Evaluation Cyclic Behavior of Concrete Shear Wall with Opening Retrofitting with Composite

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ABSTRACT

In recent years, reinforced concrete (RC) shear walls have been welcomed by structural designers with regard to their desirable seismic performance in terms of ductility. Most of the time, creating an opening in the RC shear wall due to the architectural issues, which is inevitable, results in reducing the strength, ductility and stiffness of the wall. For this reason, the issue of retrofitting the RC shear walls is developed to solve these weaknesses. In this paper, first a laboratory sample of reinforced concrete shear wall without opening was validated in ABAQUS software. After verification of the sample, the cyclic shear wall behavior of reinforced concrete with retractable opening with eight different designs horizontally, vertically, diagonally and combined by carbon fiber reinforced sheets (CFRP) in ABAQUS finite element software has been evaluated. For nonlinear static analysis, the specimens were subjected to lateral loading, cycling, and various parameters such as stiffness, displacement, and ductility were examined and compared. The results were presented in the form of capacity (force-displacement) curves, ductility, compressive and tensile failure contours. As the results show, reinforcement of shear walls of reinforced concrete with opening increases flexural strength, shear and ductility. The results showed that the RCSW8 sample increased by 12% compared to the reference sample bearing capacity. The hardness of the RCSW8 sample is increased by 15% and the ductility is improved.

KEYWORDS

RC shear wall, Cyclic behavior, Retrofitting, Composite, Finite element

1. Introduction

The reinforced concrete shears walls (RCSWs) suffer from an inadequate in-plane stiffness, flexural and shear strength as well as insufficient ductility [1]. In some cases, due to the architectural issues, openings such as doors and windows have to be placed in the wall. Accordingly, the load transfer mechanism varies due to the presence of these openings which in turn, reduce the strength, stiffness and ductility [2]. Although the stated retrofit solutions are effective in increasing the strength of the structure, many of these techniques cause significant increase in weight of the structure that changes the dynamic properties and distribution of seismic forces, which contradicts the original design of the structure. Accordingly, use of the CFRP sheets has been introduced in recent years as a practical approach to strenghthen th RCSWs. Among advantages of the CFRP that researchers use in different shapes and arrangements, quick and easy implementation, low cost, high hardness to resistance ratio, increase and great corrosion resistance could be mentioned [3]. In 2018, Aslani and Kohnehpooshi evaluated the effect of openings on behavior of the RCSWs and reinforcing the walls with opening using the CFRP sheets with varying thicknesses of 0.09, 0.18 and 0.27mm and tested three different patterns for wrapping the CFRP sheets. To this end, the specimens were numerically analyzed using ABAQUS software. Based on the results, creating an opening and enlarging it, reduces the lateral load-carrying and energy absorption capacities as well as stiffness but in turn, increases the wall displacements. Moreover, it was observed that the closer the opening becomes to the base of the wall, the energy absorption capacity is reduced [4]. In 2019, Lima et al. strengthened eighteen RCSWs with opening making use of the CFRP sheets. Then, the cracking patterns, damage states, ultimate strength and strain values were discussed. The tests results indicated that the CFRP sheets could enhance the ultimate strength of the wall by 14 to 59.7% [5].

2. Verification of the Numercial Model with Experimental Results

In order to verify the finite element model, the experimental studies conducted by Hosseini et al. [6]were considered. In 2019, Hosseini et al.

evaluated various failure modes by subjecting the RCSW specimens to the cyclic loading. For this purpose, they built four RCSW specimens among which, one specimen was a control specimen and the others, included openings. In this section, first, the geometric details and material properties used in the experimental tests are presented[6] and then, details and information about simulating the RCSWs in ABAQUS are discussed.

3. Characteristics of the Experimental Specimens

All experimental specimens[6] were built with the same dimensions in length, height and thickness of 1600, 1550 and 150mm, respectively (Figure 1).

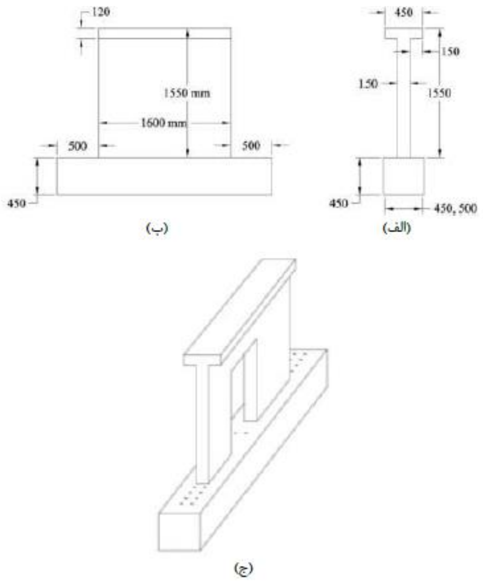


Figure 1. side view of the wall with opening [6]

