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Effective Parameters on Behavior and Load Capacity of Concrete Shear Wall with Regular Opening

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ABSTRACT: Due to architectural reasons and constraints on the plan structure, openings such as doors, windows and installations ducts have been created on the concrete shear wall. It causes some changes in behavior, stiffness, load capacity and failure mechanism of specimens. In this paper, ABAQUS software is used for finite element modeling and investigating the parameters. In order to verify the results of this software, a scaled six stories wall with two bands of openings are modeled in ABAQUS software and compared with experimental results. After verification, parameters of opening area and position, bands of opening coupling, beam dimensions and diagonal reinforcement are investigated by non-linear finite element method using concrete damage plasticity model (CDPM) under the monotonic loading.
Results further confirm that if dimensions of opening do not change the failure mechanism of the wall, the opening position will be more effective than the opening area. In specimens with two bands of opening, making a ratio of lateral pier length to middle pier length more than 50%, increases effective compressive area and coefficient correlation and thus the sample has reached its maximum load capacity. Setting the diagonal reinforcement both on coupling beam and in other compressive parts of the wall (base wall), decreases the crack propagation and augments the compressive area of the wall. It also leads to increase the load capacity of specimens by 19.6 %. The comparison of results also showed that a specimen with coupling beam height to height floor ratio of 0.52, the use of diagonal reinforcement on the coupling beam and putting up them in the base wall can be a suggestion for appropriate design of concrete shear wall with an opening.

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1- Introduction

Structural walls have been usually adopted as the main earthquake-resistant components of reinforced concrete buildings. However, they usually have some openings according to the intention of the architectural design. The opening ratios, locations and shapes are often various.

Many theoretical and experimental types of research have been done on load capacity and concrete shear wall with openings. Lin [1] and Subedi [2] conducted a finite element analysis and experimental work to study the ultimate shear strength of concrete shear wall. They concluded that the ductility and shear strength of shear wall with openings are highly affected by reinforcement around openings, especially diagonal reinforcement. Aguda [3] studied on behavior and ultimate strength of a shear wall with two bands of opening. Results showed that the methods of calculations of concrete shear wall with one band of opening can be developed for RC shear wall with two bands of openings. Research made by Yanez et al. [4] recorded a ductile failure by reaching the yielding limit of the vertical reinforcement, followed by the crushing of the concrete from the base of the small compressed pier. Balkaya and Kalkan [5] compared 2D and 3D non-linear finite element analysis of concrete shear wall with openings. They concluded that the stress flow, load capacity and crack patterns around the openings of pierced shear observed through the 3D models are more reliable. Warashina et al. [6] performed experimental and theoretical research to investigate the effect of opening location and concluded that opening dimension and location can affect compressed area of the wall. Wang et al. [7] and Chowdhury et al. [8] developed Strut and Tie modes to design concrete shear wall with different opening locations. Mosorca [9] did theoretical and experimental studies on structural walls with staggered openings. The analysis of the failure modes, obtained with the computing methodology proposed, contributed to the completion of the seismic design codes for shear walls with staggered openings.

Despite research on reinforced concrete shear walls with openings, comprehensive comparison of the effective parameters on behavior and load capacity of these samples has not been done yet. In this study, parameters of the position and area of the opening, bands of opening, coupling beam dimensions and diagonal reinforcement are investigated to reach an appropriate design of concrete shear wall with openings.

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2- Analysis

In this section, some specimens are modeled in ABAQUS software to investigate previously mentioned parameters. Lublinar et al. [10] concrete plasticity damage model (CPDM) with Maekawa model [11] and Belarbi and Hsu [12] model are used for modeling of concrete and reinforcement, respectively. Shima et al. [13] model is also used to correct cohesive stress effect. Modeling process in ABAQUS software is verified with experimental specimens.

Effect of changing positions of opening on concrete shear walls with one and two bands of openings are shown in Figures 1 and 2. Changing opening position to the amount of 75% length of wall on specimens with one band of opening 25% increases the load capacity of the wall. In specimens with two bands opening, if ratio of lateral pier length to middle pier length be more than 50%, each three-pier walls will be under pressure and the wall reaches its maximum load capacity.

