ON THE RIGIDITY AND DUCTILITY OF STEEL BRACING ASSEMBLAGE

by

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SYNOPSIS

Restoring force characteristics of bracing assemblage in steel frames will be discussed. Static tests were carried out on five models of the so-called "Y-braced" steel frame to estimate the stiffness and strength of the braced frames of different configuration. An alternate, plus and minus, loading with a small number of cycles of repetition was given to each of the specimens until they underwent large plastic deformation. Comparison was made on the behavior of the Y-braced frames with the K-braced frames so as to clarify the general features and obtain some practical data for the earthquake-resistant design of steel buildings.

INTRODUCTION

In order to furnish building frames with necessary stiffness and strength, various types of steel bracings as well as shear walls are utilized. However, the structural design of the bracings sometimes finds difficulties when we wish to adopt the cross-sections chosen from standardized rolled shapes as listed on the catalogues, because it should be noted that the dynamic analysis for the structural frames nowadays requires us the most appropriate set of definite values for the stiffness and strength for each story of the frames. Ductility of the frames to be subjected to a severe earthquake should also be secured for the safety of the structures.

Limitations in the details using the standardized rolled sections have thus enforced us to find such a solution for the design of braced frame assemblage that have continuously adjustable stiffness and strength of the braced frame unit without changing the cross-sections of the bracing members. The authors have proposed[1)] a kind of steel bracing assemblage as shown in Fig. 1, in which a pair of the braced frames are coupled like Siamese twins and we can see the configuration of the unit being appropriate for the name. Although there are some publications[2)] on the new types of steel braced frames, it is realized that the data on the stiffness and strength of the braced frames are still insufficient whenever we want to have these mechanical properties easily adjustable for the design requirements.

This paper reports the results of the experiment on the rigidity and ductility of the Y-braced frames carried out by using a column testing machine located at Kyoto University. Five test specimens of welded Y-braced assemblage were built up and were loaded alternately both in the plus and minus directions. Elasto-plastic deformation was enforced for all the test specimens. The size and the properties of the cross-sections of the members used for the specimens are tabulated in Table 1, and the mechanical properties of the material are shown in Table 2.

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RESULTS OF THE EXPERIMENT

Figs. 2 -- 6 show the load-deflection curves obtained from the experiment for the K-braced frame assemblage (Specimen Type A) and for the Y-braced frames (Specimens Type B, C, D and E), respectively. In the figures, the analytic P - δ curves are also plotted. The broken lines show the characteristics of the braced frames reconciled as the results of the evaluations in which the shear deformation of all the members and the panel zones of the beam-column and bracing-stub joints was taken into consideration. The upper branch of the chained lines represents the P - δ curve based on the assumption that the shear deformation of the stub alone would be appreciable, while the lower branch, labelled as the "frame only", shows us the result of analysis for the frame without bracings.

In Fig. 2, it can be noted that the initial stiffness of the frame is about 30 ton/mm. When the load was increased up to -135 tons, the compressive bracing member was buckled and then the load was decreasing until the magnitude of -110 tons with the deflection being still increased. After the buckling of the bracing member occurred, the rigidity of the frame has decreased by about 27 percent.

The Y-braced frame specimens showed us a better shape of the load-deflection hysteretic curves as in Figs. 3 -- 6. By changing the length of the stub, the stiffness and the strength of the braced frame assemblage have been altered to a relatively large extent. After the stress in an extreme fibre of the stub reached the yield stress, it was seen that the restoring force contribution by the Y-shaped bracing member has been kept constant so that most of the load increment thereafter was carried by the beam-column frame alone. Table 3 shows the stiffness of the braced frames as the results of the analyses done by basing upon various assumptions to compare with the results of the experiment.

