An Analytical Study of Seismic Performance of a New Type of Reduced Length Buckling Restrained Brace (RLBRB) with S-shaped Core

Reza Tahmasbi [1], Jalil Shafaei [2*]

[1] MSC Student, Faculty of Civil Engineering, Shahrood University of Technology, Shahrood, Iran
[2] Assistant Professor, Faculty of Civil Engineering, Shahrood University of Technology, Shahrood, Iran

ABSTRACT

The use of steel braces in buildings with a system of seismicity in the moment frame can significantly control the lateral displacement of the structure. One of the problems with the conventional bracing system is their buckling in compressive loads which reduces the amount of energy absorbed by the structure. The buckling restrained braces (BRBs) have been removed by the removal of buckling bracing at the pressure of common bracing, but such cases as overweight, high prices and rigorous implementations have led to the introduction of a new type of buckling brace called Reduced Length Buckling Restrained Brace (RLBRB). However, in RLBRB, due to the low cyclic fatigue phenomenon, the length of bracing cannot be over-reduced so that it can be replaced as an inactive system after an earthquake. In this research, a new and innovative idea called Reduced Length Buckling Restrained Brace with S-shaped Core is introduced, which, despite its very short length, can overcome all the problems with the RLBRB and BRB system, while also serving as a passive control system. Therefore, the analytical model in the ABAQUS finite element software was validated with the experimental results of RLBRB and BRBs of previous research work. Then, according to the results of the analysis, the profile of the longitudinal buckling curves with the S-shaped core is compared with the RLBRB and BRB braces. The results from the comparison of the proposed pattern with conventional buckling braces indicate that, despite the smaller and lighter ones, these braces have the same behavior as the BRB braces.

KEYWORDS

Buckling brace, buckling brace with S-shaped core, Inactive control system, Low cycle fatigue

* Corresponding Author: Email: jshafaei@shahroodut.ac.ir

1. Introduction

Due to the damages caused by past earthquakes in Iran and the world on steel buildings, it is necessary to pay attention to the use of modern seismic systems to reduce the damage and increase the speed of structural restoration. Despite the variety of lateral bearing systems, buckling restrained brace frames (BRBFs) have a special place in seismic resistant systems due to their high hardness, optimum energy absorption, stable cyclic behavior (hysteresis) [1-4].

Buckle bracing has disadvantages such as high weight and high price compared to other conventional bracing systems. One of the limitations of this inhibitor is the emergence of persistent deformation in large earthquakes.

To overcome the existing problems of BRBs and optimally design to make the most of the energy dissipation potential of these braces, one can focus on two parameters of hardness and strength. Cross-sectioning and reduction of the core length are suggested [5].

In this study, in order to optimize the design, considerations of cross-sectional area change and reduction of core length for a full steel buckling restrained brace are suggested.

2. Methodology

This study aims to present functional behavior at the level of conventional RLBRBs by presenting proposed brace that are shorter in length than conventional buckling restrained braces. It should be noted that in conventional buckling restrained braces the core usually consists of a surface that withstands the applied force and enters the plastic section. But in the proposed model, as shown in Fig. 1, the core has three levels with the same materials and the same cross section used for the previous brackets (ST 37-2).

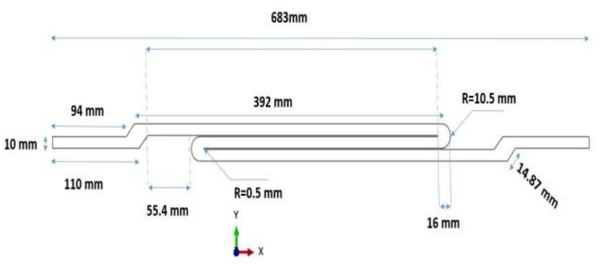

Figure 1. Details of (RLBRB) with s-shaped core

3. Results and discussions

In order to investigate the effect of low-cycle fatigue, the Miner and Nakamura relationships are studied to determine whether or not there is an optimum break in the brace. The results of the Nakamura relation show the number of cycles required to break the cycle of fatigue failure (Table 1).

