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Exploring the Behavior of Steel Plate Shear Wall with Inclined Slots

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1. Introduction

The main goal of civil engineering is finding new and efficient ways for protecting structures and equipment inside them against natural forces. In the past decades, many researchers have worked to offer appropriate methods for protecting structures. Steel Plate Shear Walls have been considered a lateral load-resistant system in the last three decades in the world. In this study, the behavior of slit steel shear walls is investigated. The purpose of creating slits in the steel shear wall is to dissipate more energy and concentrate damage in the steel sheet as well as to protect other elements, particularly gravity load-bearing ones. Due to the occurrence of the tension field, one of the drawbacks of steel plate shear wall system is the application of large forces by the steel sheet to the boundary members, causing these members to enlarge. The implementation of regular holes, the slits of different shapes, and the use of lower-capacity steel for the sheet have been suggested as solutions to this problem.

The main purpose of this study is to numerically investigate the effect of the shape and position of inclined slits on ultimate strength, initial stiffness, and energy dissipation of slit steel plate shear wall. For this purpose, numerical models are prepared using Abaqus software. However, to ensure the accuracy of the model, the results obtained should be compared with the results of existing analytical or experimental researches. To validate the modeling in Abaqus software, two experiments are presented below.

2. Validation

The slit steel wall was modeled using Abaqus software version 6.14. The wall was modeled using the S4R shell element, which is a general four-point element with reduced integration, having three degrees of transient freedom and three degrees of rotational freedom. Figure 1 compares the results of numerical modeling performed with Abaqus software and the results of a 2009 study by Vian et al.

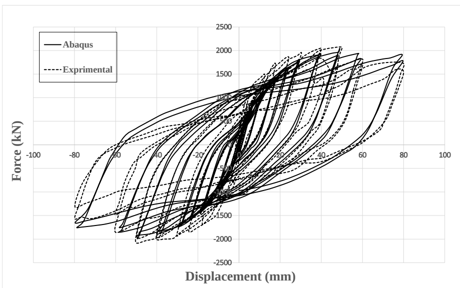

Figure 1. Comparison of the cyclic curve obtained from the numerical model and the experimental work by Vian et al. (2009)

Another study used to validate the simulation was performed by Lou et al., which contains a steel sheet that is attached to two end stiffeners.

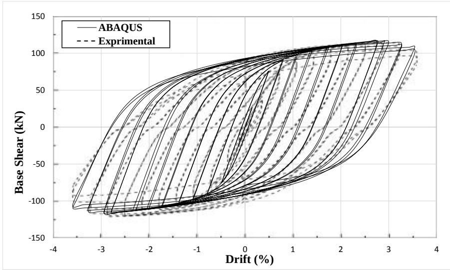

Figure 2. Comparison of the cyclic curve obtained from the numerical model and the experimental work by Lou et al. (2018)

Figure 2 compares the cyclic curve obtained from modeling with that from an experiment conducted by Lou et al. The difference between the base shear is about 3%. As a result, the comparison indicates good consistency in results.

3. Using inclined slots in steel plate shear wall

This study investigates numerically the effect of using inclined slots in steel shear walls. The idea of using a 45-degree slot in steel shear walls has already been explored in other studies, including two papers by Jin et al and Wang et al. According to Wang et al., the use of inclined slots relative to vertical ones causes greater expansion of surface yield, maximum use of sheet capacity, and greater energy dissipation due to operating truss elements in tension and compression. In a steel shear wall with vertical slots, the yielding surface and plastic joint usually appear just on sides of the strip. The steel wall in Figure 3 has two rows of inclined slots with equal distances. This type of shear wall is comparable to inverted-V-bracing as a lateral resistance system.

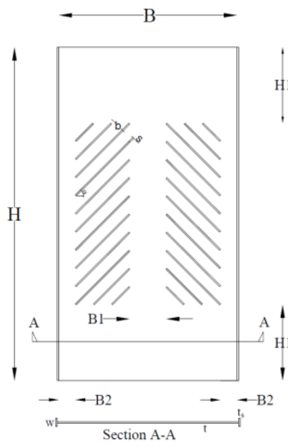

Figure 3. Steel plate shear wall with suggested inclined slots

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4. Modeling the samples

In order to investigate the effects of slot shape and position on shear wall, the configuration variables are selected as B1/B, B2/ B, H1/H, slit width, strip width, and end stiffener's cross section. The dimensions of the steel sheet are considered to be 850 × 550 × 1010 mm. When changing one parameter, others are assumed to remain constant in order to examine their effects. The following 15 models are reviewed, with the details in Table 1. The first 5 parameters indicate the slot position and in general the configuration of the steel sheet, and the last case describes different end stiffeners.

5. Comparison of results

In this section, key parameters of cyclical behavior including initial stiffness, ultimate strength, and amount of energy dissipated are examined. For this purpose, it is necessary to prepare the idealized force-displacement curves of the structures from the push diagram. This is done using the FEMA356 guidelines.

The comparison of the results of the proposed steel wall with inclined slots and the ordinary steel plate shear wall with the same dimensions indicates that despite the reduction of strength and initial stiffness in the slotted sample, this wall has a more favorable cyclic behavior and has the ability to dissipate more energy and perform better at drifts above 2%. The behavior of the slit steel wall was studied by defining 3 seismic parameters. According to Figures 4 to 6, by changing these items, the seismic parameters can change accordingly.

Table 1. Details of modeled samples

Number	Type	Model
1	width	1-Base
2		2-Width-165
3		3-Width-55
4		4-Side-27.5
5		5-Side-82.5
6	Heigth	6-Heigth-101
7		7-Heigth-151.5
8	Strip	8-Strip-35
9		9-Strip-65
10	Slit	10-Slit-12.5
11		11-Slit-7.5
12	Section	12-Box-50
13		13-Box-100
14		14-UNP-50
15		15-UNP-100

According to the results, changing the location of the slots in the samples can change the ultimate strength and initial stiffness by 19 and 25%, respectively. Furthermore, using end stiffeners with higher moment of inertia is one of the most effective ways to increase energy dissipation. For example, using Box100 cross-section as a stiffener has more than doubled energy dissipation compared to the basic sample.

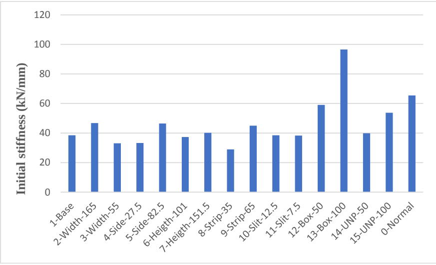

Figure 4. Initial stiffness of samples

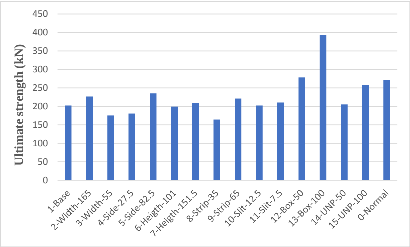

Figure 5. Ultimate Strength of samples

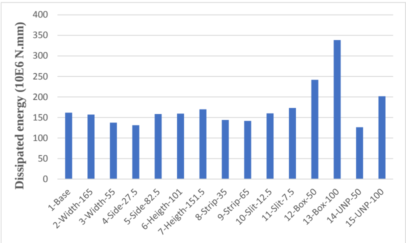

Figure 6. Dissipated energy of samples