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The Effect of Shape and Dimensions of Openers in Concrete Shear Wall with Nonlinear Static Analysis

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ABSTRACT

One of the ways of confronting lateral forces due to wind or earthquake is using RC shear walls. RC shear wall besides appropriate behavior against lateral forces it causes the plan to be cost-effective. Sometimes because of architectural reasons or implementing facility systems, there is a necessity to use shear wall with opener. In this article we study and investigate the effect of openers' location one the performance of shear wall through finite element method. For this, four walls without opener, wall with opener in the above, down and middle were modeled by ABAQUS software and the results are provided both in diagrams and figures. The results show that by comparing cracking contours in different walls, presence of opener increases the cracking tension in that part. But the tension under the walls is not very different and this could be due to the symmetry in different walls. Generally, it could be said that the best state for energy loss in the wall is seamless implementation and avoiding the creation of opener. Then, by movement of the opener to the wall base, energy loss and plasticity in the wall would be reduced. In other words, energy loss and plasticity in the wall with opener in the above is more than a wall with opener in the middle and wall with opener in the middle has better performance in energy loss with respect to wall with opener in the below. In a wall without opener the most tension and cracking is in the wall foot and this is due to the maximum shear and bending in this part. Also, with comparing pushover diagrams in different walls it is seen that for a special movement, the following walls have the most tolerance, respectively: wall without opener, walls with opener in the above, middle, and below.

Keywords:

Shear Wall, Opener, Finite Element, Cracking, Plasticity, Energy Loss, ABAQUS.

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1. Introduction

One of the resistance systems against earthquake is concrete shear wall which because of its suitable performance it is considered in past earthquakes. But some architectural limitations force the structural engineering to embed the opener in the shear walls. Especially, in high structure with central concrete kernel, around the elevator room is a suitable place for installing shear wall and connecting them vertically on each other and to create a flanged shear wall but in order to embed the elevator door we have to create a opener in of the walls which this affects the behavior of the shear wall. The ratio of opener dimensions and also the percentage usage of reinforcement are the most important influencing factors on the nonlinear behavior of concrete shear wall with opener.

2. Problem Statement

Shear wall is considered as an efficient structure for ensuring high and average buildings resistance against lateral forces. On the other hand, the necessity of presence of opener in these walls is inevitable due to architectural or structural reasons. The presence of opener in the shear wall changes the wall behavior [1-8]. Shear wall performance in tolerating lateral forces due to earthquake requires that openers would be embedded in suitable place. Improper openers lead to unexpected and unwanted failures. Therefore, the place of openers should be considered in a way that shear walls usually have special order and also the openers' patterns should be in a way that the wall behavior could be predicted. Overall, openers should be embedded in a way that wall would have a suitable bending resistance and plasticity. Shear walls with openers such as other structures could be analyzed in a approximate or precise way. Approximate methods are faster and easier for manual calculation but they are only usable for ordered and semi-ordered structures and openers. If the wall includes disordered openers or complex support system, it could not model the structure with the approximate model confidently. In this situation, it is better to use finite elements methods. Computer analysis are performed in order to precisely study the tension changes in locations around openers and wall foot and also to study the crack initiation against any changes in openers by ABAQUS finite element method. Studied model is M3 which has expressed the specifications of each material in modeling in ABAQUS software [9-14].

Table 1. Specification of consumed steel in modeling and laboratory sample.

Sample	Reinforcement type	Yield tension	Rupture tension	Rupture strain	Elasticity module	Poisson ratio
M3	Longitudinal Reinforcement	504	634	0.11	210000	0.3
	Transverse Reinforcement	745	800	0.03	210000	0.3

All units are based on N-mm

Table 2. Specifications of used concrete in laboratory model and modeling.

Sample	Cylindrical compressive resistance	Compressive tension 0.5f$_c$'	Compressive tension	Compressive plastic strain	Tensile plastic strain
M3	20	10	2.7	0.0035	0.001

3. Research Necessity

As it was said, presence of opener in the shear wall is inevitable due to architectural and structural reasons. Presence of opener in shear wall changes the behavior of the wall. Improper openers lead to unexpected and unwanted failures. Therefore, the place of openers should be considered in a way that shear walls usually have special order and also the openers' patterns should be in a way that the wall behavior could be predicted. Overall, openers should be embedded in a way that wall would have a suitable bending resistance and plasticity. Shear walls with openers such as other structures could be analyzed in a approximate or precise way. Approximate methods are faster and easier for manual calculation but they are only usable for ordered and semi-ordered structures and openers. If the wall includes disordered openers or complex support system, it could not model the structure with the approximate model confidently. In this situation, it is better to use finite elements methods. Computer analysis are performed in order to precisely study the tension changes in locations around openers and wall foot and also to study the crack initiation against any changes in openers by ABAQUS finite element method. Studied model is M3 which has expressed the specifications of each material in modeling in ABAQUS software.