Table 1. Number of cycles and failure index for S-core (RLBRB)

Displacement amplitude	Δε	N_f	FDI
Δby	0.00464	2274	
0.5Δbm	0.038	31	
Δbm	0.0755	7	0.938<1
1.5Δbm	0.113	3.5	
2Δbm	0.151	2	

As can be seen, the cumulative fatigue failure index is below 1, indicating that the brace failure is not up to the strain amplitude 1.5Δbm.The hysteresis diagram of the proposed brace illustrates this result well (Fig. 2).

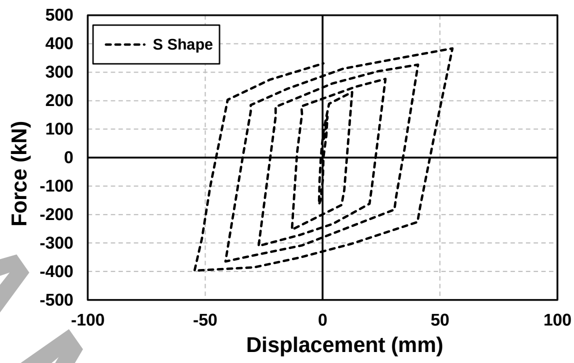

Figure 2. (RLBRB) hysteresis diagram with S-shaped core

Another important point in these braces is brace buckling under compression cycles. In this study, in order to minimize the local buckling of the core, the free distance between the core and the encasing is reduced as far as reasonable results are presented.

1.3. Controlling Watanabe's relationship for encasing

One of the most important criteria in designing a buckle-resistant mechanism is to check and control the Watanabe's relationship so that the brace does not bend and there is no significant axial force in the encasing. To this end, Watanabe et al. Sugested that the encasing should be designed to withstand the bending stiffness equivalent to the following relationship:

$$\frac{P_e}{P_y} \geq 1 \quad (1)$$

Whereas Py is the yielding member of the bonding member and Pe is the elastic buckling strength of the steel.

$$P_e = \frac{\pi^2 EI_{sc}}{L_{sc}} \quad (٢)$$

The results are presented in Table 5.

Table 2. Watanabe relationship control for (RLBRB) with s-shaped core

Py (kN)	Pe (kN)	Moment of inertia (mm^3)	Pe /Py
198	59300000	14279235.32	299494.9495

4. Conclusions

In this research, a new type of reduced length buckling restrained brace (RLBRB) with s-shaped core has been proposed. The purpose of this study was to address some of the executive and functional problems in long and reduced length buckling restrained brace. The results of nonlinear finite element analysis show that:

The restraint to the end of the AISC 341 standard loading protocol exhibits stable cyclic behavior without loss of resistance and hardness and no overall buckling has occurred.

Due to the very small gap between the core and the encasing, the local buckling was limited, which in turn caused a uniform distribution of stress in the brace.

The results of the analysis also showed that the energy dissipation of the proposed S-core brace is similar to that of conventional short-length brace.

Based on the results of this study reduced length buckling restrained brace(RLBRB) with s-shaped core are recommended as a replacement for conventional braces due to their light weight and easy portability.

5. References

[1] C. Black, I.D. Aiken, N. Makris, Component testing, stability analysis, and characterization of buckling-restrained unbonded braces (TM), Pacific Earthquake Engineering Research Center, 2002.

[2] A. Parry Brown, D. Aiken Ian, F.J. Jafarzadeh, Buckling restrained braces provide the key to the seismic retrofit of the Wallace F. Bennett Federal Building, Modern Steel Construction, 8 (2001) 123-124.

[3] A. Wada, M. Nakashima, from infancy to maturity of buckling restrained braces research, in: 13th WCEE, 2004.

[4] Q. Xie, State of the art of buckling-restrained braces in Asia, Journal of constructional steel research, 61(6) (2005) 727-748.

[5] S.A.R. Tabatabaei, S.R. Mirghaderi, A. Hosseini, Experimental and numerical developing of reduced length buckling-restrained braces, Engineering Structures, 77 (2014) 143-160.