CONCLUSIONS

The results of the experiment for the Y-braced frames have indicated us that the frame assemblage is very ductile, and that the restoring force characteristics can be reconciled into a tri-linear idealization as shown in Fig. 7. By changing the size and the length of the stub, it is not so difficult that the Y-braced frame assemblage is designed as requested with ample ductility and with the restoring force characteristics being within a range limited in the two extremes of the curve OAB (case of the K-braced frame) and the curve OCD (case of the frames without bracing members) in Fig. 7.

BIBLIOGRAPHY

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2) T. Takeda et al., Experimental Study on the Steel Braced-Frames (Part 3), New type of the steel braced frames, Report of the Technical Research Institute, Ohbayashi-Gumi, Ltd., No. 6, Aug. 1972, pp. 15 - 19.

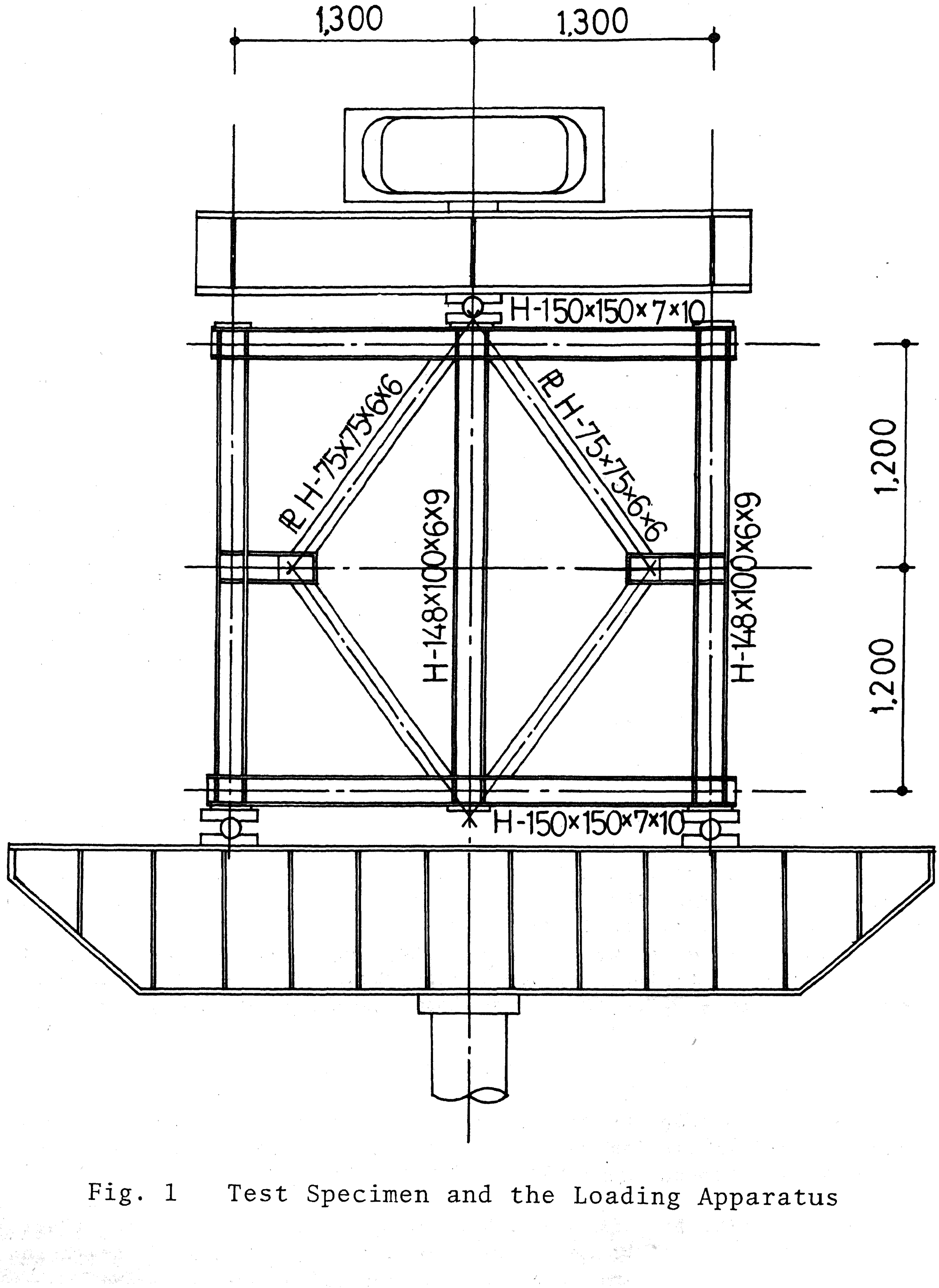

Fig. 1 Test Specimen and the Loading Apparatus

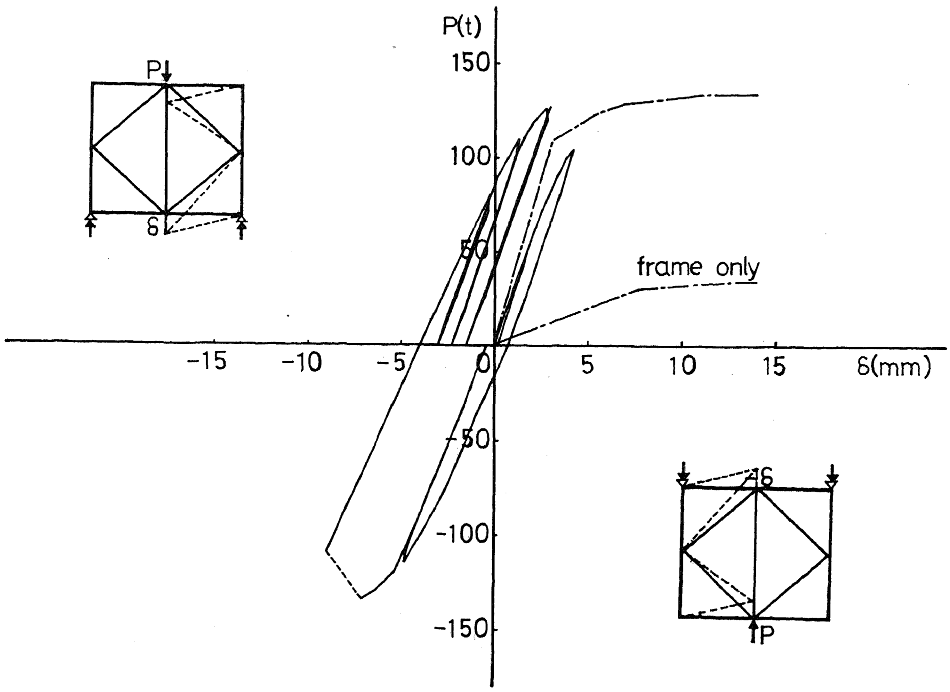

Fig. 2 Example of the Restoring Force Characteristics of the K-braced Frame (Specimen Type A)

