Optimum Location of Shear Wall in G+6 Building at the Outer Periphery Using Pushover Analysis

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OPTIMUM LOCATION OF SHEAR WALL IN G+6 BUILDING AT THE OUTER PERIPHERY USING PUSHOVER ANALYSIS

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ABSTRACT

Many studies have been conducted in recent years to determine how well buildings handle lateral forces. However, the location of the shear wall when a building is subjected to lateral force was not thoroughly studied. It is well known that performance-based design is the best method for determining the ideal location. Pushover analysis is used to find the best location for this study. When conducting a pushover analysis, the relationship between base shear and roof displacement is typically depicted in the capacity curve. Various shear walls are placed throughout the building as part of this analysis to determine the exact location. The PushSW6 model had the highest shear carrying capacity out of 13 models tested, making it the best option for placement. When compared to the model without a shear wall, the shear carrying capacity of the PushSW6 model is 76.66% higher. From here, it is clear that PushSW6's shear walls will be the best location out of the 13 models.

Keywords: Shear wall; Pushover; Displacements; Capacity curve; Base shear

1. Introduction

This article examines how shear wall position affects lateral displacement, storey drift, storey shear, and storey stiffness in RC frames. We looked at fourteen different types of G+6 structures, one of which is a bare frame model with no shear wall and the other thirteen have shear walls at various locations. After running a nonlinear static pushover analysis on each of the 14 models, the results for lateral displacement, storey drift, storey shear, and storey stiffness are compared, and an optimum location for the shear wall is determined.

Sayed Mahmoud [1] explored the G+7 building with a shear wall in seven different locations. Created finite-element models with shear walls are distributed over either the outer panel or the inner panel in accordance with ASCE 7–10 design standards. The seismic assessment was carried out by utilizing nonlinear time history analysis for all of the buildings with various shear wall positions. The findings of the study show that the position of the shear wall has a substantial impact on the seismic response. Finally, building layouts with the shear wall on the inside outperform those with the shear wall on the outside by 50% in seismic response. This 50% reduction may result in a low-cost earthquake design.
Titiksh G et al. [2] investigated G+10 buildings with and without shear walls. Three of the four cases are buildings with a shear wall, while the fourth is a building without a shear wall. ETABS was used to do the analysis. The structure was constructed to withstand gravity loads and lateral force in accordance with Indian requirements. When all four cases were compared, the shear wall at the inner core box type wall was found to be the most effective. Finally, by comparing all four situations, the best position was discovered by shear.

Kim et al. [3] proposed an efficient method for a three-dimensional high-rise building with shear walls Three-dimensional mega elements for walls and floor slabs were created to reduce modeling and analysis time, and a substructure was generated by assembling the super elements. Static and dynamic analyses of example structures with various types of openings have been performed to test the productivity and correctness of the proposed method. They concluded that the proposed method is very effective for performing a quick and accurate analysis of high-rise structural components while requiring minimal computational time and memory.

Shaik Akhil Ahamad et al. [4] developed a way for determining the best position for a G+20 structure with and without a shear wall the reason for adding a shear wall is to stiffen the structure and make it even more resistant to lateral forces. ETS response spectrum analysis was used to determine storey drift, base shear, permissible displacement, and torsion irregularity for all of the models. In this project, a dynamic analysis was performed on type -III (soft soil) for an irregular structure in plan in all zones as specified, and it was determined that the structure with symmetrically placed shear walls will outperform structures without shear walls and structures with shear walls at one end in terms of all seismic parameters.

Erol Kalkan et al.[5] investigates a performance-based design methodology to meet seismic requirements Nonlinear static procedures (NSPs) are getting more and more common to predict seismic demands in structural components. According to the study's findings, the Adaptive Modal Combination procedure predicted peak response measures such as inter-story drift and component plastic rotations more consistently than the other NSPs studied. This paper also discusses the uniqueness of several nonlinear static procedures, as well as predicting the character of steel and concrete by comparing responses obtained from a comprehensive set of nonlinear time history analyses.
Rajiv Banerjee et al [6] looked at the best location for a shear wall in a building with an uneven shape and torsion. A total of ten different models were investigated, with shear walls placed in ten different locations throughout the structure. Each has its own distinct personality. Finally, confirming that the centre of stiffness and the centre of mass are aligned lowers torsion in the structure. Finally, the structure will be capable of withstanding earthquake forces.

