Analysis of Irregular High-rise Building Using Shear Walls At Different Locations

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Abstract- In the past sufficient amount of research was conducted on Analysis of building with and without shear wall. However very little work is found related to Analysis of irregular high rise building with shear walls at different locations. It is relevant that high rise building are increasing day by day hence its study is necessary for development point of view. So we thought to use Staad Pro V8i to analyze the certain irregular high rise building by changing the location of shear wall and see what the effects on structure are? The present work contains the experimental investigation on reducing the size of the member to make structure economical and efficient by locating shear wall at varying places in irregular shape building. The usefulness of shear walls in the structural planning of multistory buildings has long been recognized. When walls are situated in advantageous positions in a building, they can be very efficient in resisting lateral loads originating from wind or earthquakes. Reinforced concrete framed buildings are adequate for resisting both vertical and horizontal loads acting on them. Extensive research has been done in the design and analysis of shear wall high-rise buildings. However, significance of shear wall in high-rise irregular structures is not much discussed in literature. A study on an irregular high-rise building with shear wall and without shear wall was studied to understand the lateral loads, bending moment, shear effects.

I. INTRODUCTION

The tallness of a building is relative and cannot be defined in absolute terms either in relation to height or the number of stories. But, from a structural engineer's point of view the high rise building can be defined as one that, by virtue of its height, is affected by lateral forces due to wind or earthquake or both to an extent that they play an important role in the structural design. Shear walls are a sort of structural system that has lateral resistance to the building or structure. They are vertical components of the structure i.e. the horizontal force resisting system. They are made to counteract the result of lateral masses engaged on the structure. In residential construction, shear walls are straight external walls that usually provide all of the lateral support for the building. The design approach adopted in the Indian Code IS 1893(Part I): 2002 ‘Criteria for Earthquake Resistant Design Of Structures’ is to ensure that structures possess at least a minimum strength to withstand minor earthquake occurring frequently, without damage; resist moderate earthquakes without significant structural damage though some non-structural damage may occur; and aims that structures withstand major earthquake without collapse. Reinforced concrete (RC) buildings often have vertical plate-like RC walls called Shear Walls (Figure 1.1) in addition to slabs, beams and columns. These walls generally start at foundation level and are continuous throughout the building height. Their thickness can be as low as 150mm, or as high as 400mm in high rise buildings. Shear walls are usually provided along both length and width of buildings. Shear walls are like vertically-oriented wide beams that carry earthquake loads downwards to the foundation. Shear walls in high seismic regions require special detailing. Shear wall buildings are a popular choice in many earthquake prone countries, like Chile, New Zealand and USA. Shear walls are easy to construct, because reinforcement detailing of
walls is relatively straight-forward and therefore easily implemented at site. Shear walls are efficient, both in terms of construction cost and effectiveness in minimizing earthquake damage in structural and nonstructural elements.

![Fig 1.1: Building with shear wall.](image)

### II. LITERATURE REVIEW

[1] Asnhuman et al., (2011) - They have conducted study on research on lateral-load resisting system in high rise building. From the study, it was observed that shear wall was very high-in plane stiffness and strength, which can resist large horizontal loads and support gravity loads. Solution for shear wall location in multi-storey building based on its both elastic and elasto-plastic behaviors was determined. Earthquake load was calculated and applied to building of 15 stories located in zone IV. Elastic and elasto-plastic analysis was performed using both STAAD pro 2004 and SAP V 10.0.5 (2000) software package. Parameters like shear forces, bending moment and storey drift were computed in both the cases and also for different location of shear wall. Dead load and live load have been taken as per IS 875 (part 1) (1987) and IS 875 (part 2) (1987). Results showed that the top deflection had been exceeded the permissible deflection, i.e. 0.004 times the total height of building, [IS 1893 (part 1) (2002)]. Load combination was 1.5 (DL + EQ) and (0.9DL + 1.5 EQ). Study concluded that, the top deflection was reduced and reached within the permissible deflection after providing the shear wall in any of the 6 - 7 frames and 1 - 12 frames in the shorter direction.

