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Seismic Guardians: Redefining Shear Walls for Unshakable Residential Structures

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ABSTRACT

This thorough analysis provides a detailed overview of developments, obstacles, and future prospects in this important field of structural engineering by synthesizing current works on shear wall design for seismic protection in multi-story residential structures. Shear walls are discussed in terms of location, organization, and creative design strategies. Shear walls are essential for resisting lateral stresses and guaranteeing stability during seismic occurrences. Shear walls arranged in a central core are shown to be helpful in minimizing top-story displacement during seismic activity. Studies on materials show improved strength, ductility, and stiffness, such as corrugated steel plates. The article includes experiments that investigate the behavior of shear walls under different loading scenarios, including information on aspects ratio effects, overturning resistance, and the connection between panel height and drift/shear strength. The impact of anchoring solutions on wall movement is closely examined. Furthermore, research using computer tools such as STAAD.Pro and ETABS provide quantifiable data on the behavior of buildings, highlighting the beneficial effect of shear walls in minimizing displacement.

Introduction

A shear wall is a type of structural element used to offset lateral pressures applied to a building. When shear stresses on the building grow as a result of earthquakes, these walls become even more crucial in seismically active zones. Shear walls are stronger, more rigid, and able to withstand stresses applied in-plane along their height. Properly planned and detailed shear walls have shown to perform exceptionally well in buildings during previous earthquakes [1]. Shear walls are crucial structural components, particularly in tall structures that are vulnerable to seismic and wind impacts from the side. They provide the whole lateral displacement the necessary strength and rigidity. And surrounding elevator shafts and stairwells, there may be internal or exterior walls, or occasionally both [2]. In recent years, there has been an increasing focus on the design and analysis of shear walls in residential buildings. This is due to their significant role in bearing lateral shear forces and providing stability during seismic events. Several studies have been conducted to investigate the performance of shear walls under different loading conditions and to optimize their design for cost-effectiveness and energy efficiency. One of the key findings from post-earthquake reconnaissance missions is that structural wall buildings with shear walls exhibited good seismic behavior [3]. This highlights the importance of incorporating shear walls, especially in regions prone to earthquakes, to ensure the safety of occupants and prevent total collapse [4].

To improve the seismic behavior of shear walls, scholars have explored various methods, particularly focusing on the joints and energy dissipation devices. Some promising approaches include incorporating shear walls with slits, using a combination filling of energy dissipation shear walls, and implementing shear walls with vacillated rocking energy swings. These innovative techniques have demonstrated enhanced optimization performance compared to traditional shear wall structures. However, it is important to note that the design of shear walls must take into consideration the increased seismic forces they may experience. In some cases, shear walls may be undesirable unless they are made sufficiently ductile. This is because shear walls that are not designed for lateral loads can lead to insufficient safety margins and compromise the stability of the building.

To overcome these challenges, extensive research, both analytical and experimental, has been conducted to study the inelastic behavior of reinforced concrete shear walls. In the field of structural engineering, shear walls play a crucial role in ensuring the seismic response and overall stability of residential buildings. These vertical components are designed to bear horizontal shear forces and provide resistance against lateral loads, such as those caused by earthquakes or strong winds. Research conducted at the Laboratory of Steel Structures of the "Politehnica" University of Timisoara in Romania has provided valuable reference values for testing. the shear strength of full-scale wall panels made from cold-formed stud frames and various cladding arrangements commonly used in residential buildings. These reference values serve as a benchmark for evaluating the available shear strength of walls. Shear walls play a crucial role in providing lateral support and enhancing the seismic resistance of multi-story residential buildings. Shear walls are typically constructed using materials such as reinforced concrete or steel, and they are strategically placed throughout the building to distribute horizontal loads and prevent excessive.

Literature Review

Yamaguchi et al. [5] Conducted a series of experiments to investigate the behavior of wood framed shear walls under different loading conditions. These experiments included monotonic and cyclic tests with varying loading rates, as well as pseudo dynamic tests and shake table tests using the El Centro earthquake record. It was observed that the tests with higher load cycling and greater amplitudes exhibited a deterioration in post peak strength. Furthermore, the results of the fast reversed cyclic tests closely aligned with those of the shake table tests. An in-depth analysis of the Fake dynamic tests and shake table tests revealed similar magnitudes of load cycle amplitudes, although different outcomes were obtained.