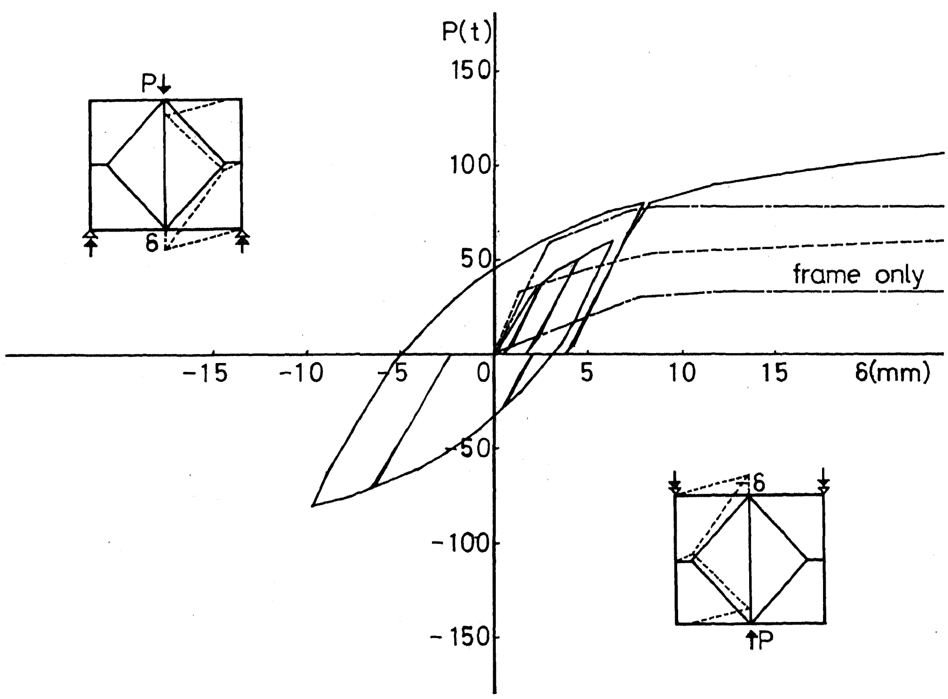

Fig. 3 Restoring Force Characteristics of the Y-braced Frames (Specimen Type B)

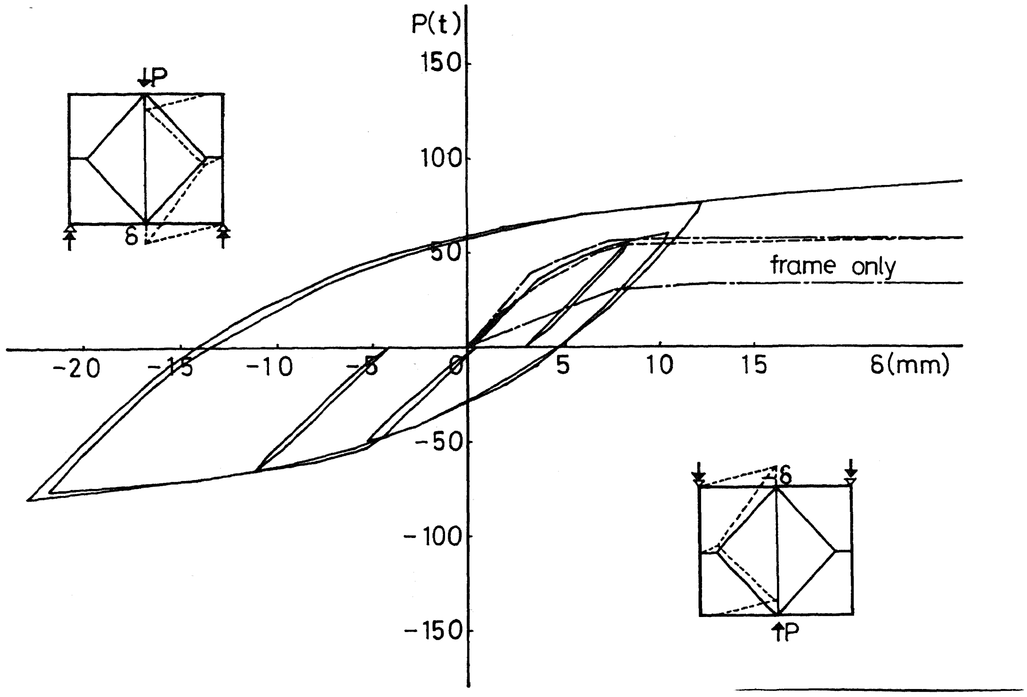

Fig. 4 Restoring Force Characteristics of the Y-braced Frames (Specimen Type C)

