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ALL STEEL BUCKLING RESTRAINED BRACE WITH OPTIMUM GEOMETRY

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Buckling restrained braces (BRB) have been exceedingly used for resisting seismic forces in framed structures. In spite of that, their design criteria are not well established yet. The exiting codes do not specify the full process of design for buckling restrained braces. For major structures the process of design includes testing of BRB specimens. Implementation of full scale or scaled testing is not feasible for most structures. Thus for design of common buildings the designer must depend on reliable data produced for similar configurations.

A series of tests have been planned at the laboratory facilities of the International Institute of Earthquake Engineering and Seismology (IIEES), in order to produce such reliable data for an improved type of full steel brace. These tests are a continuation of a previous set of tests on steel BRB's that depicted some weak point at the transition regions of the core. The aim here is to produce a robust type of brace that can be constructed without strict building requirements. Upon review of the work done so far by other researchers the scope of the work was to include a parametric study of the significant factors. These factors are width to thickness ratio of the core, number and lengths of the yielding parts of the core, arrangement of the end stiffeners preventing yielding and buckling of the end segments. Other effects investigated are, geometry and the gap of stoppers used to prevent slippage and provide restraint, details and bolt spacing of the restraining mechanism, the process used for cutting the elements, and the effect of loading rate on the behavior of brace. The IIEES test facilities dictated some restrictions on the details for connecting the specimens to the testing machine. The tests were carried out under quasi-static loading up to a target displacement. Stability of the brace under investigation was provided by a set of restraining elements and end stiffeners. In designing both of these elements stiffness as well as strength criteria was considered. The restrain elements were designed to satisfy the following relations:

$$\frac{p_e^R}{p_y} \geq \left(1 + \frac{\frac{\pi^2 E}{2\sigma_y} \cdot \frac{a+g}{L}}{\frac{L}{D}}\right) = \gamma \qquad (1B)$$

$$\frac{p_e^R}{p_y} \geq 1.5 \qquad (1A)$$

Thus, the buckling capacity was taken to be larger than 1.5 times that of the core yielding load and more than β times the loading capacity. γ is a function of the original tolerance and slenderness of the restrained element. The end segments were designed based on the requirements for buckling of thin walled members. The width to thickness ratio is a significant parameter in this case.

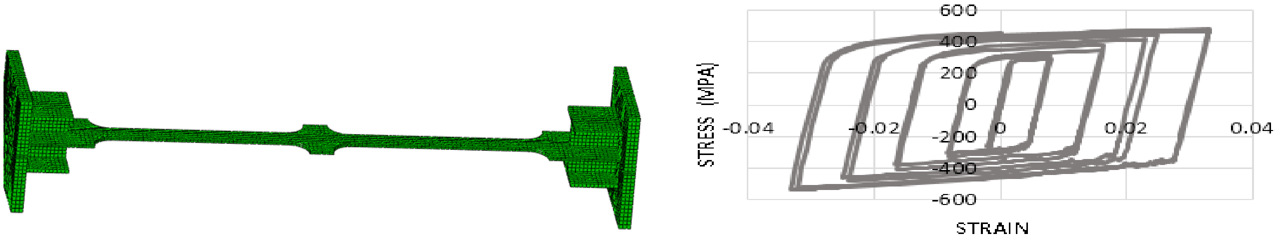
A value between 4 and 8 proved to be appropriate. For the latter parameter Investigation of the shape and dimensions of the core element resulted in a two- piece yielding segment with a stopper at the middle of the core. The size of the yielding segment affects the response of BRB because it influences the compression over strength factor, β as well as the cumulative core deformation factor, η. It could also affect low cycle fatigue life of BRB. Determination of the optimal yielding length of the core involves strain demands induced by the drift ratio of the frame. Table 1 shows the values of β and η for various drift demands calculated by relations 2A and 2B and the values obtained by experiment are shown in parenthesis. In this table Δbm is member drift.

$$\eta = \frac{2\sum_{i=1}^{n} \Delta\varepsilon_p}{\varepsilon_{by}} \leq 200 \qquad (2B) \qquad\qquad \beta = (1+2\varepsilon)^2 \leq 1.3 \qquad (2A)$$

Table 1. Values of parameters (β) and (η) in terms of strain demand

Strain Demand	2Δbm	Ly Total length of yielding (cm)	β (Test)	η (for same loading)	Additional cycles before fatigue failure
ε=2.5(Drift ratio) ε=0.0335	3	90	1.14 (1.20)	391	11
ε=3(Drift ratio) ε=0.0402	3	75	1.17 (1.162)	536	9
ε=3.5(Drift ratio) ε=0.0469	3	64	1.2 (1.166)	625	3

Considering the dimensions of common buildings, the maximum length of the yielding segment was found to be 90cm for the model. Testing was done for cores with various lengths in order to determine the optimum length. The core lengths for which the compression strength factor was less than the maximum value specified in the code, (β =1.3) were considered only. The analysis was performed by the computer program Abaqus. Abaqus model and the resulting hysteresis curve of one of the test specimens are shown in Figure 1.



(a) (b)

Figure 1. Specimen (1) a. Numerical model of the core; b. Hysteresis curve of specimen 1 under loading protocol

The tested brace shows a large capacity for energy absorption. However, the shorter length of the yielding part of the core causes a reduction in fatigue strength, which must be optimized for that matter.

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