Journal of Computing and Electronic Information Management
ISSN: 2413-1660 | Vol. 14, No. 1, 2024

A Review on Seismic Performance of Steel Plate Concrete Walls with Openings

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Abstract: Double steel plate concrete combination wall is a new structural form, with reinforced concrete structure does not have the advantages: both sides of the steel plate can be used as a template for concrete pouring, control the width of cracks in the concrete and extension of leakage, to avoid premature collapse, out of the working state, and at the same time can mitigate the hazards of the impact of the flying object to play a protective role; filled with concrete to enhance the stability of the steel plate to avoid the premature bulging of the steel plate. Drumming. Opening holes in the shear wall structure will not only reduce the integrity of the shear wall, but also affect its seismic performance. When faced with different functional requirements, the selected opening design program will also be different, but for the specific hole arrangement method there is no clear provisions given in the code. Therefore, a large number of scholars at home and abroad have carried out research on shear walls with different opening sizes, locations or shapes by means of experiments and simulations to analyze the influence of these factors on shear walls with openings first.

Keywords: Steel plate shear wall; Seismic performance; Pierce.

1. Status of domestic research

Guo Zonghong [1] of Hebei University of Engineering studied the seismic performance of corrugated steel plate shear walls with sinusoidal openings by conducting load tests. The main conclusions are as follows: The longer the steel plate length, the thicker the plate thickness, the smaller the height and the wider the width of the hole, the fuller the hysteretic curve of its shear wall.

Wang Zhongquan [2] from Northeast Petroleum University used ABAQUS to model a combined shear wall silo to investigate the effect of the size and location of the opening on the seismic performance of its shear wall silo. The main conclusions are as follows: (1) The energy dissipation capacity of all the shear walls with open holes is higher than that of those without open holes. (2) The initial stiffness of shear walls with openings is reduced, and the larger the size of the openings, the smaller the initial stiffness of the combined shear walls.

Li Weiman of Dalian University of Technology [3] investigated the effect of each parameter on the seismic performance of corrugated steel plate shear wall by using finite element analysis software ABAQUS, and concluded that (1) as the area of the opening decreases, the thickness of the steel plate increases, and the height-to-width ratio is smaller, and the bearing capacity and the initial stiffness of its shear wall are enhanced subsequently. (2) The seismic performance of corrugated steel plate shear walls with circular openings is better than those with square openings.

Wang Wei et al [4] from Suzhou University of Science and Technology (SUST) conducted hysteretic simulation using finite element software ABAQUS with opening rate and opening radius as the study parameters. The study shows that the overall energy dissipation performance of the wall panel is better when the opening rate of the wall panel is around 10%; the energy dissipation performance of the shear wall panel with an opening radius of 80mm is the best.

Wang Wei et al. from Xi'an University of Architecture and Technology [5] investigated the effects of opening aspect ratio and opening location on the load carrying capacity and energy dissipation capacity of corrugated steel plate wall by establishing ABAQUS finite element model. The results show that the load carrying capacity and energy dissipation of the steel plate wall is maximum when the height-to-width ratio of the opening is in the range of 0.33-0.5, and minimum when the hole is opened in the center.

Deng Enfeng et al [6] from Zhengzhou University analyzed by using finite element software ABAQUS to establish a refined finite element analysis model analysis of corrugated steel plate shear wall with open holes. The results show that when the location of the hole is close to the outer edge of the frame, its shear wall has high lateral stiffness.

Xueying Niu [7] investigated the effect of hole opening method on the force performance of open hole container house by using the analysis software ABAQUS to establish model numerical simulation, and the results show that: the location and size of the open hole have a greater impact on the force performance of its containers, while the shape of the hole has a smaller impact on its force performance.

2. Status of research abroad

Roberts et al [8] investigated the effect of opening size on the seismic performance of steel plate shear walls by conducting low circumferential repeated load tests on steel plate shear walls with open circular holes. The results show that: the specimen has higher ductility and absorbs more energy as the shear displacement increases; the stiffness and strength of the corresponding steel plate decreases when the size of the hole increases.