[2] Shaik and Vinod (2013) - They have conducted the study on Seismic performance evaluation of multistoried R.C framed building with shear wall. The elastic as well as in-elastic analysis were carried out for the evaluation of seismic performance on 6,12,24 and 36 storied moment resisting R.C. framed building using E TAB software. Eight models were prepared for each type of storey with plan area of 30m x 20m and height of 3m. Approximate method was used for lateral static and dynamic analysis of wall frame based on the continuum approach and one dimensional finite element method. Structure was analyzed for various load combination as per IS 1893(part-1)-2002 for seismic zone. Capacity curve was drawn based on load deformation responses. Result showed that the storey displacement for 6 and 12 storey building behave like shear building due to less height, while 24 and 36 storey building exhibit flexural behavior as grater height than lateral dimension. Non- linear static pushover analysis showed that lateral stiffness has the least value for the model without shear wall and also influence of shear wall was quite large for shorter building. Study concluded that provision of shear wall symmetrically in the outer most moment resisting frames give better performance for regular shape building.
[3]. Chandurkar and Pajgade (2013) - They conducted a study on seismic analysis of RCC building with and without shear wall using software ETAB v 9.5.0. They compared parameters like lateral displacement, story drift and cost required for economy and effectiveness of shear wall. 10 story building model with 3m height for each story was studied on the software. The buildings were assumed to be fixed at the base. Four models were prepared and the models were, Model 1 was bare framed structure, Model 2 was dual system with shear wall one on each side, Model 3 was with shear wall on corner with L=4.5m and Model 4 was with shear wall on corner with L=2m. The analysis was done for zone II, III, IV and V. The results obtained were: displacement of all models for zone II, III, IV was reduced upto 40% as compared to zone V. Story drift was maximum for Model 1 whereas it was minimum for Model 3. The corner shear wall in 2m was economical among all models. Quantity of concrete was more for model 3. After analysis it was concluded that shear wall was effective for buildings with 10+ storey and it was not effective for buildings below 10 stories. Also shear wall was proved to be effective and economical at adequate locations only.

[4]. Chaitanya and Lute (2013) - They have studied the G+11 storey residential building with precast reinforced concrete load bearing wall. This study analyzed load bearing wall and one way slab for gravity and lateral load using ETABS software. Analysis was done for various wall forces, displacement and moment which had been work out for different load combination. G+11 storey shear wall building was considered for one acre of site with 350 units. Around 400 sqft of carpet area per unit was taken with 300 units per floor. Technology used was total precast solution with load bearing RCC shear walls and slabs and the modelling was done in ETABS. Shear wall structure having G+11 storey was analyzed for gravity and lateral loads. The parameters like axil force, out of plane moments, lateral loads, shear force, storey drift, storey shear and tensile forces were observed for different stories. Results showed that the variation of axial force with stories was linear and the difference in maximum axial force between storey 11 and 12 was 7.26 %. Study concluded that the variation of lateral loads with stories was non-linear, the difference in maximum lateral loads between storey 11 and 12 was 0.54 % and the variation in shear force with stories was non- linear and the difference in maximum shear force between storey 11 and 12 was 19.98 %.

[5]. Lakshmi et al.,(2014) - They have studied the performance of the structures under frequently occurring earthquake ground motion resulting in structural damage as well as failure have repeatedly demonstrated the seismic vulnerability of existing buildings, due to their design based on gravity loads only or inadequate level of lateral load. The method was important to ensure strength and stability. The comparison of various parameter such as storey drift, storey shear, deflection, reinforcement requirement in columns etc., of a building under lateral loads based on strategic position of shear wall studied were carried out. The ETABS 9.5 and SAP 2000. V.14.1 were used for analysis. The finite element analysis software ETABS9 9.5 was used to create the 3-D model and run the linear static and dynamic analyses and pushover analysis was done in SAP 2000.V.14.1. Eight different models were considered. Result showed that base shear was the maximum expected lateral force that will occur due to seismic ground motion at the base of structure. Study conclude in medium high rise building ( ie >10storeys) provision of shear wall was founding to be effective in enhancing the overall seismic capacity characteristics of the structure. Study also concludes that maximum reduction in drift value was obtained when shear walls were provided at corners of the building.