4. Research Hypothesis

•In this research, RC nonlinear finite element method analysis and plasticity behavioral model together with tensile hardening are used for modeling concrete behavior.

•In order to analyze the modeled samples, nonlinear static analysis (monolithic/pushover) was used and also the nonlinear effects of materials and geometrical nonlinear in modeling were taken into consideration.

•In cyclic loading, reductive behaviors get more complex which includes opening and closing capillary cracks which were identified previously. It is seen that by changing the direction of loading, elastic hardening is increased and this is an important characteristic of concrete behavior in two-way loading. The effect of this behavior is more apparent when loading from tensile state is converted to compressive state which closes the cracks and restores the compressive hardness.

•ABAQUS finite element software has provided three different mix for concrete analysis in a state on which confining pressure is applied: cracked concrete in ABAQUS/standard, fragile concrete in ABAQUS/Explicit and damaged paste concrete in ABAQUS/Standard and ABAQUS/Explicit.

•In order to define concrete specifications in the software, 'damaged concrete plasticity' model which was provided by Lubiner and Lee & Fenves in 1998 was used. This model is a continuous model based on plasticity which essentially has the capability of analyzing concrete structures and modeling the damage in the concrete. Actually, this criterion takes into consideration the compressive and tensile damages.

•In ABAQUS modeling, concrete and steel behavior are separated and then they are laid on each other and the effects of engagement between concrete and steel such as anchor slide and approximate action are introduced.

•In order to model the consumptive steel, a two-linear model and also tension criterion of Fon-Mises were used.

5. Validation

In order to validate the results, Greifenhagen and Lestuzzi study which was performed in 2005 was used. In this study, in order to study the bending resistance and transformation capacity of shear wall of reinforced concrete, four samples of shear wall in 1.3 scale were taken into consideration as shown in Figure 1. Shear wall which had the closest specifications to the studied models was selected and the results for a one loading cycle for the laboratory sample and shear wall without opener were compared as shown in Figures 2, 3 and 4.

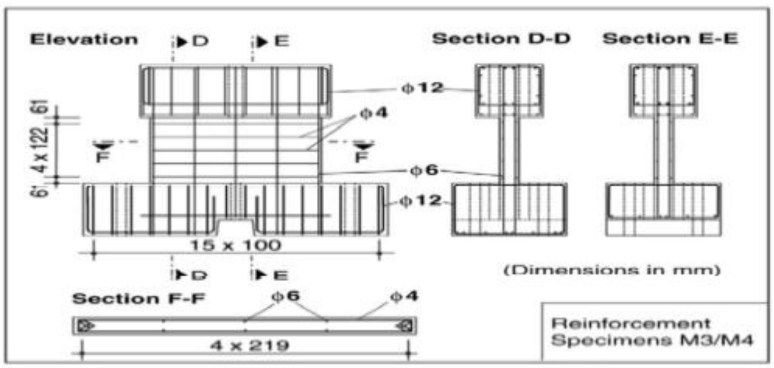

Figure 1. Specifications of sample wall in validation article.

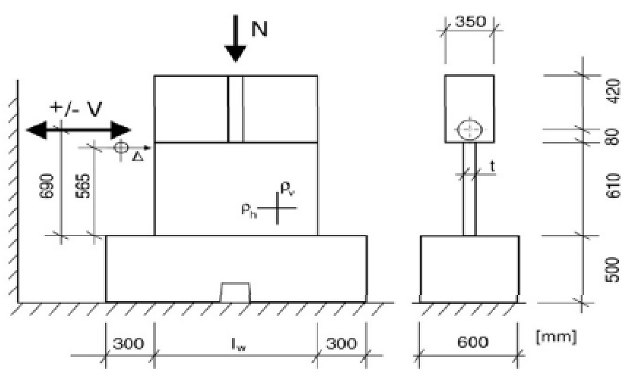

Figure 2. Dimensions and size of tested wall.