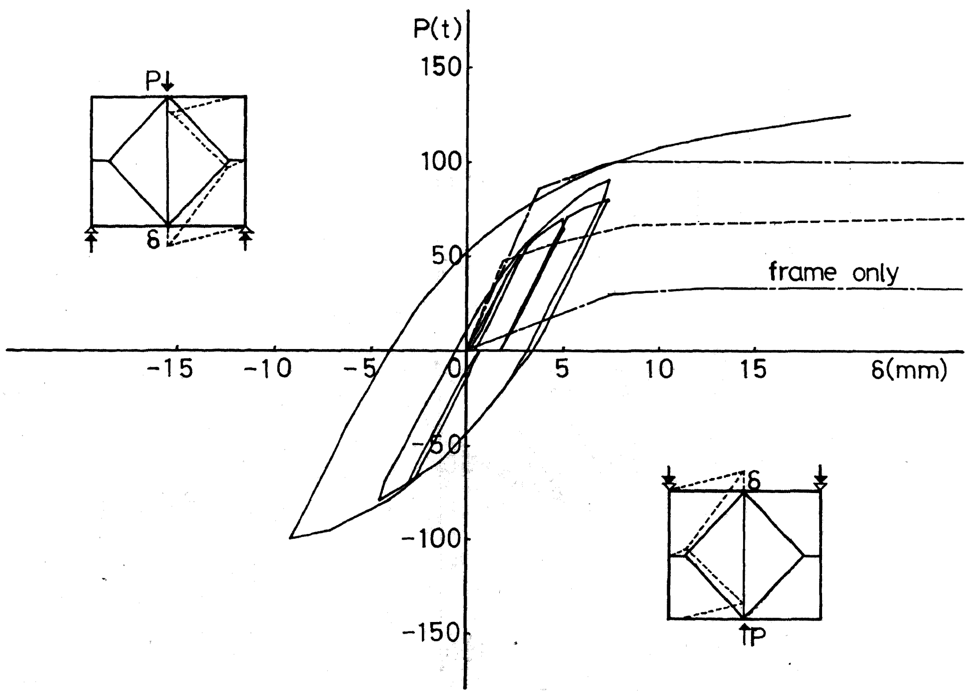

Fig. 5 Restoring Force Characteristics of the Y-braced Frames (Specimen Type D)

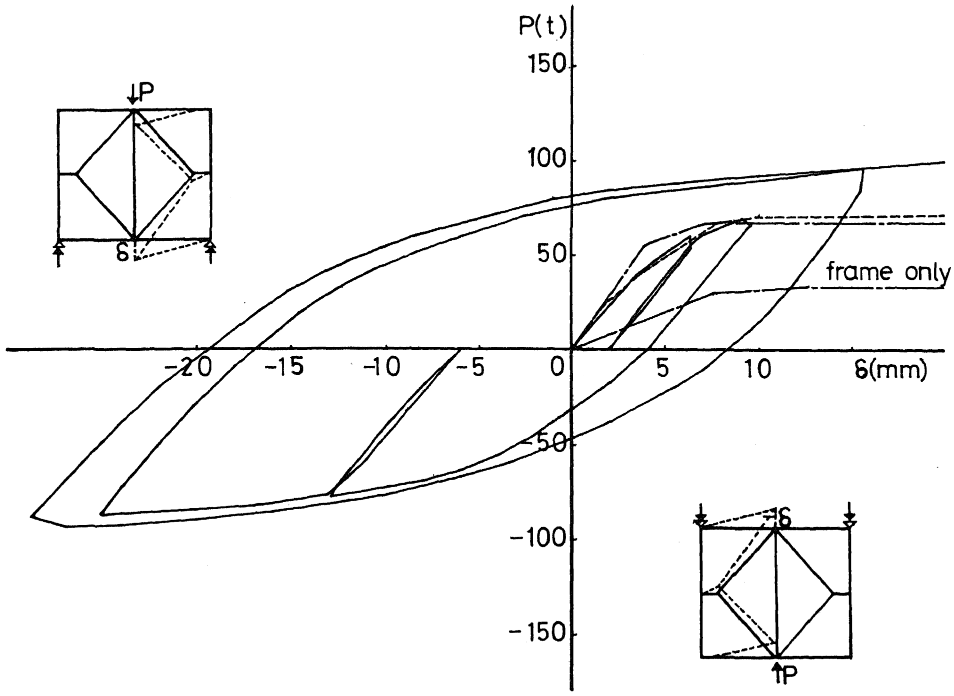

Fig. 6   Restoring Force Characteristics of the Y-braced Frames (Specimen Type E)

