Study on the behavior of buildings using steel with low yield point

A. Watanabe & H. Nakamura
Nippon Steel Corporation, Tokyo, Japan

ABSTRACT: It has been desired to develop such braces as can permit choosing the required rigidity, yield strength independent of the susceptibility to buckling. The brace presented in this paper is a buckling-resistant structural member consisting of a steel with low yield point enclosed in a concrete-filled square steel tube. This brace shows stable hysteresis if the yielding load working on the core member is smaller than the buckling load of the steel tube. This paper reports the results of the dynamic analysis of earthquake response of an existing 16-story steel building.

1. INTRODUCTION

It is widely known that bracing is effective in improving the rigidity and strength of a building. However, braces which are subjected to buckling sharply decline in yield stress under compressive loading. Therefore, difficulty is involved in handling them in plastic design of high-rise buildings, etc., which require high ductility. Though it is possible to design a brace having a cross-sectional area large enough to prevent buckling within a specified plastic limit, the freedom of structural design decreases because the brace load bearing ratio and structural rigidity and strength required become excessively high.

With the aim to solve this problem, the authors et al. developed a ductile brace, the steel pipe and concrete of which prevent buckling. It has been confirmed that the ductile brace offers exceptionally stable hysteresis loop. As shown in Fig. 1, the unbonded brace is made of a core member coated with a material and enclosed with a steel pipe and concrete. The steel pipe bears the moment and the core member bears the axial load.

It has also been confirmed that the rigidity and yield stress of the ductile brace can be freely adjusted by changing the yield point and cross-sectional area of the core member. When the rigidity and yield stress of a brace can be established separately, the freedom of structural design increases. For example, by using a steel with low yield point for the brace, it becomes possible to increase the absorption of seismic energy and keep the columns and beams within their elastic limits, or by using a high-tensile steel,

it becomes possible to reduce the rigidity of the brace frame to match the rigidities of other frames.

In the present paper, the effect of a ductile brace using a steel with low yield point as its core member is confirmed by a dynamic analysis of earthquake response of an existing 16-story steel building.

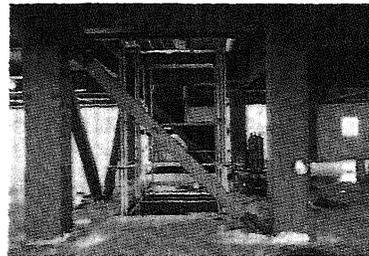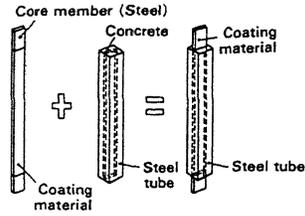Photo 1. 16-story steel building
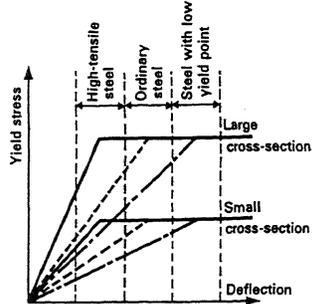

Photo 2. The ductile brace

Fig. 1. The ductile brace

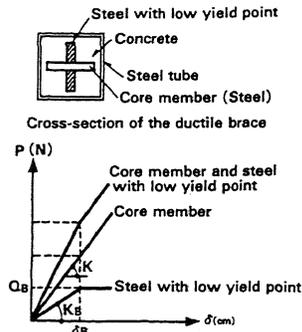
Fig. 2. Brace hysteresis loop range

Fig. 3. Establishing hysteresis loop characteristic of the ductile brace

2. APPLICATION IN BUILDINGS

Using a shear model, a dynamic analysis of earthquake response was conducted on an actual building employing a steel with low yield point. The steel used was one having a yield point of approximately 108 (N/mm²). As shown in Fig. 3, the hysteresis loop of the
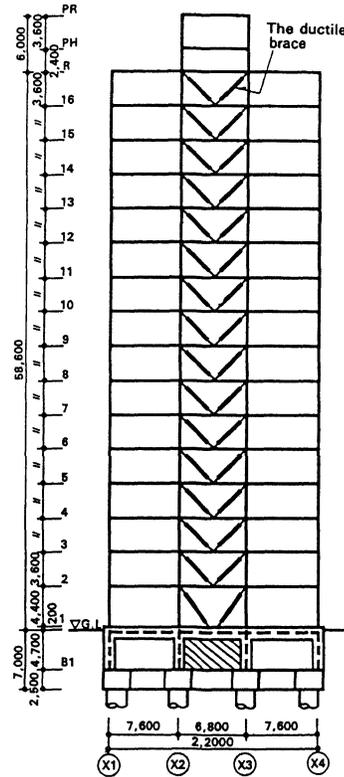