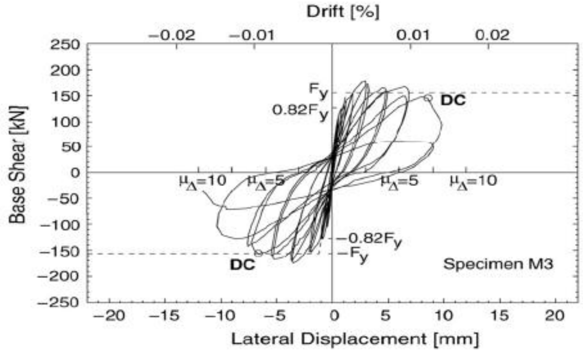

Figure 3. Relationship of force-dislocation seen in cyclic static samples.

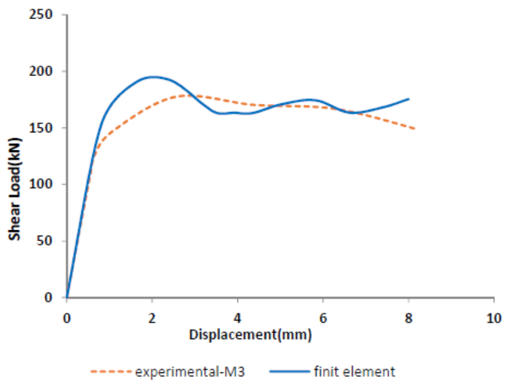

Figure 4. Comparing the results in one loading cycle for M3 laboratory sample.

As it was seen, closeness diagram of results in two models is shown which implies that finite element results in this study are correct and reliable.

6. Results

In this part, results of analyzing shear walls with different openers were provided. Used the 8-node and 2-node elements were used for concrete elements and fitting, respectively as shown in Figures (5, 6, 11, 12, 17, 18, 23 and 24). In this research, all mentioned steps in this chapter are analyzed. Results of analysis are provided by Figure and contours of tension. Analysis result are provided as diagrams and contours of tension and cracking. As shown in Figures (7, 8, 9, 10, 13, 14, 15, 16, 19, 20, 21, 22, 25, 26, 27, and 28)

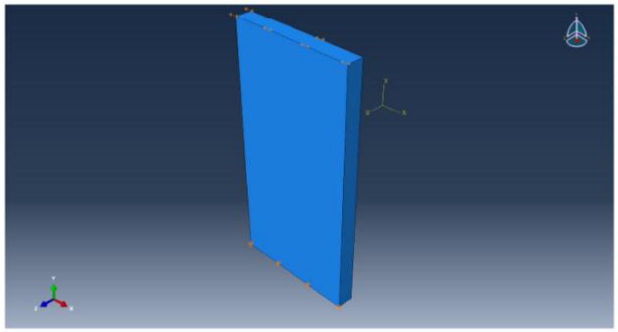

Figure 5. Loading in shear wall without opener.

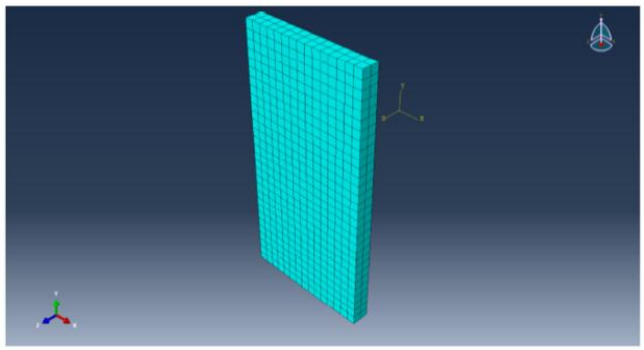

Figure 6. Grid in shear wall without opener.

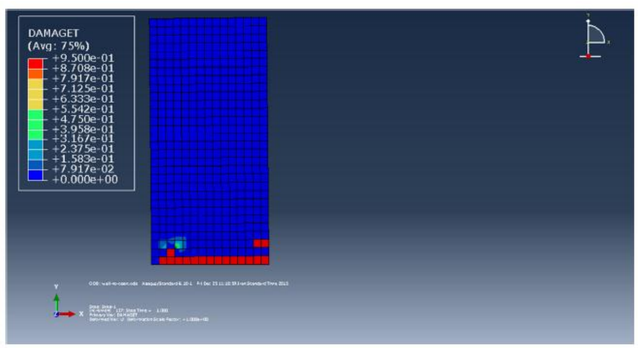

Figure 7. Cracking contour for wall without opener.