[6]. Aainawala and Pajgade (2014) - They have performed analysis on building with and without shear wall using E TAB v9.0.7 software. Models were prepared for G+12, G+25 and G+38 located in zone 2, 3, 4 and 5 with square plan area of 16m x 16m and 3.5m height. Structure without shear wall were heavy
due to large beam and column size and become uneconomical. The building was assumed to be fixed at the base and the floors act as rigid diaphragms. The section dimension of structural elements are changed for different buildings. Displacement curve and storey drift curve was drawn of all the model for different earthquake zone. Quantity of material required for each type of model was calculated and dynamic analysis was carried out. Result showed that displacement and drift in model 3(shear wall at corner) is less as compared to other model which is within limit as per I.S.1893 (part 1):2000. Also the cost required in model 3 is comparatively less than other model in all zones. Study concluded that size of the member like column can be reduced with shear wall so less obstruction will be there because of reduced size of members. Variation in column size at different floors in model 1 affects the storey drift while in case of model 3 it doesn’t due to presence of shear wall.

![Fig 2.1: Displacement of curve for zone 5](image)

[7]. Tarun shrivastava et al., (2015) - They have conducted the study on effectiveness of shear wall frame structure subjected to wind loading in multi-storey building. Different cases were prepared with different configuration of shear wall. Frames of 8 storey R.C.C. structure in medium soil with a ground plan of 20m x 18m and height of the structure is 25.6m. Assuming wind pressure of 1.5 KN/m² and special moment resisting frame, analysis was carried out with shear wall at different location for regular shape building. Various parameters such as lateral deformation, storey drift index, maximum bending moment and shear force were calculated. Result showed that model 3 with core shear wall case is most suitable as moment percentage of moment and shear force resisted by shear wall in this case is 93.2% and 98% which was much greater than other cases. Also model 3 is stiffer against lateral loads. Study concluded that effectiveness of shear wall was not helping too much in reducing the base shear but providing more lateral stiffness and taking maximum share of the moment.

[8]. Mohd et al., (2015) - They have studied the G+15 building structure by using STAAD Pro vi8 software in different zones. This study included the main consideration factor which affects the structure to perform poorly during earthquake, in order to achieve the appropriate behavior during future earthquake. IS code 1893(Part 1):2002 was used for seismic analysis. A comparatively analysis was done on base shear, displacement, axial load , moment in Y and Z direction in column and shear force , maximum bending moment and maximum torsion in beam. Modeling was done using STAAD Pro vi8 software. Thirteen models were prepared by using Indian code. Models included bare frame, frames with shear wall and frames with bracing. Lateral seismic force and load combination was applied to the models and analysis of models were done. A G+15 building structure was analyzed and compared with shear wall and three different patterns of bracing with three different positioning of it during the earthquake considering all the
four zones. Parameters like displacement, axial force, bending moment for column and shear, moment, torsion for beam were calculated. Study concluded that shear wall was very efficient in case of earthquake to reduced lateral displacement of frame and horizontal deflection induce in shear wall and location of shear wall and brace member has significant effect on the seismic response than the plane frame. Study also concluded that, shear wall construction will provide large stiffness to the building by reducing the damage to the structure.

Vaidya (2015) - They has studied the seismic analysis of building with shear wall on sloping ground. Behavior of shear wall at various positions in a building on sloping ground was considered in this study. Four mathematical models was analyzed by using finite element software SAP 2000. Model 1 was frame type structural system and other three models were dual type i.e. shear wall frame interaction structural system with three different positions of shear wall. Analysis was done on G+7 residential building situated in seismic zone IV. In Model 2 four walls were provided towards the shorter column on corner, in Model 3 walls were provided towards longer column of the building and Model 4 was arranged symmetrically in plan. Response spectrum was carried out as per IS 1893:2002(Part I). After analysis comparison was done for the effect of displacement, storey drift and forces. Study concluded that displacement was found to be minimum in Model 3 in which shear wall was provided towards long column side and the reduction was upto 43.62% as compared to other models. Story drift was minimum for Model 3 along sloping side. In case of maximum forces, model 2 showed minimum shear force but torsional force was maximum whereas shear force was maximum for Model 3. After analysis study also concluded that the shear wall location was found to be more effective towards shorter column as compared to other locations.

Ali et al., (2015) - They studied that 2005 earthquake brought vast destruction in Pakistan which resulted in revision of building code of Pakistan (BCP). Also studied that the inclusion of shear wall adds stiffness to structure and aids in lateral drift under seismic load. Comparative study was carried out using ETABS software by varying location and cross section shear wall for stock exchange building, Islamabad. Important parameter was considered like maximum storey drift, storey drift, base shear forces and time period of structure. Response spectrum analysis has been carried out on 4 cases depending upon location of shear wall and best possible case was selected which is finally compared with actual building. Result showed that maximum lateral displacement for model 2 was minimum as compared to original building and other model i.e. 34.8mm. Study concluded that change location 2 was most efficient for locating shear wall and resulting in 26.4% reduction in base shear as compared to original building.