Fig. 4.(a)   Framing elevation

Table 1.   List of models

| Story	δ_B (cm)	K_B (t/cm)	K(t/cm)	K1=K+K_B(t/cm)	δ_B / δ_Y	Q_B /Q_Y	K_B /K
PH	–	–	48	48	–	–	–
R	–	–	158	158	–	–	–
16	–	–	304	304	–	–	–
15	1.344	67.7	337	405	0.58	0.12	0.20
14	0.935	97	369	466	0.41	0.11	0.26
13	0.827	110	407	517	0.34	0.09	0.27
12	0.694	131	420	551	0.25	0.08	0.31
11	0.614	148	443	591	0.22	0.07	0.33
10	0.597	152	461	613	0.21	0.07	0.33
9	0.538	169	475	644	0.19	0.07	0.36
8	0.508	182	502	684	0.17	0.07	0.36
7	0.448	203	553	756	0.18	0.06	0.37
6	0.413	220	551	771	0.16	0.06	0.40
5	0.377	241	596	837	0.16	0.06	0.40
4	0.358	254	613	867	0.16	0.06	0.41
3	0.326	279	657	936	0.15	0.06	0.42
2	0.316	288	737	1025	0.15	0.06	0.39
1	0.294	309	784	1093	0.13	0.06	0.39
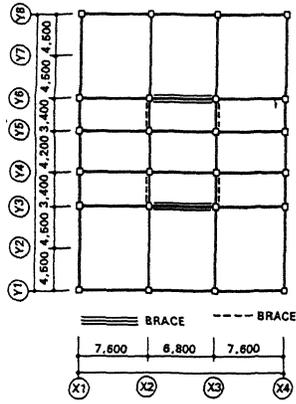
Fig. 4.(b) Floor construction plan

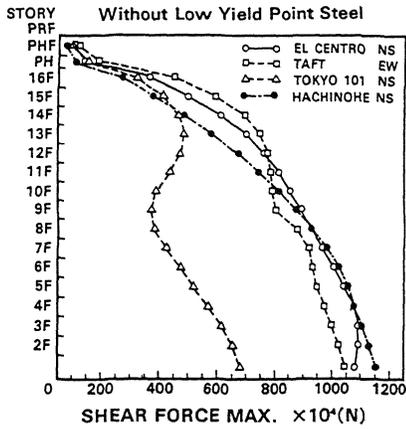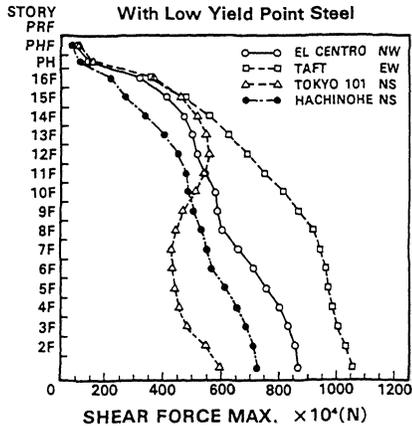Fig. 5.(a) Maximum response value of shear force

Fig. 5.(b) Maximum response value of shear force

steel was assumed to be bi-linear against the story shear deflection and overlapped with the actual hysteresis loop characteristic.
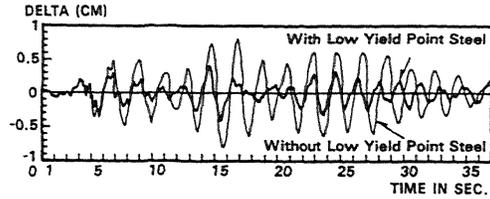

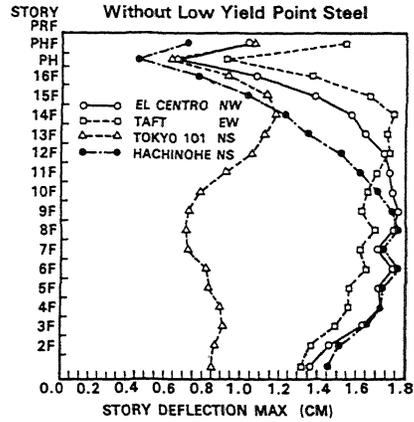Fig. 6. Time-serial story deflection (4th floor)

Fig. 7.(a) Maximum story deflection

Four seismic waves--El Centro NS, Taft EW, Tokyo 101 NS and Hachinohe NS--were used as input data. The analysis was made at a level of 25 cm/s. A comparison was made between a ductile brace using the steel with low yield point and a ductile brace not using the steel. The results are described below.

Maximum response value of shear force

The maximum response value of shear force is shown in Fig. 5. Depending on seismic waves, the maximum response value of shear force on the first floor decreased by approximately 10%.