Suresh M R et al [7] exact location of a shear wall in a G+ 20 tall building was investigated. The primary objective of this study is to determine the most effective, efficient, and optimum location of shear walls in a high rise irregular R.C structure. Shear walls have a high impact stiffness and strength, allowing them to withstand both gravity loads and lateral loads due to earthquakes and wind. To determine base shear, equivalent static analysis is used in this study. Eventually, the building with shear wall would increase the strength and stiffness of the building; additionally, the plan without shear wall would produce more displacement and drift when compared to the plan with shear wall.

Mrs.Manjula Bidari et al [8] studied optimum location of shear wall for G+12 building. Four distinct models were considered, three with shear walls and one without; these entire shear walls were preserved at the core, corner, and perimeter. According to IS 875 Part 3, live loads, dead loads, and wind loads are all analyzed. The load combinations are based on Indian regulations. Frequency, Time period, storey drift ratio, and base shear were all observed and reported for each model. If not placed correctly, the existence of a shear wall can be considered a dead load. Shear walls, in general, increase the building's strength and stiffness. Conclusion: Keeping shear walls at the building’s periphery reduce wind response in the x direction.

Bibek Baral et al [9] investigated on lateral load resisting technique for high rise building using shear wall. As we all know, shear wall systems always produce good strength and stiffness for a structure. To determine the best location for a multi-story building, a G+7-story building with a shear wall in six different positions was considered. Earthquake load is calculated in accordance with IS: 1893-2002 (Part-1). ETABS was used to create the model. The following parameters were discovered in IS1893, such as the response reduction factor, importance factor, and zone factor.

Balaji U et al [10] investigated G+13 residential building. ETABS was used to design the structure. The static and dynamic analyses are performed with the assumption that the materials are linear and the soil condition is Type II. This nonlinear analysis takes into account effective seismic zones. Different responses, such as displacement and base shear, were computed. Finally, changes in building height may cause displacement to increase.

Anirudh Gottala et al [11] evaluated the static and dynamic behavior of a G+9 multistory building. Seismic analyses are performed using both static (seismic co-efficient method) and dynamic (response spectrum method). The following building parameters have been determined by the end of this analysis: axial force, bending moment, displacement, torsion, nodal displacement, beam and column end forces, and so on. Finally, the moments obtained from dynamic analysis are 35 to 45 percent greater than those obtained from static analysis, and the static column torsion value is negative, whereas the dynamic column torsion value is positive.

The software used for this analysis is called Seismostruct. The building was originally designed in STAAD Pro and then sent to Seismostruct. This software is used for research and academic projects in 110 countries around the world. Adaptive pushover analysis, pushover analysis, eigen value analysis, static and dynamic time history analysis, increment dynamic analysis, and buckling analysis are all performed with this software. Finally, Seismostruct helps and contributes to the ongoing search for greater mitigation of the dangers associated with earthquakes to mankind, no matter how meagerly, by providing a full range of earthquake engineering tools and methods that feature not only technical excellence, but also reliability and comfort of use.
Using Simostruct, 13 models with a bare frame model and a different location for the shear wall have been analyzed. Afterwards, the needed results were taken from STAAD-PRO and fed into Seismostruct. Pre-processing in Seismostruct was completed and final results taken from post-processing. Top displacements were noted as a result.

1.2 Scope of the work

Earthquakes are a sensitive issue in society, and many studies have been conducted to save people by building structures that are resistant to lateral force. Many papers contend that shear walls are one of the best solutions for lateral force resistance. The location of shear walls in high-rise buildings is not critical, the manner in which they are placed is important. Shear walls can be found in two places in a structure: the inner core and the outer edges. Many papers and works are created for the inner core, but far fewer are created for the outer periphery. This paper will go into detail about which location is best for providing shear walls in the outer periphery.

2. Methodology

2.1 Modeling of the 3D structure

According to the earthquake resistance design criteria, a residential building (G+6) is taken with area of 700 sqm. Size of each panel is 5m X 4m. Staad-pro was used to analyze the building, and the maximum lateral force was measured for each model. In Staad Pro, the load was applied and the building was designed after completing the geometry. Out of the 14 models analyzed, 13 have shear walls at different locations [Table2] the other is a bare frame (without a shear wall). It will be sent to seismostruct for further analysis. The two major divisions of seismostruct are preprocessor and postprocessor. In the preprocessor, initial steps include material selection, section properties, elements classes, nodes, element connectivity, constraints, restraints, loading phases, displacement targets, code-based checks, and analysis output. Post processing will produce eigenvalue results, displacement targets, step output, distorted shapes, action effect diagrams, and element action results.