Salenikovich and Dolan [6], Conducted an experiment in which they examined walls with different aspect ratios and tested them for both static and cyclic conditions to assess their resistance to overturning. The ductility and stiffness of the walls were observed to be consistent under both testing protocols. The results indicated that walls tested monotonically, with aspect ratios less than or equal to 2:1, exhibited a capacity of 13% and a corresponding displacement greater than 30%.

H.Veladi et al. [7], This study included cyclic tests performed on steel shear walls, with differences in the aspect ratios of both the shear walls and the infilled panels.. The decrease in height of the shear panels resulted in a reduction in drift and an improvement in shear strength. Conversely, an increase in the height of the panel enhanced the drift but also led to a significant plastic energy absorption, ultimately causing a decrease in shear strength. Shear strength and drift were shown to be increased and decreased by using broad panels, cyclic testing, and different aspect ratios.

Ni and Karacabeyli [8], The shear walls operation maintained with anchoring utilizing hold downs, with no hold downs, and with dead loads but no hold downs was investigated. The investigation utilized static and cyclic reverse loads in accordance with ISO (1998) guidelines. The experiment entailed evaluating the movement of walls with and without hold downs. The results showed that the shift of walls with no hold downs or vertical forces was half that of walls with hold downs but no vertical load.

Kevin B.D.White [9], Directed experiments involving the application of monotonic earthquake loadings on wood frame shear walls that were both fully and partially restrained. The results of these experiments revealed that when subjected to partially anchored subduction zone earthquakes, the walls exhibited failure modes that were consistent with both monotonic and cyclic tests. On the other hand, when subjected to fully anchored subduction zone earthquakes, the walls displayed failure modes that were consistent with cyclic tests. It is worth noting that completely fixed monotonic tests did not result in bolt rupture or nail pulling out, and thus did not lead to failure.

Max Guendel et al. [10], Conducted tests and calculations on steel walls to make them better at withstanding earthquakes. They looked at different types of steel and how they were connected to the walls. Some types of steel worked well and were strong, but didn't bend very much. Other types of steel were stronger and could bend more without breaking. When the steel was connected to the walls with special bolts, it made the walls even stronger. This is important because it helps protect buildings during an earthquake. It also helps distribute the force of the earthquake so that it doesn't damage the foundation or the beams inside the building.

Zhijuan Sun, Jiliang Liu, and Mingjin Chu [11], executed a cyclic loading experiment on an innovative variant of a flexible slit shear wall. This novel approach aims to enhance the seismic functioning of traditional shear wall buildings. In comparison to regular shear walls, the fresh wall exhibits remarkable ductility, with the failure process unfolding progressively in two distinct stages: The entire wall platform and the subsequent torn wall platform. The investigation revealed that the adaptive slit shear walls, fortified with multiple seismic reinforcements, successfully achieve ductile failure while effectively averting brittle shear failure.

Kumar, T.A., & Padmanabham, K.C. [12], In this study, we looked at how different kinds of buildings perform in an earthquake. We compared buildings that had special walls ‘shear walls’ to buildings that did not have these walls. We used a computer program called ETABS to help us with our study. We wanted to see how much the buildings moved from side to side, how much each floor leaned or tilted, and how strong the buildings were at the base. We found that the buildings with shear walls moved less than the ones without them. The floors in the buildings without shear walls leaned more than the ones with them. The buildings with shear walls were also stronger at the base. This means that the walls helped the buildings stay together better during an earthquake. The way the load, or weight, is transferred in the buildings with shear walls is also better than in the buildings without them. This is an important factor in making sure the buildings don't collapse during an earthquake.