Story deflection

Figures 6 and 7 show the time-serial story deflection and maximum story deflection. Depending on story and seismic wave, the maximum story deflection decreased by approximately 30%.
Figure 8 shows the hysteresis curve for the 4th floor, and Fig. 9 shows the plasticity factor of the brace using the steel with low yield point. Figure 10 shows the degree of entry into the plastic region of the brace. It was confirmed that the brace using the steel with low yield point became plastic from the ground up to 13th floor. The maximum value of plasticity factor was approximately 4 and the maximum residual story deflection was approximately 2 mm.
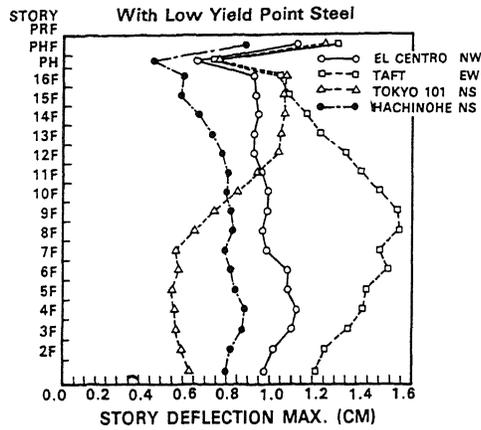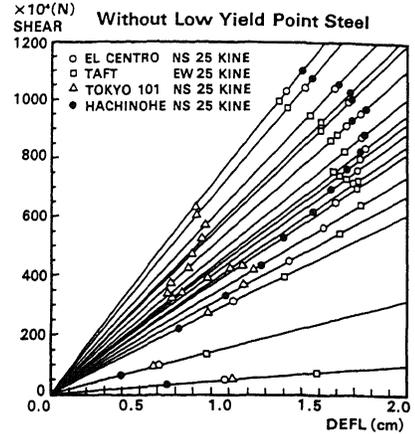
Fig. 7.(b) Maximum story deflection

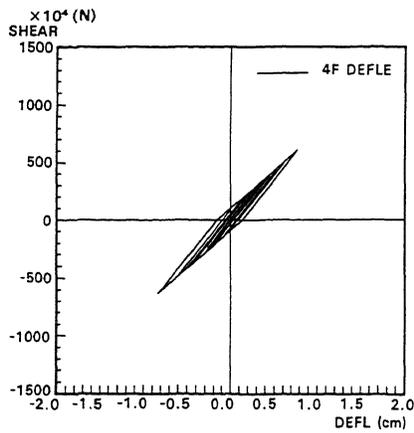Fig. 10.(a) Degree of entry into plastic
region of brace

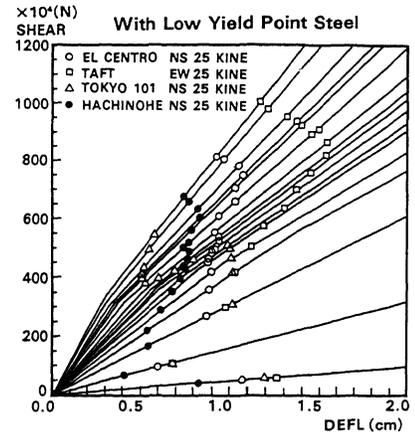Fig. 8. Hysteresis curve (4th floor)

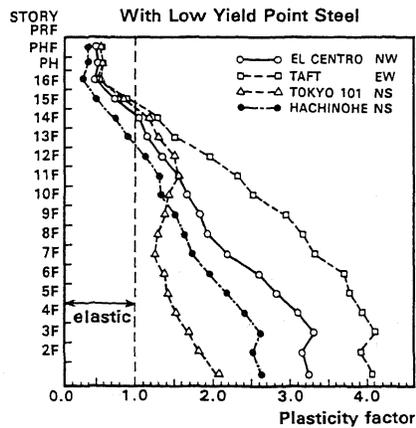
Fig. 10.(b) Degree of entry into plastic
region of brace

Fig. 9. Plasticity factor of brace using
steel with low yield point

3. CONCLUSION

Though the present paper is concerned with
only one example, the validity of using a
steel with low yield point for a brace having
stable hysteresis loop was confirmed by a
dynamic analysis of earthquake response of a
building using such a brace. In the future,
the authors intend to study the brace fatigue
under repetitive loading.

REFERENCES

Akira, W. 1990. Properties of Brace Encased
in Concrete-Filled Steel Tube. IABSE. BRUS-
SELS. 493-494

Yasuyoshi, H. 1988. Properties of Brace
Encased in Buckling-Restraining Concrete
and Steel Tube. 9WCEE. Tokyo-Kyoto. IV719-
724