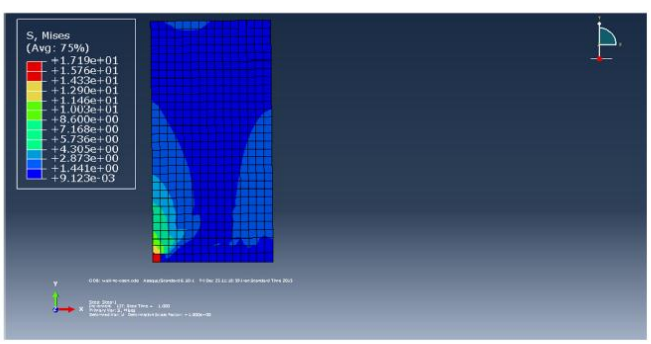

Figure 8. Tension contour in shear wall without opener.

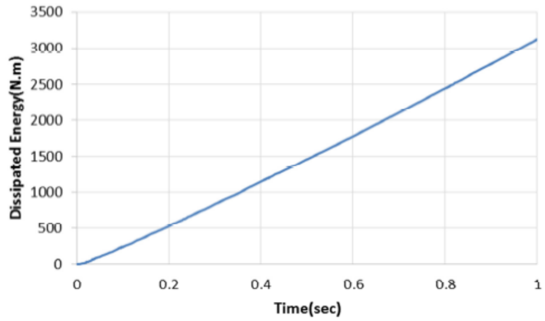

Figure 9. Energy loss in wall without opener.

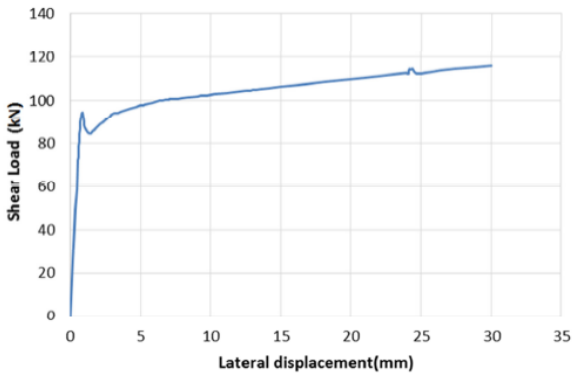

Figure 10. Pushover diagram for wall without opener.

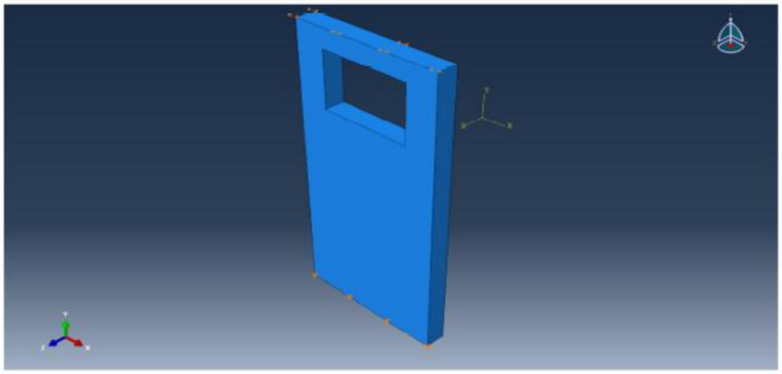

Figure 11. Loading in shear wall with opener in the above.

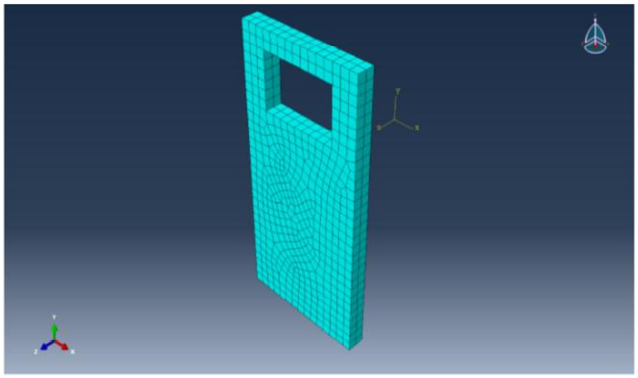

Figure 12. Grid in shear wall with opener in the above.

