On the other hand, initial elastic stiffness in specimen BOX_G was increased by only 5%, indicating that RHS column is hardly affected by the presence of the gusset-plate when a rectangular hollow section (RHS) was used for the column.

3.2. Distribution of the principal stress at the gusset-plate

Distribution of the principal stress at the gusset-plate at the cycle of ±1/200 radian amplitude is shown in Figure 7. It was found that shear forces were transferred between the beam, the column, and the gusset-plate. In particular, the principal stress, shear-transfer, was concentrated on the toe of the gusset-plate. As compared in distribution of the principal stress at the toe of the gusset-plate, the shear-transfer between the toe of the gusset-plate and RHS column flange was less than that of test specimen H_G.

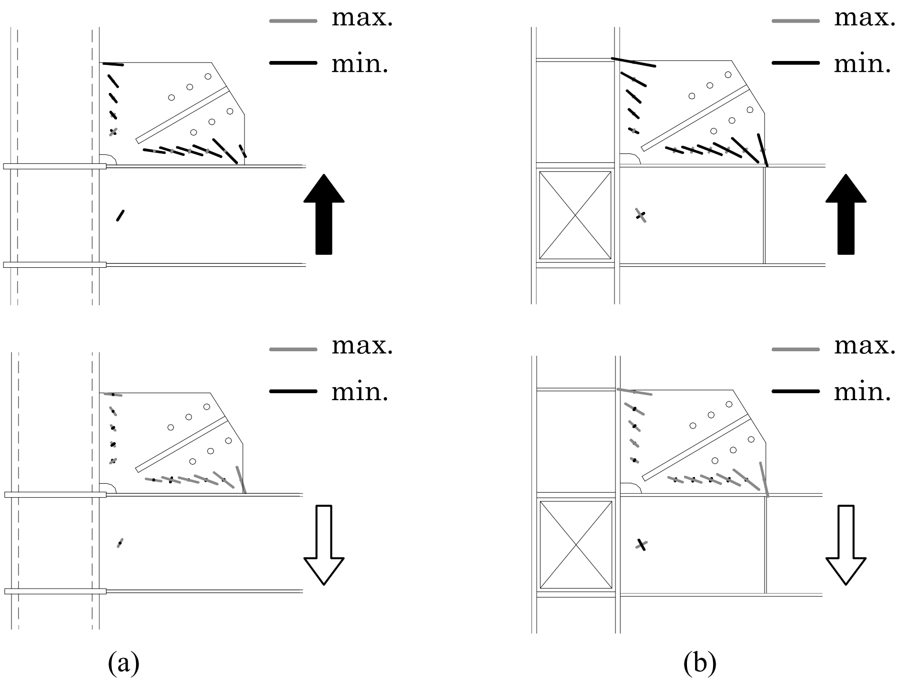
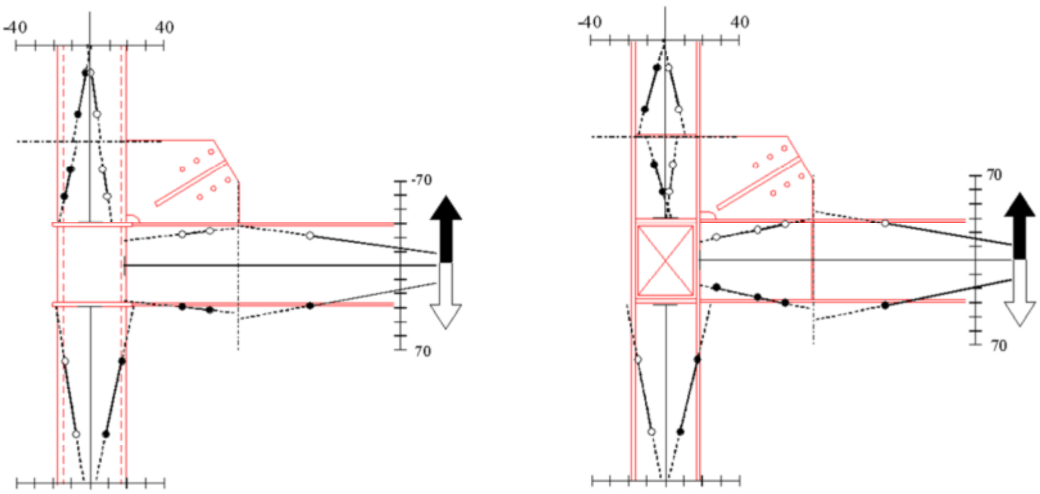


Figure 6 Distribution of the principal stress at the gusset-plate:
(a) Box_G; (b) H_G

3.3. Distribution of bending moments at the beam and columns

Distribution of bending moments at the beam and columns at the cycle of ±1/200 radian amplitude is shown in Fig. 8. Bending moments were decreased between the toe of the gusset-plate and beam-end by the presence of the gusset-plate. It was indicating that shear forces were transferred between the beam, the column, and the gusset-plate. On the other hand, bending moments were hardly affected by the presence of the gusset-plate when a rectangular hollow section (RHS) was used for the column.



(a) (b)

Figure 7 Distribution of the principal stress at the gusset-plate:
(a) Box_G; (b) H_G

4. CONCLUSIONS

This paper presents an experimental study of beam-column frame subassemblies to verify structural behavior of the beam affected by the presence of the gusset-plate, removing influences of a brace forces. It was found that effective length of the beam shortened by the presence of the gusset-plate connections. It was indicating that the critical section of the beam was moved to the toe of the gusset-plate. On the other hand, effective length of the column was hardly affected by the gusset-plate when a rectangular hollow section (RHS) was used for the column.

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