Agrawal, S.C. [13], Said that a shear wall is a special kind of wall that helps keep a building strong during an earthquake. Even though buildings with shear walls can still get damaged during earthquakes, these walls can help reduce the damage. The way a building moves during an earthquake depends on how heavy it is and how strong it is in different directions. Shear walls are used to make buildings better at handling earthquakes. They can make buildings safer during big earthquakes. When buildings are really tall, it's important to make sure they can stay stiff and not move too much during an earthquake. Adding shear walls to a building can help with this, and it's also a cost-effective way to make the building stronger. However, putting shear walls in tall buildings can be tricky because it can make it difficult to fit everything together and pour concrete. Shear walls are often used in tall buildings to keep them from collapsing. When shear walls are placed in the right spots in a building, they can help stop the building from moving too much during an earthquake.

Fares, Anas [14**],** said where the walls are placed in a building can make a difference in how well it can withstand an earthquake. The walls in the middle of the building are better at keeping the building sturdy than the walls on the outside. The walls in the middle help the floors stay strong and balanced, and they are the best choice for making sure the building doesn't move too much during an earthquake.

Tajzadah, Jawid & Desai, Proff & Agrawal, Vimlesh [15], Found that a shear wall is a strong wall that helps buildings stay sturdy during earthquakes. When the shear wall is positioned in the middle of the building, it works really well at keeping the building safe. But if the shear wall is placed farther away from the middle, it doesn't work as well. To make sure the building can resist twisting during an earthquake, it's best to put the shear walls in the middle of the building. However, the best position for shear walls can change depending on how big they are and where they are placed.

Yadav, G.D., & Jamle, S. [16**],** Stated that the amount that a building can move sideways in certain directions gets bigger when the walls are made smaller. When the amount of open space in the walls is more than 10%, the sideways movement gets even bigger for buildings with two cores. The strength of the building's foundation decreases when the weight of the building decreases because there is more open space. In both sideways directions, building core case 6 is the best option when 50% of the walls are open. The amount of force on the columns increases at first when there is a small amount of open space, but then it decreases. Building core case 6 is the most cost-effective option with 50% open space. The twisting of the beams is the highest in building core case 2 when the walls are made smaller. For buildings with one core, building core case 5 is the best option because of the effects of earthquakes. Similarly, for buildings with two cores, building core case 6 is the best option.

Hagag et al. [17], Said that if the openings in a wall are less than 20% of the total wall area, the size of the openings is more important than how they are arranged in affecting the strength of the wall. But if the openings are more than 20% of the wall area, how they are arranged becomes more important. The height of the window opening also has a big effect on the strength of the wall. Small openings don't have a big effect on how much weight the wall can hold.

Prathibha Reddy T, Vinutha S, Khaled Mahdi Al-Qudaih [18], Made an analysis carried out by ETABS, it has been determined that the displacement experienced in both regular and irregular buildings is significantly reduced when shear walls are present, as opposed to when they are absent. This reduction is quantified as a percentage of 7.72% when shear walls are provided, compared to a much higher percentage of 50.11% when shear walls are not provided. Furthermore, the displacement observed in buildings without shear walls is notably greater when compared to those with shear walls. This finding underscores the efficacy of shear walls in enhancing a building's ability to withstand wind and seismic forces. In summary, the presence of shear walls in a building confers a heightened resistance to the detrimental effects of wind and seismic forces, as demonstrated by the reduced displacement experienced in both regular and irregular structures.

Vaishya & Chandak [19], This study looked at how different parts of a tall building can affect its stability during an earthquake. They compared the impact of walls that resist sideways forces in different places in the building, as well as replacing some of these walls with beams. They measured things like how much the building moved, how strong the sideways forces were, and how much the building twisted and bent. They used a computer program called STAAD Pro to do all the calculations. The results showed that the best place to put the walls and beams was on the sides of the building. They also found that the building was most stable when there were no walls, but adding walls or beams made it stronger. Overall, having walls or beams in the building made it move less during an earthquake.

Mishra [20], examined a comparative investigation of a G+15 storey building in Zone IV. This investigation focuses on the analysis of the shear wall at the corner to determine parameters such as axial load and moments. The analysis was conducted using the software package STAAD.Pro. The buildings were modeled with a floor area of 256 sqm (16m x 16m), with 4 bays along a 16m span each 4m. The design was carried out using STAAD Pro software. The study encompassed both lateral and longitudinal directions, as it is necessary to consider dual structural configurations in order to counteract the displacements caused by lateral effects in tall structures. The stability of the structure is also influenced by the strength criteria of the soil. Therefore, it is important to check the soil type according to the Indian Standardization IS 1893-2016 (part 1). Additionally, earthquake analysis should be performed for specific zones or cities in order to analyze the data in different ways. It is crucial to validate the analysis of different parameters and ensure compliance with Indian Standards within the specified limits. The results were obtained using STAAD.Pro. Version 2004.