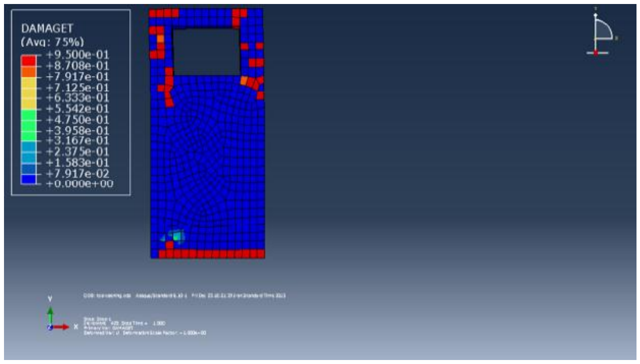

Figure 13. Cracking contour for wall with opener in the above.

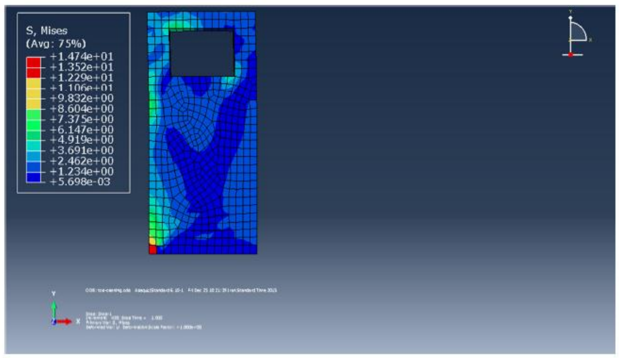

Figure 14. Tension contour in wall with opener in the above.

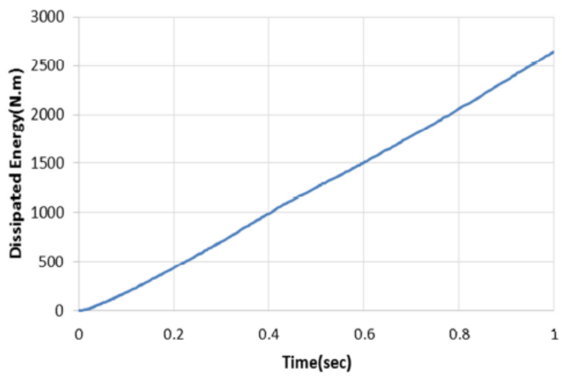

Figure 15. Energy Loss in wall with opener in the above.

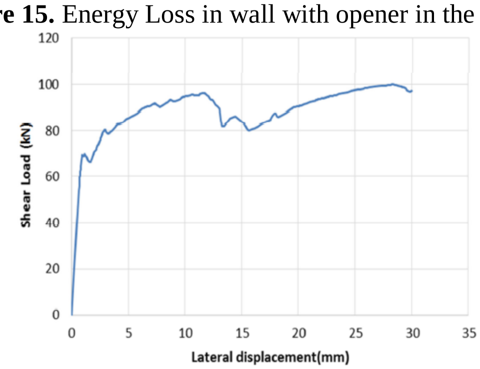

Figure 16. Pushover diagram for wall with opener in the above.

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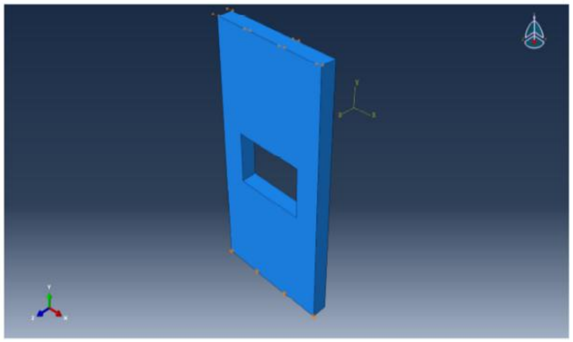

Figure 17. Loading in shear wall with opener in the middle.

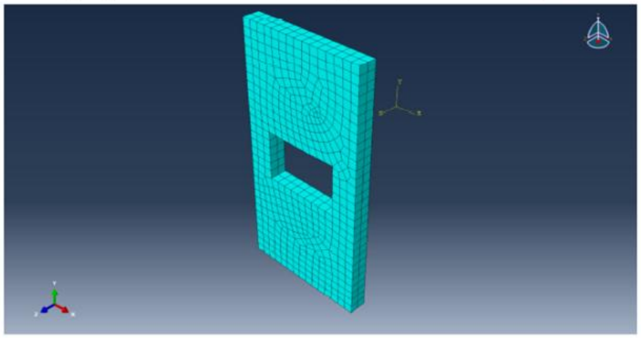

Figure 18. Grid in shear wall with opener in the middle.