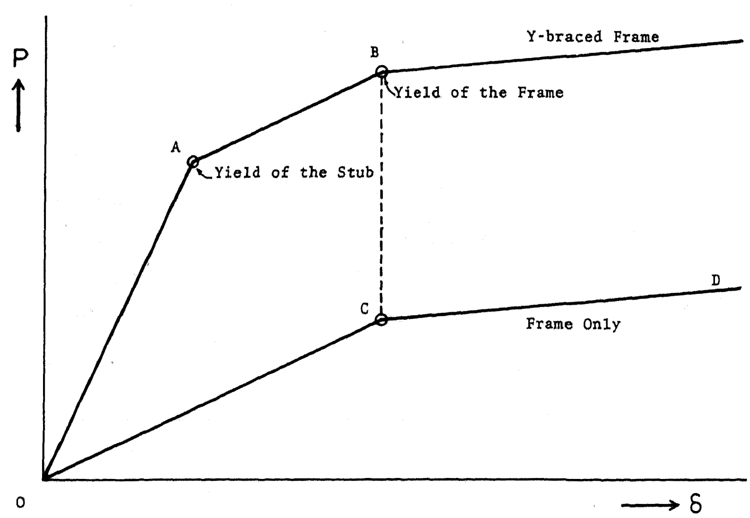

Fig. 7   Idealized Restoring Force Characteristics of the Y-braced Frames

Table 1. Properties of the Cross-sections

Type of Specimen	Member	Cross-sections	Area (cm^2)	Moment of Inertia (cm^4)	Section Modulus (cm^3)	Stub Length & Slenderness Ratio
in common	Column Beam	H-150x150x7x10 H-148x100x6x 9	40.14 26.84	1,640 1,020	219 138	
A	Bracing	H- 75x 75x6x 6	12.78	42.3	11.3	λ = 48.7
B	Stub Bracing	H-148x100x6x 9 H- 75x 75x6x 6	26.84 12.78	1,020 42.3	138 11.3	l = 20 cm λ = 44.6
C	Stub Bracing	do.	do.	do.	do.	l = 40 cm λ = 41.2
D	Stub Bracing	H-210x100x6x 9 H- 75x 75x6x 6	29.52 12.78	2,173 42.3	207 11.3	l = 20 cm λ = 44.6
E	Stub Bracing	do.	do.	do.	do.	l = 40 cm λ = 41.2

Table 2. Mechanical Properties of Material

	Yield Stress (ton/cm^2)	Ultimate Strength (ton/cm^2)	Elongation (%)	Young's Modulus (ton/cm^2)
H-148x100x6x9 (Flange)	2.75	4.35	25.6	1,930
H-150x150x6x9 (Flange)	2.50	4.29	29.3	2,100
Plate 9 mm	2.79	4.40	28.5	2,180
Plate 6 mm	3.56	5.18	27.3	2,080

Table 3. Stiffness of the Braced Frames (Unit: ton/mm)

Type of Specimen	Result of Experiment	Results of Analyses		
		Shear Deformation of the Stub --- Not Cosidered	Shear Deformation of the Stub --- Considered	Shear Deformation of All Members & Panel Zones -- Considered
A	30.0	35.7	---	---
B	19.0	28.6	22.5	23.8
C	10.0	14.9	12.8	11.4
D	21.0	30.3	25.0	26.7
E	11.0	17.2	14.9	13.5