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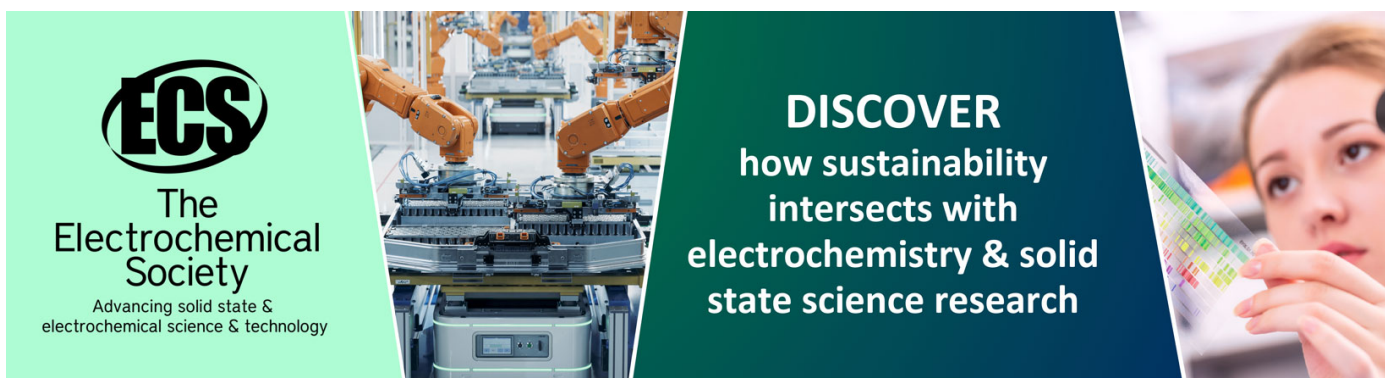
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Parametric finite element analysis of Buckling-Restrained Braces

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Abstract. The Buckling-Restrained Braces is an excellent seismic energy dissipator. In this paper, the effects of the three core width-thickness ratios, gaps, and constraint ratios of the Buckling-Restrained Braces on the seismic performance of the Buckling-Restrained Braces are studied and modeled and analyzed by ABAQUS. The simulation results show that the Buckling-Restrained Braces has the best seismic performance when the width-to-thickness ratio is 10-16; when the gap is 1-2mm, the Buckling-Restrained Braces has the best seismic performance; when the constraint ratio is about 5, the Buckling-Restrained Braces has the best seismic performance.

1. Introduction

Buckling-Restrained Braces is an efficient energy-absorbing shock absorber. It is mainly composed of three parts: steel supporting inner core, outsourcing constraining member, and non-bonding material or gap set between the above two [1-3]. In this paper, the parametric analysis of the common plate type Buckling-Restrained Braces is carried out. The core element is low-yield point steel and the structure is plate type. When the support is subjected to axial pressure, the deformation and stress of the core element will be very complicated. As the axial pressure continues to increase, the core unit will contact and squeeze with the restraining unit. Throughout the loading process, the linear Buckling-Restrained Braces will involve nonlinear problems, including geometry, material, contact, and damage. These problems greatly increase the difficulty of analyzing the Buckling-Restrained Braces. Performance research brings confusion [4-5].

In this paper, the ABAQUS finite element software is used as a platform, and is modeled through the ABAQUS/CAE module to analyze the mechanical properties of the Buckling-Restrained Braces. The seismic performance of the Buckling-Restrained Braces is analyzed by studying the influence of the core width-thickness ratio, clearance, restraint ratio and other factors on the energy consumption of the Buckling-Restrained Braces.

2. Model design of one-line Buckling-Restrained Braces

By designing multiple sets of Buckling-Restrained Braces with different parameters for numerical simulation to study their energy dissipation performance, the specific model design is as follows, and the specific dimensions are shown in Table 1:

(1) In order to study the effect of different width-thickness ratios of Buckling-Restrained Braces core plates on the energy dissipation performance of type Buckling-Restrained Braces, three sets of models were designed with width-thickness ratios of 8, 16, and 32 respectively.