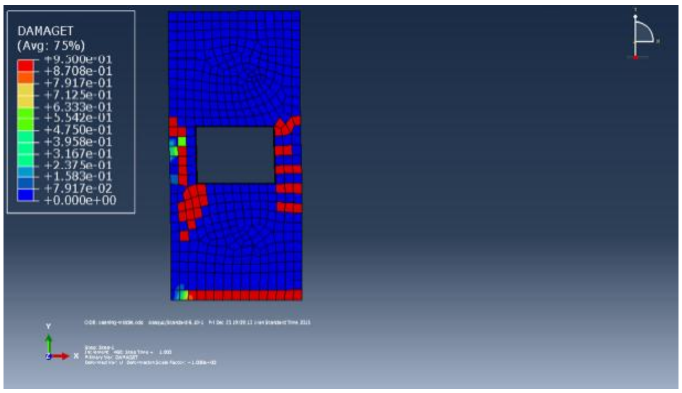

Figure 19. Cracking contour for wall with opener in the middle.

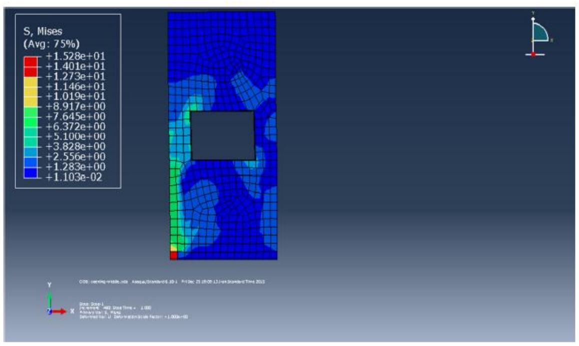

Figure 20. Tension contour in wall with opener in the middle.

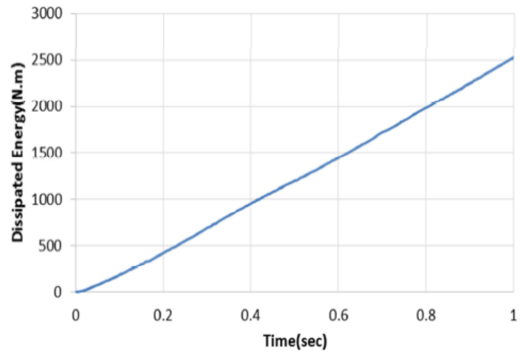

Figure 21. Energy loss in the wall with opener in the middle**.**

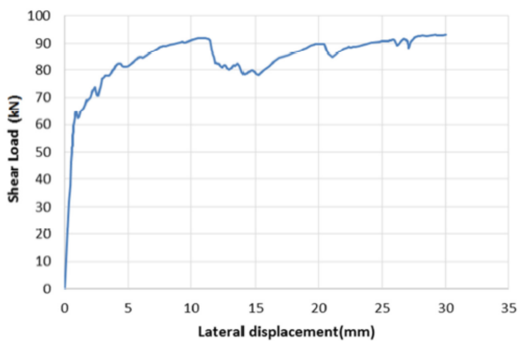

Figure 22. Pushover diagram for wall with opener in the middle.

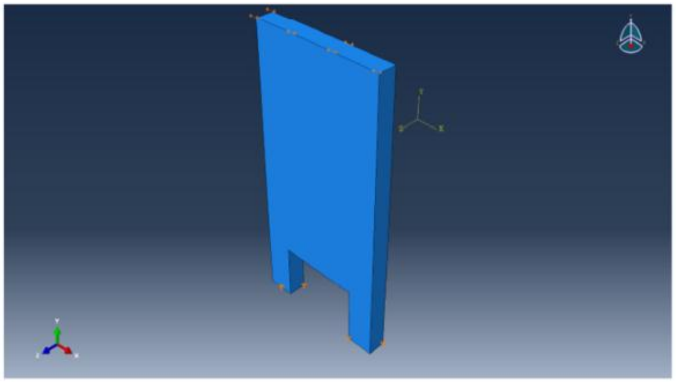

Figure 23. Loading in shear wall with opener in the bottom.