Kashyap Shukla, Nallasivam K. [21], In the beginning of the research, they made models of tall buildings. They used a special computer program to make nine models of buildings with 30 floors. The first model was a square shape without strong walls, and the other eight models were rectangular with strong walls. The time it takes for the buildings to shake got shorter when they added strong walls. The model with strong walls in the middle had the biggest change in shaking time compared to the other models. The models with strong walls on all four corners had the shortest change in shaking time. The best way to handle forces from the side was to have strong walls in the shape of a core in the middle. The research showed that the location and layout of the walls are important. Buildings with walls on the corners are more affected by shaking than buildings with walls in the middle. Buildings with walls on the corners and in the middle did better than buildings with walls only on the corners. Forces from the sides, like earthquakes and wind, affect how tall buildings are made. The models with strong walls in the shape of a core in the middle moved the least during earthquakes, 1.8 times less than models without strong walls. But buildings with different strong walls on each corner did the worst at resisting earthquakes.

M H Mohammadi et al. [22], said that when building a reinforced concrete building, we need to think about things like the story, how strong the building is against earthquakes, and how stiff it is. We usually find that putting a special wall called a shear wall in different places in the building can make it stronger against earthquakes. Sometimes, we find that the building doesn't move as much during an earthquake when the shear wall is in a certain place. The best place to put the shear wall is in the middle and in a balanced way. It's also important to think about how the building is shaped when we're deciding where to put the shear wall. Sometimes, it's a good idea to use both shear walls and bracings to make the building even stronger against earthquakes.

Sun et al. [23], When a sideways force is applied to the precast shear wall, it can bend, slide, or shear. Bending happens when the wall rotates vertically without sliding. Slip happens when the wall slides horizontally. Shear happens when the wall deforms due to stress without sliding. In this study, we don't think slip is important because it is very small.

Alárcon et al. [24], When a building is being designed to withstand earthquakes, it is important to make sure it can handle strong shaking without collapsing. Researchers have found that the building needs to be stronger in one direction (Y) compared to the other direction (X) to be safe. This means that if the building is designed to be flexible and not too rigid, it will be less likely to collapse during an earthquake. The researchers also discovered that the shape of the curves that show how the building responds to shaking should be less steep. This means that the building can handle a wider range of shaking without getting damaged. The difference in strength between the two directions of the building shows that it is more likely to collapse in the Y direction. This means that the design of the building needs to be adjusted to make it more balanced and equally strong in both directions.

Conclusion

From the literature mentioned above, Engineers have studied how to make buildings strong and safe during earthquakes. They found that putting strong walls in certain places can help the buildings stay steady when the ground shakes. They also found that the arrangement of shear walls is important for serving the desired purpose.
It has been found that the arrangement of walls in the core of the building is the best shape for the best results during an earth quick.
Also, the studies revealed to which extent the shear wall will be affected by the size of opening and when it will be more affected by the position of opening, the drift will be greater with openings.
The tests revealed how walls made of different materials behave when they are pushed or pulled in different ways.
They found that the size and shape of the walls can affect how well they stand still, and how much they move when they are pushed.
They also found that adding bracing to hold the walls in place can make them stronger. These tests have been done on walls made of wood, steel, and concrete to give us a better understanding how these walls react during earthquakes and other strong movements.
It is found that it's important for walls to be able to bend and flex without rupture.
A special computer programs STAD.pro, Etabs, etc. used to help understand how buildings move during earthquakes. These programs show that buildings with strong walls don't move as much during an earthquake, and the software results were very close to the action of building when an earth quake take place.
As A result, any tall building of 3+ floors should have shear walls in its structure giving the assembly more integrity so as to withstand the sway and the movement from the earth quake.

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