(2) In order to study the effect of the gap between the inner core plate of the Buckling-Restrained Braces and the constraining unit on the energy dissipation performance of the Buckling-Restrained Braces, three sets of models were designed, with the gaps of 1, 3, and 5, respectively.

(3) In order to study the influence of the external restraint element of the Buckling-Restrained Braces on the energy dissipation performance of the Buckling-Restrained Braces, the concept of its restraint ratio was introduced, and three sets of models were designed with the restraint ratios of 0.05, 0.8 and 5, respectively.

Table.1 Model design group size table (mm)

	Model number	Core energy consumption section size	The size of restraint plate 1	The size of restraint plate 1	gap	friction coefficient
Different aspect ratio	A-BRB-1	$3800 \times 280 \times 30$	$4000 \times 502 \times 30$	$4000 \times 100 \times 32$	1	0.3
	A-BRB-2	$3800 \times 280 \times 16$	$4000 \times 502 \times 30$	$4000 \times 100 \times 18$	1	0.3
	A-BRB-3	$3800 \times 280 \times 8$	$4000 \times 502 \times 30$	$4000 \times 100 \times 10$	1	0.3
Different gaps	B-BRB-1	$3800 \times 280 \times 22$	$4000 \times 502 \times 30$	$4000 \times 100 \times 24$	1	0.3
	B-BRB-2	$3800 \times 280 \times 22$	$4000 \times 502 \times 30$	$4000 \times 100 \times 28$	3	0.3
	B-BRB-3	$3800 \times 280 \times 22$	$4000 \times 502 \times 30$	$4000 \times 100 \times 32$	5	0.3
Different constraint ratios	C-BRB-1	$3800 \times 280 \times 16$	$4000 \times 400 \times 1$	$4000 \times 10 \times 18$	1	0.3
	C-BRB-2	$3800 \times 280 \times 16$	$4000 \times 400 \times 8$	$4000 \times 10 \times 18$	1	0.3
	C-BRB-3	$3800 \times 280 \times 16$	$4000 \times 400 \times 30$	$4000 \times 10 \times 18$	1	0.3

3. Finite element parameter analysis of Buckling-Restrained Braces

3.1. Effect of different core element width-thickness ratio on Buckling-Restrained Braces performance

A reasonable width-to-thickness ratio is to ensure that the component does not buckle locally under compression and the bearing capacity decreases. To ensure that the Buckling-Restrained Braces has a stable bearing capacity and energy dissipation capacity, it is particularly important to choose a suitable core width-to-thickness ratio. The low-cycle cyclic reciprocating loading of different models to obtain the stress cloud of Buckling-Restrained Braces is shown in Figure 1.