2.2 Pushover Analysis

Initially, eigen value analysis is used to determine the time period and mode. After determining the mode and time period, the same building is subjected to pushover analysis. To perform push over analysis, three critical steps must be completed [14]. At first, we assumed that the force-displacement relationship was nonlinear. Yield strength, post-yield stiffness, and stiffness degradation are all included. The second step is to compute target displacement. The third step is to choose a reasonable load pattern and push the structure under that load pattern. In this case, the load pattern increases gradually until it reaches the desired displacement [13]. When a structural member begins to yield, its stiffness is adjusted until the roof displacement reaches the target displacement or the structure collapses. At this point, the seismic performance of the structure is determined.

Due to the lack of a theoretical foundation, pushover analysis relies on basic assumptions.

- The response of this analysis is controlled by a single degree of freedom.
- Throughout time history response, the shape vector remains constant.

2.3 Shear wall

Shear walls, in addition to slabs, beams, and columns, are common features of reinforced concrete (RC) buildings. These walls typically begin at the foundation level and continue all the way up the building's height. Their thickness can range from 150mm to 400mm [Table1] in high-rise buildings. Reinforced concrete shear walls provide strength and stiffness to buildings in the direction of their orientation, which significantly reduces lateral sway of the building and, as a result, damage to the structure and its contents. Because shear walls carry large horizontal earthquake forces, their overturning effects are significant. To reduce the negative effects of twisting in buildings, shear walls must be symmetrically located in plan. They could be arranged symmetrically in either or both directions.

3. Results and discussion

In this paper, a study is conducted for a G+6 residential building, and base shear is calculated using pushover analysis. Table [1] provides a detailed list of the building's specifications. A final curve was drawn between base shear and drift for all 14 models. Out of which PushSW6 bears maximum shear. The model carries more shear than others. As a result, PushSW6 takes 75% more shear than Push WSW. When shear walls are placed in the correct location, they add strength to the building; otherwise they are just dead weight. The building without shear wall gives more displacement and more drift compare to plan with shear wall along two edges.

The distance between two consecutive floors divided by the height of the floor is known as storey drift. Based on the results of this research, the top displacements were translated into storey drift by dividing their height. The storey drift was determined for each model, and a capacity curve was created between the base shear and storey drift. Figure 3 shows the link between base shear and drift ratio.

As the shear wall moves away from the centre of gravity, its shear bearing capacity decreases. As a result, the centre of gravity is crucial. There are a total of 13 models with shear walls that have been studied. Only four of the thirteen types have two shear walls, with the other nine models having four. Two shear walls may be seen in the following figures: Fig. 5, Fig. 7, Fig. 9, and Fig. 11. Shear walls are shown in Fig. 5 in longitudinal orientation, with the building's centre at the outside edge. Furthermore, because it has shear walls in the centre of the buildings, the percentage variation is determined using Fig. 5 as the origin. The 3Dview in Fig. 6 clearly shows that the design in Fig. 5 is strong enough to withstand 17980kN base shear [8].

The other two cases, Figs. 9 and 11, perform worse in terms of shear resistance. In both cases, the shear resist ance capacity is reduced by 9.454% and 15.44%, respectively. The reason behind the centres of mass and stiff ness do not coincide [6].

The shapes of the following figures contain four shear walls. Nine distinct models with four shear walls are illustrated in Figs. 3, 13, 15, 17, 19, 21, 23, 25, and 27 and 17250kN is the maximum shear resistance capacity of PushSW1.