4. Numercial Modeling of RCSWs in ABAQUS Software

Numerical modeling of the RCSW is integrated using 3D homogeneous components and its dimensions are proportional to the dimensions of the experimental model. The compressive strength, density and elastic modulus of concrete are 31MPa, kg/m^3 and 26GPa, respectively. For generating the meshes, 8-noded 3D elements with size of 50mm have been used. To define the rebars, homogenous 3D solid elements have been used and 2-noded truss elements were utilized to mesh the rebars. The other data of the rebars is given in Table1.

Table 1. Properties of the Rebars as Reinforcement

Type	Section area (mm^2)	Density (kg/m^3)	Element type	Mesh dimention (mm)
D6.5	33.2	7850	T3D2	60
D8	50.3	7850	T3D2	60
D12	113.1	7850	T3D2	50
D20	314.2	7850	T3D2	50

Figure 2 demonstrates a comparison between the hysteresis curve of the wall without opening with the experimental model.

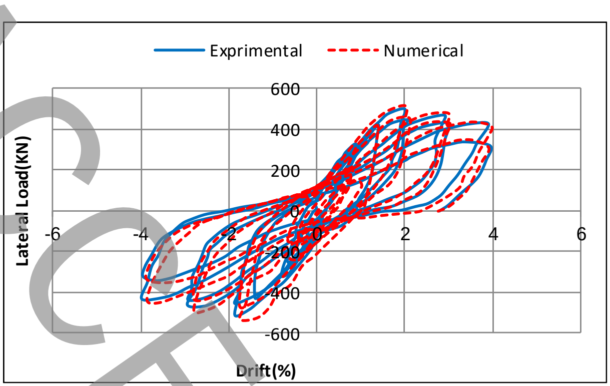


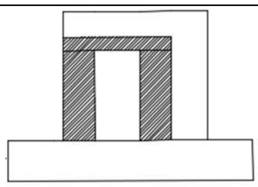
Figure 2.Comparion of Hysteretic Curves of Numerical and Experimental Models RCSW without opening

As can be seen in Figure 2, there is an acceptable agreement between the yield strength, yield displacement and ultimate strength values.

5. Numerical Modeling

Names of the finite element models are presented in Table 2.

Table 2. Naming and specification of finite element models

Sample reinforcement pattern	Sample name
	RCSW1

6. Results and Discussion

The force-displacement curves for the RCSWs with opening and retrofitted using different patterns and arrangements of CFRP have been illustrated in Figure 3,4.

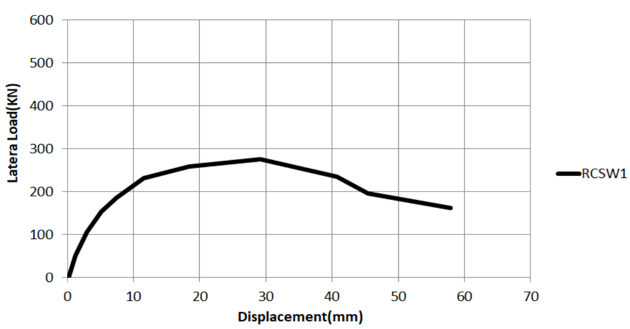


Figure 3. An Force –displacement curves of the RCSWs with opening

Figure 4 shows the tension failure contours when the walls are cracked.

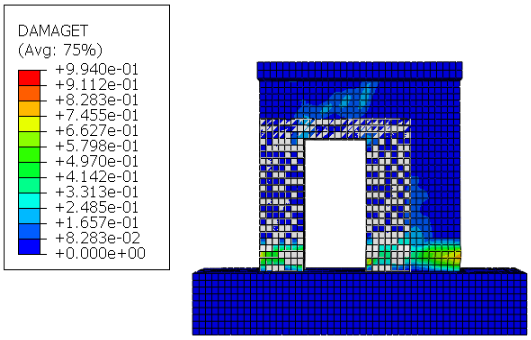


Figure 4. Tension Damage Contours at the Final Stage of Cracking

strain values at base of the wall are greater. As the right side and top of the opening have not been completely retrofitted in this model, the diagonal cracks at top of the opening inside the coupling beam and in the final step of loading, the crack between the pier and foundation leads to collapse of the wall. As can be seen, the dominant failure mode is sliding shear.

7. Conclusions

Type of retrofit technique for the RCSWs with opening was effective on the failure mechanism in a way that although, the load-carrying capacity was enhanced, sliding shear failure mode was observed in all specimens.

8. References

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