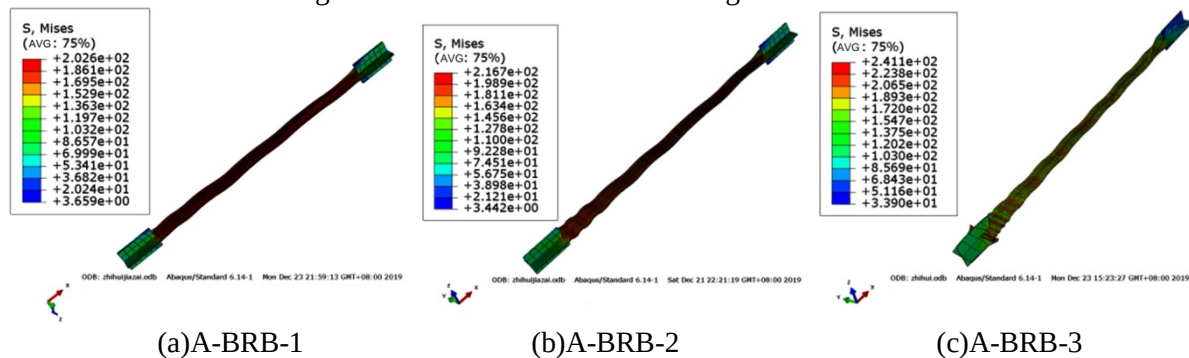


Figure 1 Stress cloud diagram of the core unit

It can be seen from Figure 1 that under the low-cycle cyclic reciprocating load, when the core unit width-to-thickness ratio is 8.67, the stress of the core unit's energy dissipation section is evenly distributed along the length direction, the maximum stress is 202.6Mpa, and the energy dissipation section stress is mostly in 186-202Mpa. In between, reaching the full-section yield energy dissipation stage, half-wave deformation occurs in the middle part of the core element, but the wave number is small and the deformation is not obvious. When the width-thickness ratio of the core element is 16, the stress of the energy dissipation section of the core element is evenly distributed along the length direction, and the maximum stress is 216Mpa. The stress distribution of the overall energy dissipation section is between 192-216Mpa, which basically reaches the full section yield energy dissipation, and

the core element appears. Half-wave bending, the number of half-wave bending is large at the loading end, and the deformation and bending are obvious; When the width-thickness ratio of the core element is 32, the core element reaches full-section yield energy dissipation, and the core element generates a large amount of half-wave bending deformation. The half-wave deformation is dense at the end and the deformation is also the most serious.

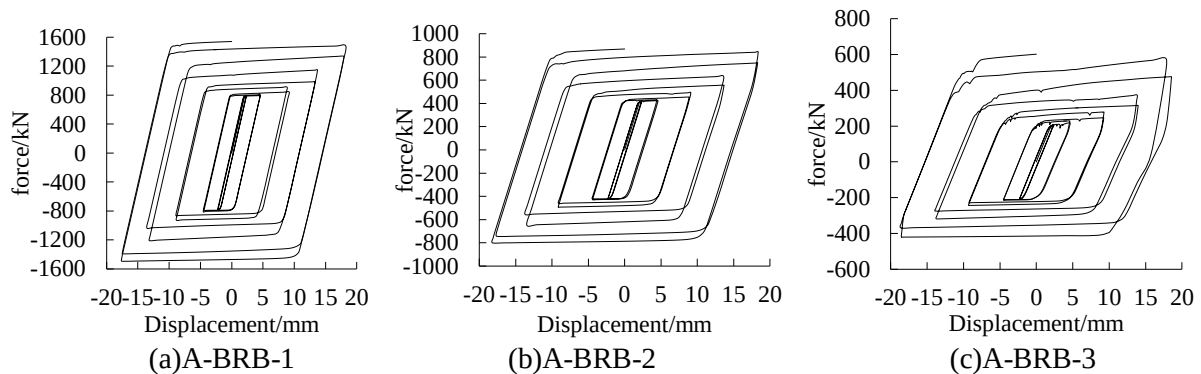


Figure 2 Hysteresis curves of Buckling-Restrained Braces with different width-to-thickness ratios

It can be seen from Figure 2 that under the condition of ensuring the same width of the core unit, the larger the width-to-thickness ratio, the smaller the ultimate bearing capacity; when the core width-to-thickness ratio is 8.67, the overall hysteresis curve is very full, without obvious jitter, maximum The tension and the maximum pressure are not much different, indicating that the support energy dissipation ability is very strong; When the core width-to-thickness ratio is 16.25, the support hysteresis curve is full without obvious fluctuations, the hysteresis loop area is large and stable, and the tension and compression stress is symmetrically distributed, indicating that the support energy consumption effect is better; When the width-thickness ratio of the core is 32, the hysteresis curve of the support is no longer full and deformed. It is found through research that when the width-thickness ratio is 12-16, the energy consumption of the Buckling-Restrained Braces is most stable.

3.2 Effect of different clearances on Buckling-Restrained Braces performance

According to the working principle of Buckling-Restrained Braces, there must be a certain gap or non-bonding material between the core unit of the Buckling-Restrained Braces and the constraining unit. Therefore, to ensure that the Buckling-Restrained Braces has a stable bearing capacity and energy dissipation capacity, select the appropriate gap is particularly important. The model is subjected to low-cycle cyclic reciprocating loading, and the stress cloud of the Buckling-Restrained Braces under different gaps is shown in Figure 3.