The shear resistance capacities of the models PushSW6, PushSW7, PushSW8, and PushSW10 depicted in Figs. 13, 15, 19, and 21 are 19131kN, 18081kN, 18275kN, and 17512kN, respectively. In comparison to PushSW1, the aforementioned four models continue to gain strength. According to the data presented previously, PushSW6 (Figure 13) performs the best among the four models. It can withstand 10.904% greater shear than PushSW1 (Fig. 3). In this case (PushSW6), two shear walls are located along the longitudinal axis, while the other two are located along the transverse axis. This configuration of shear wall [6] may be the primary cause of the excellent performance. Model PushSW10 (Figure 21) has demonstrated the smallest increase of the four. Figure 22 depicts a 3D view of PushSW10 Compared to PushSW1; the strength increase is only 1.54 percent greater. The strength of PushSW7 and PushSW9 will increase by 4.81 and 5.94 %, respectively, when compared to PushSW1.

Figs. 17, 23, 25, and 27 depict the PushSW8, PushSW11, PushSW12, and PushSW13 models, and their shear resistance capacities are 15110kN, 16570kN, 16704kN, and 15169kN, respectively. In comparison to PushSW1, the above four models continue to lose strength. Because PushSW1 is the progenitor of four-shear wall models. Figures 17 and 27 perform the worst in comparison to Figure 3. The decrement in strength for these two instances is nearly identical, hovering around 12.2% [Table3 of PushSW1]. Figures 9, 12, 13, and 14 depict 3D views of the four preceding models. When compared to PushSW1, Figs. 23 and 25 indicate a moderate decrease of approximately 3.5%.

The PushWSW model shown in [Fig. 29] was created without a shear wall. The 3D view of Figure 29 is depicted in Figure 30. Using this model as a base, the percentage variation of shear carrying capacities of other models is calculated. PushSW1[Fig. 3], PushSW2[Fig. 5], PushSW3[Fig. 7], PushSW4[Fig. 9], and PushSW5[Fig. 11] can withstand 17250kN, 1790kN, 18023kN, 16280kN, 15204kN, and 19131kN base shear and have shear carrying capacities of 59.29%, 66.03%, 66.43%, 50.34%, and 40.40%, respectively, in comparison with the PushWSW. The model without a shear wall has the lowest shear resistance capacity, which is 10829kN.

PushSW7, PushSW8, PushSW9, PushSW10, PushSW11, PushSW12 and PushSW13 can withstand 18081kN, 15110kN, 18275kN, 17512kN, 1657kN, 16704kN, and 15169kN base shear and have 66.97%, 39.53%, 68.75%, 61.71%, 53.03%, 54.25%, and 40.08% [Table3] higher strength than Push WSW.

All the models' graphs between modes and time periods are shown in Fig. 31. From the Fig.31, PushSW8 has the longest time period (2.375 seconds) and PushSW1 has the shortest time period (0.4551 seconds).

When it comes to base shear strength, PushSW6 has 76.67% more strength, while PushSW8 has 39.53% less strength and can only withstand base shear of 15110kN, according to Fig. 32.

4. Conclusions

The G+6 building was used in this study, and it was studied with a shear wall using pushover analysis with 13 distinct models. The STAAD PRO and SEISMOSTRUCT are the software's were used to do all analysis. Ultimately, the optimum location was discovered by keeping shear resistance capacity as a key factor. The following are the findings of this study.

(i) The building with a shear wall in two directions produces more displacement and drift than the building with a shear wall on four sides. The provision of a shear wall along four edges can reduce storey displacement and storey shear, as well as increase strength and stiffness of the structure.

(ii) The shear wall is positioned along four of the edges (5m from the x-axis, two walls on opposite ends of the periphery in long directions, two in short directions) is considered the best position for the shear wall and PushSW6 outperforms all 13 models. When compared to the bare frame model Push WSW, it has 76.67 % more strength and can withstand base shear of 19131kN.

(iii) PushSW5, PushSW8, and PushSW13 are three model shear walls that have been placed near the corner. As a result, the aforementioned models are weaker than the remaining models. Based on the observations above, the centre of mass and stiffness may not have been as close as they could have been. This could explain why the models mentioned above are weaker. When comparing the above three models to PushSW6 (highest strength), the approximate strength decrements are 47%.

(iv) Push SW8 lags behind all 13 models. When compared to the PushSW6 model, it has 57% less strength and it can withstand base shear of 15110kN.

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Ethics declarations

Conflict of interest

The authors have not disclosed any competing interests.

Author Contribution

RMS: Conceptualized the presented idea, derived the methodology interpretation of results, writing original draft.

SS: Designed and performed the experiments, analyses the data and contributed to the final version of the manuscript.

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