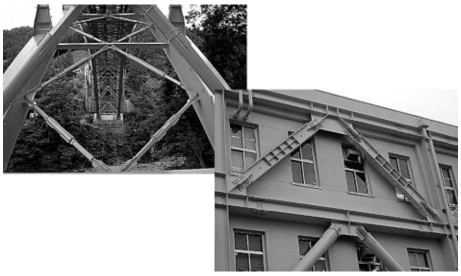

Hysteresis Dampers for Controlling Seismic Response of Bridges and Structures

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1. Introduction

Since the Great Hanshin Earthquake, research has been carried out on seismic resistance reinforcement and seismic response control design mostly of common buildings. This has resulted in development of various seismic vibration control techniques of which one example is the axial yield type hysteresis damper for insertion into braces of structures. In recent years, the required performances of the said seismic response control damper and applicable structures, such as design flexibility (freedom for presetting of axial yield force and axial stiffness), size increase, cost reduction and so forth are becoming more and more diversified.

Accordingly, Mitsubishi Heavy Industries, Ltd. (MHI) has developed some hysteresis type seismic response control dampers that demonstrate such performances. This paper introduces an outline of their structures, the characteristics of their restoring forces as verified experimentally, their cyclic deformation performances, and others.

2. Damper brace for bridges

2.1 System outline

The damper brace was developed for use on plant structures(1) and is also applicable to general structures, including bridges and buildings(2). This damper brace is an axial yield type hysteresis damper with buckling restraint member using the elastoplastic characteristics of steel elements (which show the same elastoplastic characteristics against compressive axial force as against tensile axial force). In the case of bridge structure, etc., braces required may exceed 10 or 15 meters in length and their axial yield forces may, depending on their structural scales, be as high as 10 000 kN.

In the case of buckling restraint type damper, the full length of the steel brace is generally the length of the damper itself, so that when the steel member to be manufactured is long, the buckling restraint member also needs to be large. In addition, since the axial yield force is adjusted by the section area of the damper element within the full length of the brace, the axial stiffness will also be set depending on the length of said element.

As shown in **Fig. 1**, the damper element [core member for energy dissipation (cruciform section: low yield point steel LY225) + buckling restraint pipe (rectangular section)] is placed on both ends of the brace. By this composition, the damper brace can be made longer easily.

The damper elements on both ends were connected to the intermediate pipe (circular section) to enable axial yield force adjustment by the damper elements and axial stiffness adjustment by the intermediate pipe independently of each other, resulting in wider adjustment ranges to enable setting of optimum individual performances in the entire structure design stage.

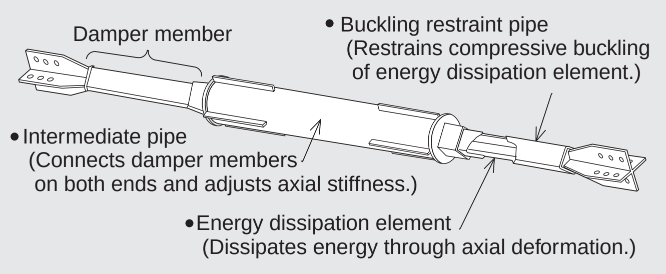

Fig. 1 Damper brace system outline
An energy dissipation element has a cruciform section and buckling-restrained by rectangular steel pipe.

2.2 Restoring force characteristics and cyclic deformation performance

Fig. 2 shows the relation between axial force and axial strain at the damper section obtained as a result of the cyclic loading test conducted using a damper brace specimen. From this figure, it can be understood that this device shows such stable elastoplastic behaviors under compressive axial force by the buckling restraint effect of the rectangular pipe. It was also confirmed from the experiment that stable restoring force characteristics can be obtained within the axial strain range of approximately ±1.5 – 2.0%, and that under cyclic loading in constant axial strain amplitude of ± 2.0%, this damper brace allows cyclic deformation performance of more than 20 times.

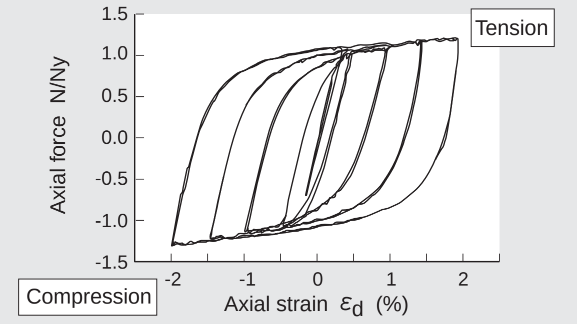

Fig. 2 Relation between axial force and axial strain
Stabilized cyclic deformation performance is shown against axial strain of ±2% under both compression and tension.