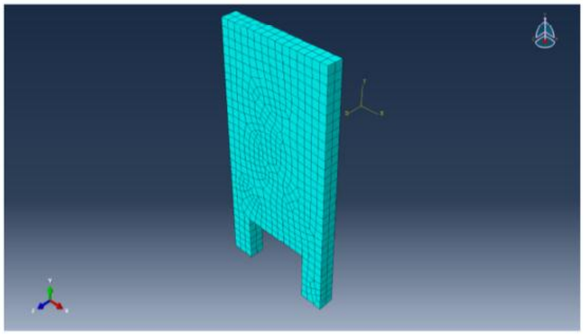

Figure 24. Grid in shear wall with opener in the bottom.

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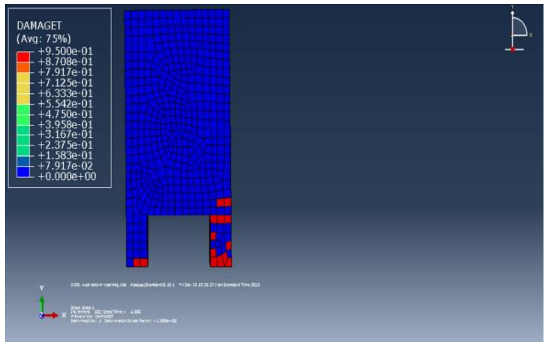

Figure 25. Cracking contour for wall with opener in the bottom.

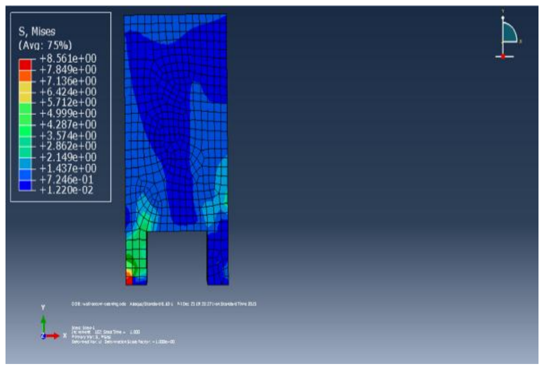

Figure 26. Tension contour in wall with opener in the bottom.

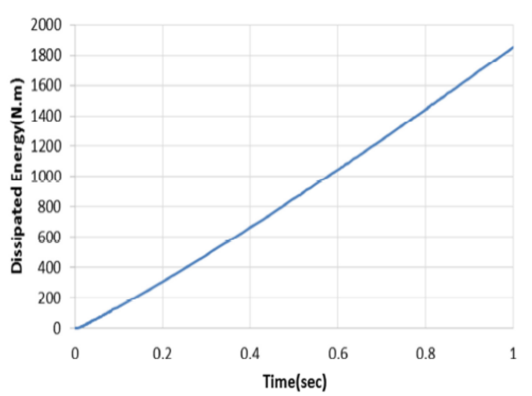

Figure 27. Energy Loss in wall with opener in the bottom.

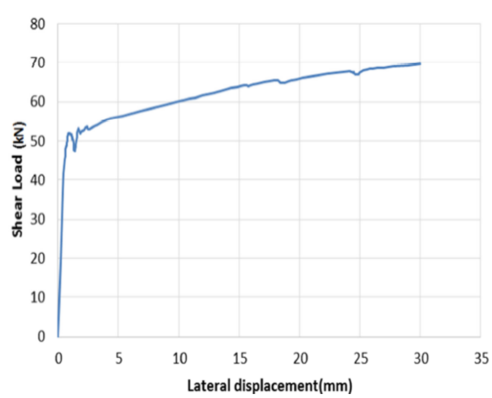

Figure 28. Pushover diagram for wall with opener in the bottom.

6. Discussion

In this section, results for wall without opener and walls with openers are compared in different sections. As shown in Figures (29 and 30).

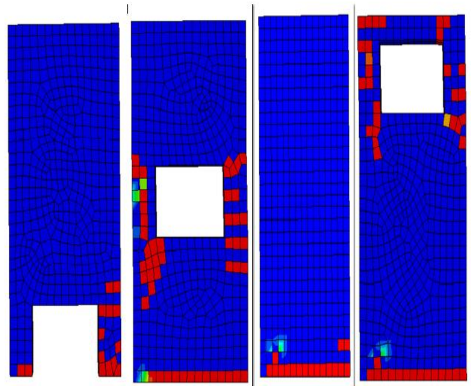

Figure 29. Cracking contour in walls without opener and with openers in different parts.