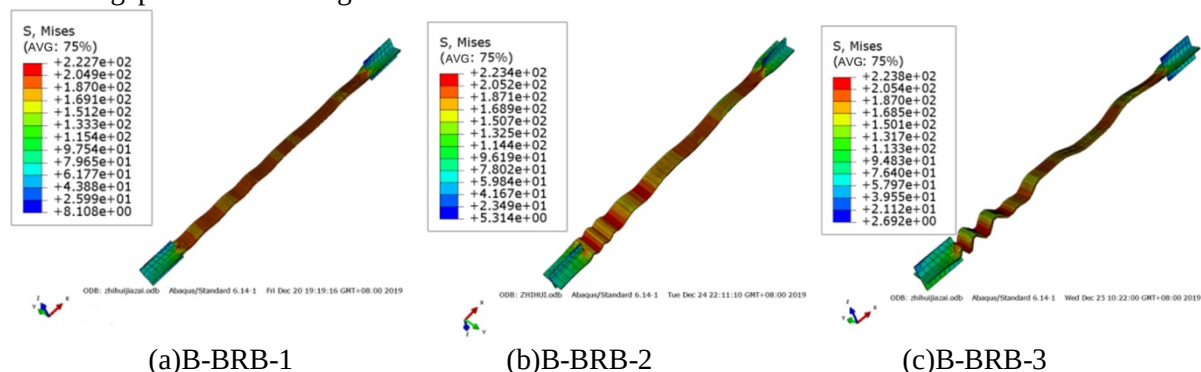


Figure 3 Core unit stress cloud

It can be seen from Figure 3 that under low-cycle cyclic reciprocating loading, when the gap is 1mm, the stress of the energy dissipation section of the core unit is evenly distributed along the length direction, the maximum stress is 222.7MPa, and the stress distribution of the overall energy dissipation section is between 187-222MPa, Basically reaching the yield energy dissipation of the full section, the inner core element appears half-wave bending deformation, its distribution law is basically uniformly distributed, and the deformation is small; When the gap is 3mm, the stress of the energy dissipation

section of the core unit is evenly distributed along the length direction, and the maximum stress is 223Mpa. The stress distribution of the whole energy dissipation section is between 187.11-223Mpa, which basically reaches the full section yield energy dissipation, and the core unit has a half wave Bending deformation, uneven deformation distribution, half-wave deformation is mostly concentrated at the loading end, and the half-wave deformation is very small in the middle and bottom; When the gap is 5mm, the stress of the energy dissipation section of the core unit is unevenly distributed along the length direction, the maximum stress is 223.8Mpa, but the stress of the overall energy dissipation section is distributed between 131.7-205.4Mpa, which basically reaches the full section yield energy dissipation. In the inner core unit, half-wave bending deformation occurs, but its distribution law is unevenly distributed. Among them, half-wave deformation is mostly concentrated at the loading end, and the number of half-wave deformations in the middle and bottom is small, but the deformation is large.