Vian [9] investigated the effect of opening holes on the mechanical properties of steel plate shear walls by conducting tests on steel plate shear walls with open holes, which showed that the initial stiffness and strength of the specimens with open holes were reduced by 15% and 19%, respectively, compared to the specimens without open holes.

Moghimi [10] established open circular hole embedded steel plate shear wall by finite element analysis software to

study the effect of hole opening on shear wall, the results show that: the diameter of the hole is the main factor affecting the structural load bearing capacity, the opening will enhance the lateral stiffness of shear wall, but at the same time, it will weaken the shear capacity of embedded steel plate.

Valizadeh [11] conducted tests on scaled down flat steel plate shear wall specimens to study the effect of open holes on the seismic performance of their shear walls, and the results of the study showed that the energy dissipation of flat steel plate shear walls with open holes is stable.

Barkhordari et al [12] analyzed the force mechanism of steel plate concrete shear walls with open square holes by using ABAQUS finite element software, and the results showed that opening the holes would be able to increase the strength of the frame beams and columns, but at the same time it would also reduce the initial stiffness and strength of the steel plate concrete shear walls.

Sabouri-Ghomi et al [13] investigated the effect of spacing of openings on single-story steel plate shear walls by testing single-story steel plate shear walls with different opening locations. The results show that the spacing of openings has little effect on the test results, and the overall bearing capacity of the shear wall with openings is reduced.

Roudsari [14] et al. modeled the open hole corrugated steel plate shear wall by ABAQUS finite element software. To study its seismic performance, the results show that the thicker the thickness of the steel plate, the higher its load carrying capacity; the structural load carrying capacity of the circular opening is higher than the structural load carrying capacity of the square opening.

Khan et al [15] investigated the nonlinear behavior of steel plate shear walls with different opening sizes and types by modeling the shear strength and stiffness degradation of steel plate shear walls with arbitrary openings, and the results showed that the shear strength and stiffness of shear walls were highest when the opening shape was circular and the location of the opening was in the center of the wall.

Darvishi et al [16] conducted large displacement tests and ABAQUS finite element software analysis of open-ended unstiffened steel plate shear walls and the results showed that the energy dissipation and ductility ratio of the open-ended specimens were 25.5 and 41.5 times higher than that of the open-ended specimens, respectively. However, the ultimate strength and initial stiffness of the open-ended specimens were reduced.

Alavi et al [17] conducted experimental studies on the seismic performance of diagonally stiffened ribbed steel plate concrete shear walls with central opening. The test results show that the shear strength can be enhanced by stiffening to make it close to that of the unopened steel plate concrete shear wall, thus enhancing the seismic performance of the structure.

Rostami et al [18] investigated the effect of different stiffening rib arrangements on flat steel plate concrete shear walls by taking the location of the opening, the aspect ratio and the arrangement of the stiffening ribs around the opening as factors, and finally proposed an improved model with both economy and good performance.

Arabzadeh et al [19] investigated the effect of opening window and door openings on the overall force behavior of open combined steel plate shear walls by conducting tests on the openings, the results of the study showed that the location and size of the openings had little effect on the performance of the shear walls, but the openings reduced the strength of the structure.

Mohammad et al [20] investigated the effect of openings on the shear wall of a test combined steel plate shear wall by showing that the effect of openings on the shear wall can be reduced by the use of hole stiffening and proposed an empirical relationship equation for calculating the ultimate strength of combined steel plate shear walls.

Ding Y,Deng E F[21] investigated the seismic performance of open and unopened corrugated steel plate shear walls by conducting quasi-static tests on them separately, and the results showed that the initial stiffness of open corrugated steel plate shear walls was lower than that of unopened shear walls, but the ultimate strength and energy dissipation rate were higher than that of unopened shear walls.