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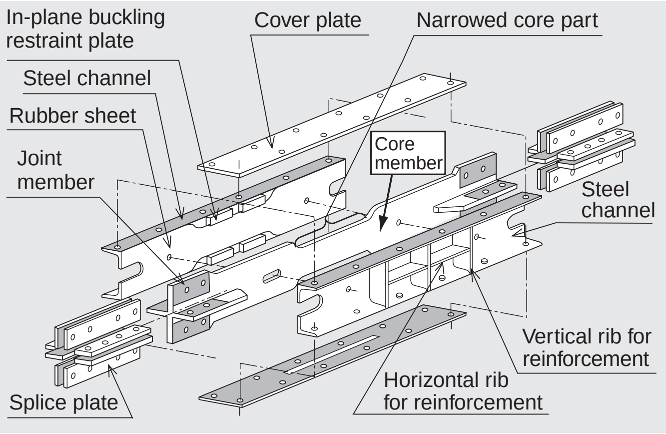
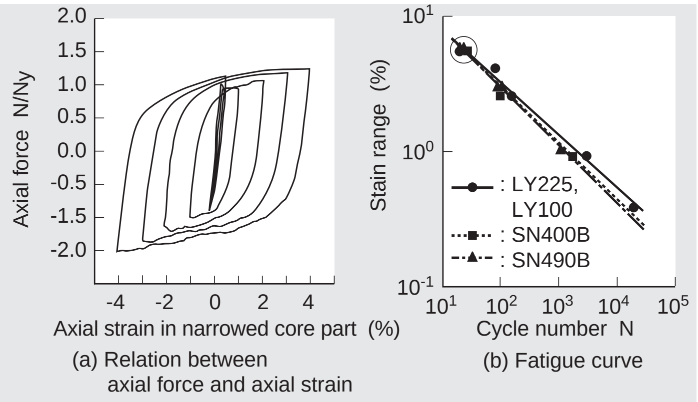


Fig. 3 Outline of building MCB damper system
Energy dissipation member is made of a flat steel plate and buckling-restrained by restraint member composed of standard type steel channel and plate.



(a) Relation between axial force and axial strain

(b) Fatigue curve

Fig. 4 MCB damper restoring characteristics and cyclic deformation performance
A stabilized cyclic deformation performance is shown under either compression or tension against axial strain of ±3-4%.

3. Mitsubishi Channel stiffened Brace (MCB) damper for buildings

3.1 System outline

The MCB damper for buildings is an axial yield type hysteresis damper with buckling restraint member using the elastoplastic characteristics of steel. The required length is three to seven meters, and in the case of a high-rise building, a few hundred such dampers are installed per building, so their structure must be simple and the price as low as possible. Also, a certain degree of design freedom (adjustment of axial force and axial stiffness) is required, as in the case of the damper brace.

Fig. 3 shows the structural outline of the MCB damper. The core steel member for energy dissipation (material: low yield point steel LY225, LY100, general steel SN400B, SN490B), is a flat steel plate. The center part of the flat steel plate is deliberately narrowed (section reduced) to yield earlier than another parts. This composition makes possible axial yield force adjustment and at the same time enables adjustment of axial stiffness by changing the length of the narrowed section.

The buckling restraint member is constructed using standard type steel channels and flat steel plate by means of the friction joint using high-tension bolt, resulting in simplification of the composition and production control as well as lower cost. Rubber sheets are placed as the non-bonding material between the buckling restraint members and the core steel member.

3.2 Restoring force characteristics and repetitive deformation performance

Fig. 4 (a) shows the relation between axial force and axial strain found as a result of the cyclic loading test performed using MCB damper specimen (core steel material : SN490B). Against compressive axial force, as in the case of Fig. 2, an elastoplastic behavior similar to that in the tensile state is shown, demonstrating that the stabilized restoring characteristics can be obtained in the axial strain range of approximately ±3.0–4.0%.

Fig. 4 (b) shows the relation between strain range and cycle number in the fatigue tests performed on MCB damper specimens with core members made of LY225, LY100, SN400B and SN490B. In the test, the axial strain range was varied from 1% (strain range of ±0.5% in each tensile and compression) thru 3% (±1.5%) up to 6% (±3.0%). It was confirmed from this result that under constant amplitude loading of strain range 6%, a cyclic deformation of 20 times or over is achieved equally on all types of core members. [The part inside a circle in Fig. 4 (b)]

4. Conclusion

This paper has reported on the development of new axial yield type hysteresis dampers for use as the seismic response control dampers for structures innovative from the viewpoint of flexibility of design (axial yield force and axial stiffness setting freedom), size increase and cost reduction, and has introduced their restoring force characteristics, cyclic deformation performances and so forth. The MCB damper for buildings was awarded an Assessment of Technology for Building Construction from the General Building Research Corporation of Japan. The damper brace also has won general evaluation from the Building Center of Japan. These seismic response control dampers can be used as structural members that are capable of dissipating energy under axial force, and efforts will be continued to widen their application areas.

Rerences

(1) Hirukawa et al., Techniques for Improving Seismic Resistivity of the Equipment Supporting Structures with Plastic-Energy Absorption Braces, Mitsubishi Juko Giho Vol.41 No.5 (2004)
(2) Uehira et al., Development of Techniques for Improving Seismic Performance of Long Span Bridges, Mitsubishi Juko Giho Vol.39 No.6 (2002)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