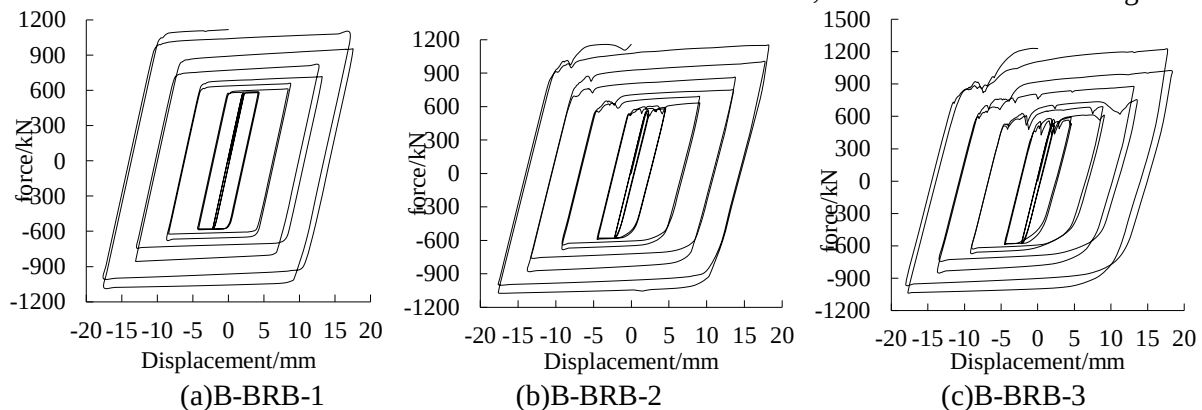


Figure 4 Hysteresis curves of Buckling-Restrained Braces under different clearances

As can be seen from Figure 4, when the gap is 1mm, the hysteresis curve is full and regular and has good convergence effect. The hysteresis loop area is large and stable. During the process of compression and tension, the hysteresis curve does not appear to shake; When the gap is 3mm, the hysteresis curve is relatively full and regular, and the convergence effect is good. The hysteresis area of each layer is large but not stable. The phenomenon of non-convergence occurs when the last lap is pressed, and the stability is poor; When the gap is 5mm, the hysteresis curve is no longer full and shuttle-like, and the convergence is poor. The area of the hysteresis loop of each layer is not only small but unstable, and it shows a trend of scattered shrinkage at the last loop of the compressed hysteresis curve. Through research, it is found that when the gap value is 1-2mm, the energy dissipation capacity of the inline Buckling-Restrained Braces is the best and most stable.

3.3 Effect of different restraint ratios on Buckling-Restrained Braces performance

The model is subjected to low-cycle cyclic reciprocating loading, and the stress clouds of Buckling-Restrained Braces under different constraint ratios are shown in Figure 5.

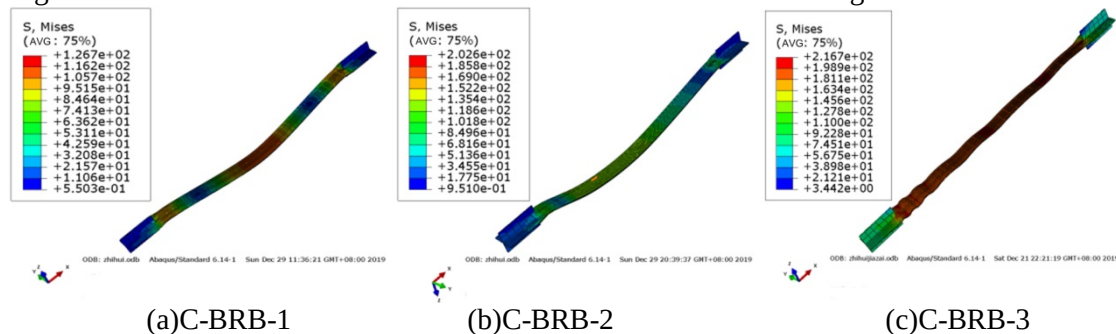


Figure 5 Stress cloud diagram of the core unit

It can be seen from Figure 5 that under the low-cycle cyclic reciprocating load, when the constraint ratio is 0.05, the stress of the energy dissipation section of the core unit is unevenly distributed along the length direction, and the stress is greater at the center of the large deformation, the maximum stress reaches 126.7Mpa, concentrated It is distributed between 105.7-126.7Mpa, and the stresses of the

remaining energy dissipation sections are between 63.62-105.7Mpa. The overall core element has not reached the full-section yield, the core element has a large buckling deformation, the central deformation is serious, and the deformation at both ends is small, And cannot be recovered; When the constraint ratio is 0.85, the stress of the energy dissipation section of the core element is basically uniformly distributed along the length direction, and the stress distribution of the overall energy dissipation section is between 84.9-101.18Mpa. The overall core element has not reached the full-section yield, and the core element has a large buckling Deformation, severe deformation in the middle, and small deformation at both ends; When the constraint ratio is 5.3, the stress of the energy dissipation section of the core element is evenly distributed along the length direction, and the stress of the overall energy dissipation section is distributed between 198.9-216.7Mpa. The whole core element reaches the full-section yield energy dissipation, and the half-wave bending occurs in the core element Deformation, the half-wave deformation is more at the loading end, and the middle and bottom half-wave deformation is less.

