INVESTIGATION OF SEISMIC BEHAVIOR OF REINFORCED CONCRETE SHEAR WALLS REHABILITATED WITH FRP SHEETS

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Concrete shear walls are considered as one of the most suitable and common lateral force resisting systems in mid-rise and high-rise buildings. The shear-walls in old buildings need to strength and rehabilitations, due to increasing the life of the structure, experiencing different earthquakes and phenomena such as creep and corrosion. Structural reinforcement on these members would have a significant effect on improving the response and behavior of the initial structure.

In recent years, the use of FRP composites has been populated and most considered method in structural improvement. Suitable and convincing characteristics of these structural element such as easy installation process, using without any change in the appearance and architectural appearance of structure and high ratio of strength to weight, could made them preliminary options in retrofitting projects. In this regard, using the FRP sheets in reinforcing shear walls should be one of the best methods to improve their seismic behavior.

The literature review shows that experimental and analytical studies on high-rise shear walls and rehabilitation of them with FRP materials are considerably less than short walls. In this research, the behavior of mid-rise and high-rise reinforced concrete shear walls with FRP sheets reinforcement has been investigated. During the study, with using ABAQUS finite element software, the effect of this strengthening method on the bearing capacity, ductility, stiffness and energy absorption has been studied. The main focus of this study is on examination the performance of reinforced mid-rise and high-rise shear walls under the combination of axial and incremental uniform lateral load. Non-linear static analysis has been used to analyze the shear wall's behavior. Regarding to this, the load is applied on specimens in the form of displacement-control method.

Reinforced concrete is a complex material in the finite element modeling. In this research, the concrete damage plasticity model (CDP) has been used to define nonlinear behavior of concrete. In order to confirm the modeling and for validating the efficiency of the models, two shear walls, related to the Thomson (2004) and Lombard (2000) tests are modeled in the software. The results show that the numerical model has been simulated the experimental results of the main walls (use as reference) with acceptable accuracy.

After verifying the modeling accuracy and being ensured about the accuracy of the output results, the analytical specimens are defined and modeled. Specimens are low-ductility and weak walls that are designed using the ETABS software and are based on the ACI-318-99 (1999) building code and meet the requirements of the 9th chapter of the Iranian national building code (Design and Construction of Concrete Structures). Gravity loading has been carried out in accordance with the 6th chapter of Iran's national building code (Design Loads for Buildings) and lateral loading based on Iran's second edition of 2800 Standard (in order to design the walls in the old buildings and need to be strengthened used the second edition instead of the fourth edition). These walls have a rectangular cross section and an aspect ratio > 2 and have been designed in three elevation groups in accordance with Table 1.

Table 1. Dimensions of the sample shear walls.

(Aspect ratio L_w/H_w L_w/H_w)	Thickness (t_w t_w, m)	Length (L_w L_w, m)	(H_w Height H_w , m)	Number of stories
2.86	0.3	5.6	16	**5**
4	0.3	5.6	22.4	**7**
5.71	0.35	5.6	32	**10**

In order to study the effect of different FRP layouts on the behavior of mid-rise and high-rise shear walls, two modes, including the cross and horizontal wrapping FRP are performed in all three wall groups.

In this regard, in every altitude group, there are three walls, one of them has been a control wall with no reinforcement on it, and two other walls are reinforced with two expressed arrangements. The walls are initially rehabilitated with CFRP sheets. After determining the best type of combination between the two arrangements, the wall with optimal layout has been reinforced and analyzed with using GFRP sheets again. Then the results have been compared. With this in mind, the study was conducted in three groups of altitudes, with two kinds of combinations and two different materials of FRP. The results and diagrams for each sample have been analyzed and evaluated. Some of the results of the study are as follows:

Bearing capacity of the samples has increased in both geometrical combination and both materials. However, this increase is low using one sheet of reinforcement sheet. The maximum increasing in bearing capacity is attributed to the rehabilitated CFRP horizontal wrapping specimens and the value is 7.01% in the wall with 16.0 m heights, 6% in the wall with 22.4 m height and 2.86% in the 32 m wall.

Ductility of the wall has increased in all samples. The maximum magnitude of this increase is observed in the GFRP wrapped specimens, which can be due to the higher strain rupture of these sheets than CFRP sheets. This maximum value in samples with elevations 16, 22.4 and 32 meters is 16.19%, 21.9% and 17.55%, respectively.

The use of FRP sheets increases the absorbed energy of the specimens. The highest increase in energy absorption was observed for the 16-meter sample in horizontal wrap mode with GFRP at 29.06%.

The initial stiffness of the specimens has increased slightly with the reinforcement sheets. The maximum stiffness increase is 10.6% and is related to the 22.4 meter sample confined by CFRP sheets.

By examining the results of the three groups of shear walls, it can be said that with increasing specimens' height, the effect of one reinforced sheet layer on the seismic behavior of the rehabilitated shear walls decreases.

According to the results, in a mid-rise and high-rise retrofit design CFRP composites can be used if there is an increase in load capacity of the samples. Whereas, if increasing in ductility is preferable to increasing its carrying capacity, the use of GFRP sheets can be beneficial and economically viable.

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