3. Current problems

The force characteristics and seismic performance of shear walls with rear openings need to be studied in depth

At present, scholars at home and abroad have fully studied the relationship between different forms of openings and the seismic performance of shear walls with openings first.Scholars at home and abroad have conducted sufficient research on the relationship between different forms of openings and the seismic performance of first-opened hole shear walls, but due to the fact that when additional holes are installed in existing shear walls, not only the openings in which the steel reinforcement bars are directly cut offHowever, due to the fact that when adding holes to the existing shear wall, not only the way of cutting off the reinforcement directly is different from that of opening the holes first, but also the structural characteristics and stressing mode of the shear wall with holes opened afterward are obviously different.The current research on post-cavity shear wall is not deep enough and systematic.

Lack of research on the effects of the number and arrangement of openings on the seismic performance of shear walls with rear openings

In the existing research, there are more studies on the influence of the arrangement of multiple openings on the seismic performance of shear walls, mainly focusing on the influence of whether the multiple openings in slender shear walls are regularly arranged in the vertical direction or not, and there are also a small number of studies based on the relationship between the changes in the width of the wall limb between multiple openings and the seismic performance of shear walls. However, the above studies are all based on the shear walls with openings first, and there is a lack of research on the seismic performance of shear walls with openings later under the corresponding circumstances.

The restoration effect of viscous steel reinforcement on the seismic performance of shear walls with openings needs to be studied in depth.

For the shear wall structure that needs to open holes in advance, certain reinforcement measures will be taken in the design, and a large number of scholars at home and abroad have already conducted research on the use of steel plate reinforcement of shear walls with open holes, and the results show that this method can effectively improve the seismic performance of shear walls with open holes, but the effect of the opening of holes on the mechanical properties of the shear wall is different from that of the first hole, and the research on the use of viscous steel reinforcement of shear walls with open holes is relatively small. The corresponding

technology and theory are not yet mature. Therefore, it is necessary to carry out further research on the effect of viscous steel reinforcement on shear walls with different types of openings at the back.

Lack of theoretical calculations based on the influence of the number and arrangement of holes on the bearing capacity of shear walls with rear openings

Current research has made it clear that rear openings lead to a decrease in bearing capacity. However, the influence factor of the number of holes has not been included in the calculation model of the bearing capacity. Therefore, for the effect of the number of holes on the bearing capacity of shear walls, further derivation of the calculation model is needed.

Lack of theoretical calculations of the bearing capacity of post-cavity shear walls reinforced by adhesive steel reinforcement

Sticky steel reinforcement method has been proved to be a very effective reinforcement method in theory and practice, but there is no relevant theory to quantitatively measure its reinforcement effect. Therefore, by studying the theoretical calculation method of the effectiveness of adhesive steel reinforcement, it helps to select a more reasonable and economical reinforcement program.

Study of fewer open hole walls

Open-cell steel plate shear wall has the advantages of easy to meet the functional requirements of the building and simplify the construction, but its force mechanism is different from that of the unopened-cell steel plate shear wall, which will result in the decline of seismic performance, and it is still under-researched in terms of the design method of the structure and the research is mainly focused on the flat wall panels and the combination of wall panels.

4. Conclusion

In summary, as of 2023, scholars in various countries have carried out a lot of research work on various types of steel plate shear walls, especially the most mature research on flat steel plate shear walls, forming a perfect design and calculation methods and a comprehensive and systematic understanding; the diversity of wall panels and side frames has brought about different degrees of seismic performance of steel plate shear walls, and the combination of each other expands the scope of steel plate shear wall applications. The combination between them has expanded the application range of steel plate shear walls. At the same time, a series of studies have been carried out at home and abroad on the development of steel plate shear walls with openings. It is found that the force mechanism is different from the unopened steel plate shear wall, which will cause the decline of seismic performance, the design method of the structure is still understudied, and the study mainly focuses on the single-opening shear wall mainly with window and door openings, and the study of the effect of the size, shape and location of the hole on the shear wall.

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