III. METHODOLOGY

Shaik and Vinod (2013) - The frame elements were modelled as beam elements. The masonry infill was modelled as quadrilateral shell element (with in-plane stiffness) of uniform thickness of 0.23mm. The nonlinear properties for columns were assumed to be a plastic P-M-M hinge and for the beams as plastic moment hinge. The plastic hinges were defined according FEMA 356 with the designed rebar distribution. The shear walls were modelled with Mid-Pier frame elements with P-M-M Interaction hinge. The results of different models were compared in terms of overall behavior of the structural systems. The slab is modelled as rigid (in-plane) diaphragm. The load deformation responses of the numerical models were followed through to collapse by means of the capacity curve. The nonlinear static Pushover analysis was performed for RC frame building with masonry infill and shear walls. The software, ETABS [CSI, 2004] was used for the elastic analysis using response spectrum approach and to perform pushover analysis.
[3]. Chandurkar and Pajgade (2013) - For the study, a 10-story building with a 3-meters height for each story, regular in plan was modeled. These buildings were designed in compliance to the Indian Code of Practice for Seismic Resistant Design of Buildings. The buildings were assumed to be fixed at the base and the floors act as rigid diaphragms. The sections of structural elements were square and rectangular and their dimensions were changed for different building. Storey heights of buildings were assumed to be constant including the ground storey. The buildings were modeled using software ETAB Nonlinear v 9.5.0. Four different models were studied with different positioning of shear wall in building. Models were studied in all four zones comparing lateral displacement, story drift, % $A_{st}$ in column, concrete quantity required, steel and total cost required in all zones for all models.

[6]. Aainawala and Pajgade (2014) - For the study, a G+12, G+25, G+38 building with 3.5 meters height for each storey, regular in plan was modeled. This building consists of four spans of 5 meter, 3 meter, 3 meter and 5 meter in X direction and in Y direction as shown in figure 2. The square plan of all buildings measures 16m x 16m. Shear walls were modeled using three different positions. These buildings were designed in compliance to the Indian Code of Practice for Seismic Resistant Design of Buildings. The buildings was assumed to be fixed at the base. The buildings were modeled using software ETAB Nonlinear v 9.0.7 four different models were studied with different positioning of shear wall in different zones and for various heights to find out the best location of shear wall in buildings. Models were studied and dynamic analysis was performed for G+ 38 models in all the four zones comparing the lateral displacement, storey drift, concrete quantity required, steel and total cost required in all the zones.

[9]. Vaidya (2015) - Building was modelled by using finite element software SAP 2000. Beams and columns were modelled as two nodded beam element with six DOF at each node. Slab and shear wall was modelled by using shell element. Walls were modelled by equivalent strut approach. The thickness of strut was same as thickness of brick infill wall and only width of the strut was derived. Four models for the building were prepared. Model one was of frame type structural system and other three models were of shear wall frame interaction system. Total four shear walls were provided two on sloping side and other two on other side of the building. In model II all the four walls were provided towards the shorter columns of the building on corner, i.e. two on sloping side and two on other side. In model III all the four walls were provided towards the longer columns of the building. In model IV shear walls were arranged symmetrically in plan. Response spectrum analysis was carried out on the models as per IS 1893:2002 (Part I). Comparison between each of the following model was made based on analysis results and are presented in graphical format.

[10]. Ali et al., (2015) - The building was modeled in ETABS with following assumptions,
1. Floors and beams are modeled as rigid elements.
2. Slabs are modeled as shell elements.
3. Beam column joints are taken as rigid joints.
4. All supports are modeled as fixed supports.
5. The system was assumed to be linearly elastic.
6. For mass source 100 % D.L and 25% L.L is used. The mass is lumped at each story level.
IV. CONCLUSION

1. Top deflection was reduced and reached within the permissible deflection after providing the shear wall in shorter direction.
2. Shear wall symmetrically in the outer most moment resisting frames give better performance for regular shape building.
3. Size of the member like column can be reduced with shear wall so less obstruction will be there because of reduced size of members.
4. The shear wall location was found to be more effective towards shorter column as compared to other locations.
5. Shear wall at outer side was most efficient and resulting in 26.4% reduction in base shear as compared to original building.

REFERENCE