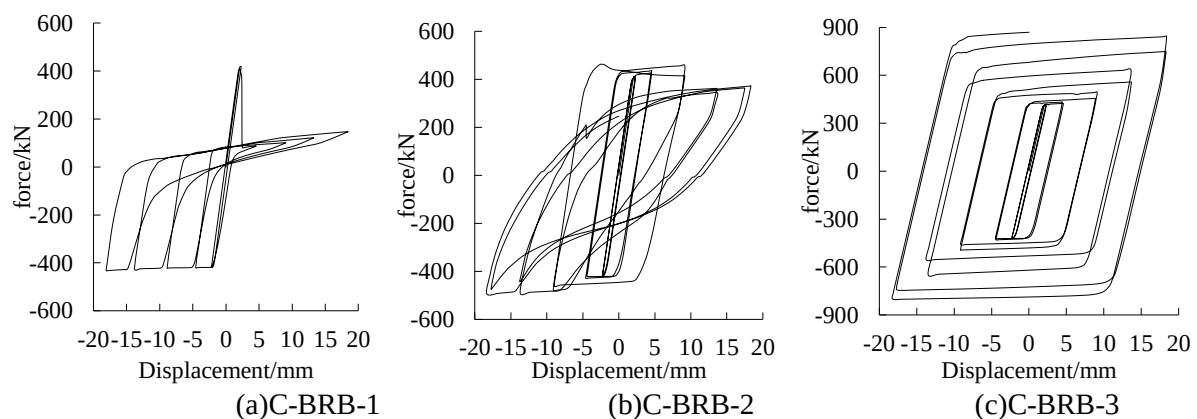


Figure 6 Hysteresis curves of Buckling-Restrained Braces under different clearances

It can be seen from Figure 6. When the constraint ratio is 0.05, the hysteresis curve is scattered and does not converge, the area of the hysteresis loop is small and unstable, and when the yield load is continued to be loaded, the member has been destroyed and cannot bear the energy dissipation, and the compression curve cannot form a full Hysteresis loop; When the constraint ratio is 0.85, the hysteresis curve is shuttle-shaped and has poor convergence, and the bearing capacity increases less. The area is small and unstable during the fourth and fifth cycles. The bearing capacity under compression is far less than the bearing capacity under tension; When the constraint ratio is 5, the hysteresis curve is relatively full and the convergence effect is good. The area of the hysteresis loop is large and stable. The tensile and compressive bearing capacity is basically symmetrically distributed. The shape-shaped Buckling-Restrained Braces has better energy consumption ability.

4. Summary

In this chapter, the finite element software ABAQUS is used as a tool to perform low-cycle cyclic reciprocating numerical simulation on the Buckling-Restrained Braces. By designing and establishing 9 different types of Buckling-Restrained Braces, the different width-thickness ratios, gaps, and constraints of the core elements are studied. The impact of the energy dissipation performance of the support was finally determined by finite element analysis as follows:

(1) By numerically simulating three sets of in-line Buckling-Restrained Braces with different core width-to-thickness ratios, it is found through research that the energy consumption of Buckling-Restrained Braces is the most stable when the width-to-thickness ratio is 10-16.

(2) Through numerical simulation of the three groups of Buckling-Restrained Braces with different gaps, it is found through research that when the gap is 1-2 mm, the Buckling-Restrained Braces has the best energy dissipation capacity.

(3) Through numerical simulation of the three sets of Buckling-Restrained Braces with different constraint ratios, it is found through research that when the constraint ratio is greater than 5, the one-line Buckling-Restrained Braces have better energy dissipation capabilities.

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