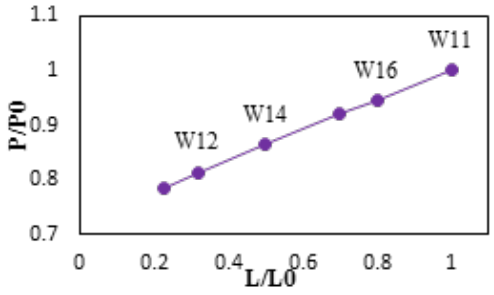

Figure 1. Effect of opening location on walls with one band of opening

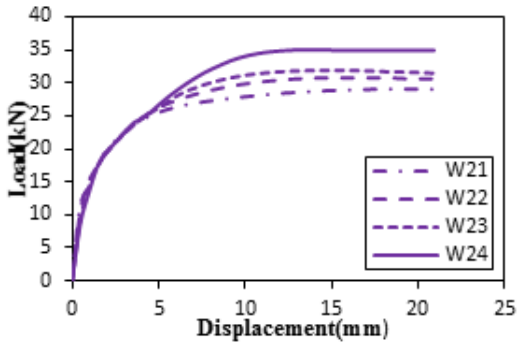

Figure 2. Effect of opening location on walls with two bands of opening

Figures 3 and 4, show the effect of length and height of coupling beam on the load capacity of designed shear walls. As can be seen in the figures, increasing the length of the coupling beam has no effect on the load capacity of the sample. However, the increasing in height of coupling beam from 38 % to 52 % floor height, due to enhancement capacity and stiffness of the beam, can decrease lateral drift and increase load capacity of the wall.

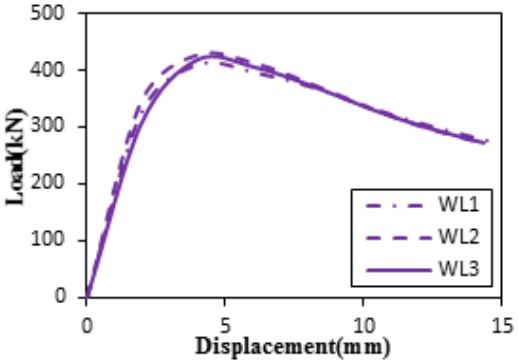

Figure 3. Effect of coupling beam length on load capacity of the specimens

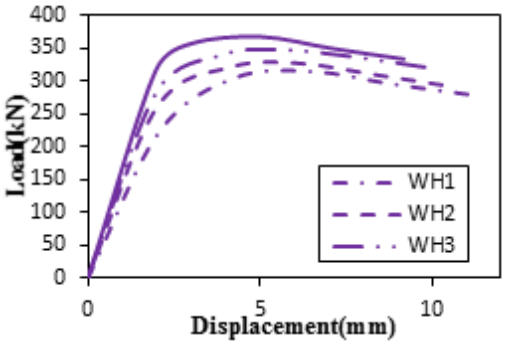

Figure 4. Effect of coupling beam height on load capacity of the specimens

Figure 5 shows the failure mechanism, the wall without diagonal reinforcement (WL1), wall with diagonal reinforcement in the coupling beam (WDIA1), and the wall with diagonal reinforcement both in the coupling beam and the base wall (WDIA3), from left to right. It can be seen that putting diagonal reinforcement both in coupling beam and in the base wall, reduces crack propagation in all parts of compression area and cause load capacity amplification.

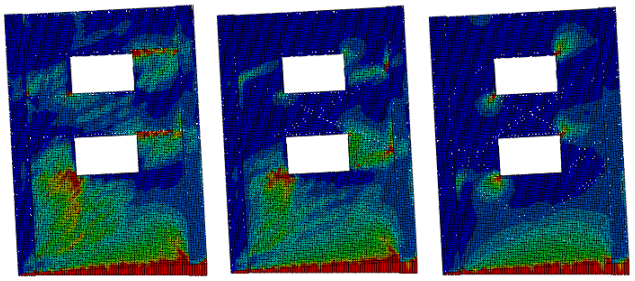

Figure 5. Failure mechanism: WL1, WDIA1, WDIA3

Finally, by comparing the investigated parameters in this paper, amounts an recommendation are shown in Table 1. The values are suggested in order to achieve appropriate design of concrete shear wall with opening.

Table 1. Suggested amounts and recommendation

Parameters	Amount/ Recommendation
Opening location	Symmetric on the center of wall
Percentage of diagonal reinforcement in coupling beam	1/7%
State of putting diagonal reinforcement	Both in coupling beam and the base wall
Coupling beam height to floor height ratio	0/52
Specimen with one more band of opening	Side pier length > Middle pier length

3- Conclusions

1- The position of the opening is one of the most important factors on the correlation coefficient and compressive effective area of shear wall. Thus, according to the ineffectiveness of the compressive area by changing the load direction, the best place to create the opening is symmetrically at the center of the wall.

2- To achieve maximum compressive area, correlation and its maximum load capacity on specimens with two bands of openings, the ratio of the side pier wall to middle pier should be larger than 50%.

3- The comparison between specimens with one and two bands of opening and maximum reduction of correlation coefficient with making the opening in the base wall (despite no change in the ratio of the opening area to total area of the wall) showed that, if opening dimensions do not change the bending failure mechanism of the wall, opening location would be more effective in reduction of the load capacity than the opening area.

4- If the height of the coupling beam becomes half of the height floor, due to the stiffness and capacity elevation, the wall reaches to its maximum load capacity.

5- Putting diagonal reinforcement both in the coupling beam and the base of the wall reduces the crack propagation in all compression areas and enhances ductility and load capacity of the wall. The method of the reinforcement can be suggested as a new way of designing concrete shear wall with an opening.

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