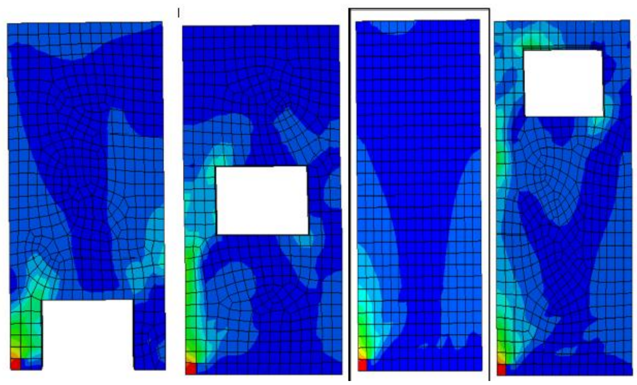

Figure 30. Tension contour in walls without opener and with openers in different parts.

Comparing cracking contours in different walls implies that presence of openers leads to cracking in the wall in that region. As Shown in Figures (31, 32, and 33).

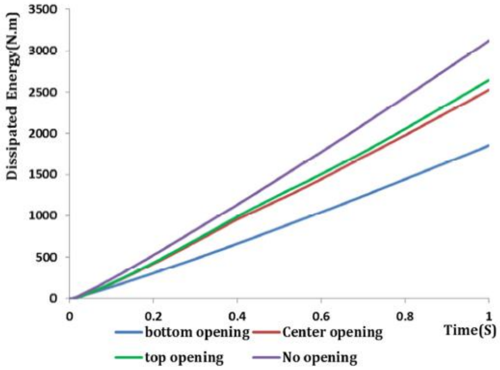

Figure 31. Energy loss in walls without opener and with openers in different regions.

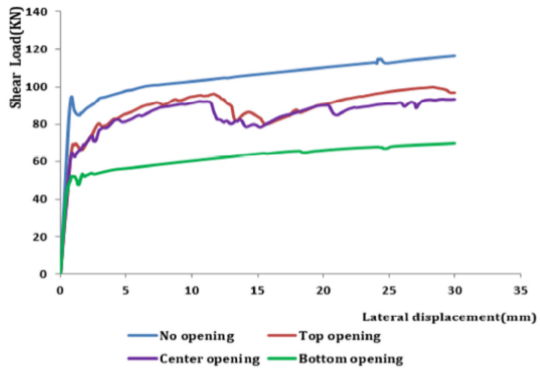

Figure 32. Pushover diagram in walls without opener and with openers in different regions.

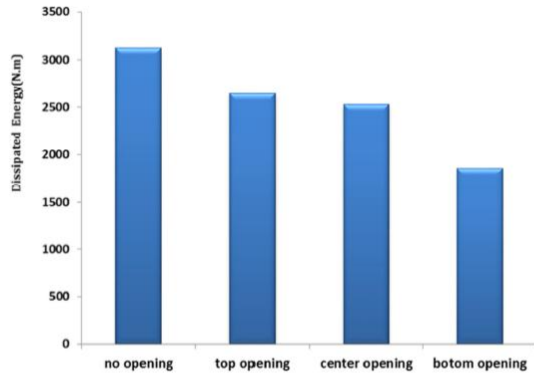

Figure 33. Comparing plasticity of walls without opener and with openers in different regions.

4. Conclusion

In the wall without opener, the maximum tension and cracking are in the wall foot and this is because of presence of maximum shear and bending in this region. Comparison of tension cracking contours in different walls shows that presence of opener created cracking in the wall in that region.

Comparing tension contours shows that creating opener in the wall increases the tension around the opener. But the tension in the bottom of wall is not very different and this leads to symmetry of different walls. The best state for the energy loss in the wall is seamless implementation and avoiding the creation of opener. When the wall is without opener, the maximum energy loss could be seen. Then, movement of opener toward the wall foot leads to reduction of the energy loss. In order words, energy loss in the wall with the opener in the above is more than the wall with the opener in the middle and the wall with opener in the middle has better performance in energy loss with respect to wall with opener in the bottom. The cause of this is the maximum shear and bending in the bottom of the wall. Therefore, presence of wall in this part is effective in energy loss. Comparison of Pushover diagram in different walls shows the better performance of wall without opener than walls with opener. We could conclude that in walls with openers, wall with opener in the above has better performance than wall with opener in the middle and wall with opener in the middle has better performance than wall with opener in the bottom. Plasticity in wall without opener is more than wall with opener and from above to the bottom, plasticity is reduced. It is understood that the presence of opener reduces the performance of the wall against earthquake. Therefore, it should not use the openers as far as it is possible and if it should be used, appropriate action would be performed.

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