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RESEARCH ARTICLE

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EFFECT OF LOCATION AND OPENINGS IN SHEAR WALL ON BEHAVIOR OF STRUCTURAL FRAMES IN EARTHQUAKE PRONE REGIONS AND IN HIGH RISE BUILDING

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ABSTRACT

Shear walls are provided in high rise structures and structures located in higher seismic vulnerability areas. The primary purpose of shear wall is to resist lateral forces arising due to earthquake or wind. This project aims to study effect of location and openings in shear wall on behavior of structural frames. A RCC medium rise building of 10 stories with floor height 3m subjected to earthquake loading in Zone II,III,IV,V has been considered Significant outcome of the study includes shear wall at lift well location partially reduces displacement in X direction, Shear walls in X direction (case3) , on Periphery (case4) and additional shear wall in X direction (case5) greatly reduces displacement in X direction, shear walls in X direction only marginal contributes in the reduction of displacement in Z direction .However shear wall in Z direction as per case no.4 there is significant reduction in z direction. The displacement increases gradually from ground floor to top floor with increase in percentage of openings. If openings are required in shear wall detailed analysis of structure is essential as it may lead to erratic increase in forces on columns.

Keywords: Shear wall, Horizontal displacement, earthquake forces, moment

1. INTRODUCTION

Shear walls are vertical elements of the horizontal force resisting system. Shear walls are constructed to counter the effects of lateral load acting on a structure. In residential construction, shear walls are straight external walls that typically form a box which provides all of the lateral support for the building. When shear walls are designed and constructed properly, and they will have the strength and stiffness to resist the horizontal forces. In building construction, a rigid vertical diaphragm capable of transferring lateral forces from exterior walls, floors, and roofs to the ground foundation in a direction parallel to their planes. Examples are the reinforced concrete wall or vertical truss. Lateral forces caused by wind, earthquake, and uneven settlement loads, in addition to the weight of structure and occupants; create powerful twisting (torsion) forces. These forces can literally tear (shear) a building apart. Reinforcing a frame by attaching or placing a rigid wall inside it maintains the shape of the frame and prevents rotation at the joints. Shear walls are especially important in high-rise buildings subjected to lateral wind and seismic forces.

In the last two decades, shear walls became an important part of mid and high-rise residential buildings. As part of an earthquake resistant building design, these walls are placed in building plans reducing lateral displacements under earthquake loads. So shear-wall frame structures are obtained.

Shear wall buildings are usually regular in plan and in elevation. However, in some buildings, lower floors are used for commercial purposes and the buildings are characterized with larger plan dimensions at those floors. In other cases, there are setbacks at higher floor levels.

2. Brief literature Review

Shear wall is a structural element used to resist horizontal forces parallel to the plane of the wall [1]. Shear wall has highly in plane stiffness and strength which can be used to simultaneously resist large horizontal loads and support gravity loads. Shear Walls are specially designed structural walls include in the buildings to resist horizontal forces that are induces in the plane of the wall due to wind, earthquake and other forces. They are mainly flexural members and usually provided in high rise buildings to avoid the total collapse of the high rise buildings under seismic forces. In this project, study of 25 storey's building in zone V is presented with some investigation which is analyzed by changing various location of shear wall for determining parameters like storey drift, storey shear and displacement is done by using standard package ETAB. Creation of 3D building model for both linear static and linear dynamic method of analysis and influence of concrete core wall provided at the center of the building.

The results of a time history study for tall concrete buildings are presented in [2], addressing the effects of openings in concrete shear walls under near fault earthquake ground motions. A ten-story building was modeled with three different types of lateral resisting systems: complete shear walls, shear walls with square opening in the centre and shear wall with opening at right end side. Studied models were analyzed with nonlinear software under the two mentioned records. The results evaluated were time history of displacements and basal shears of the investigated models. Results of the analyses

showed a substantial decrease in terms of strength of the wall for shear walls with openings. In the model with opening at centre of the wall, maximum lateral displacement was up to 8% less than maximum lateral displacement of the model with opening at the right end side; while for the complete shear wall that decrease was up to 17% less. The investigated building shows a specific behavior of the openings, when compared with the complete wall case, which causes an increase in the time history of displacements. Finite element analyses of a panel with opening, showed a dramatic decline in ultimate force up to 54%. This study verified large lateral displacements and ductility for shear walls with openings in comparison with complete shear wall.

3. Findings of the Study

A RCC medium rise building of 10 stories subjected to earthquake loading in Zone V has been considered. In this regard, STAAD ProV8i software have been considered as tool to perform. Displacements, axial forces and bending moment have been calculated for six different column to find out the effect of location and openings in shear wall in the building. The plan of the building without shear wall as shown in Figure.1 has been considered to carry out the study. Eight different cases have been taken for analysis.

Case1-without shear wall
Case2-shear wall at lift well
Case3-shear wall parallel to X direction
Case4- Shear wall on the periphery
Case5- Additional Shear wall parallel to X direction
Case6 -25% opening in Shear Wall
Case7 -50% opening in Shear wall
Case 8- Shear Wall up to foundation

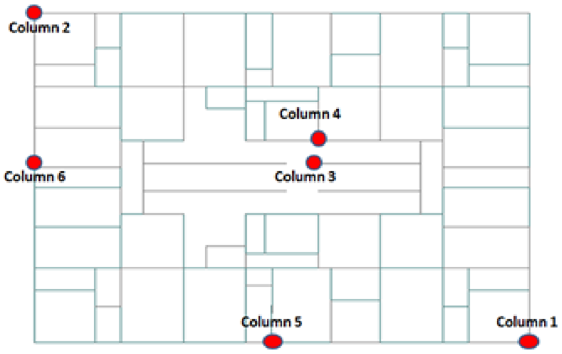
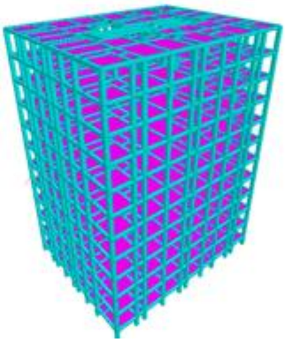
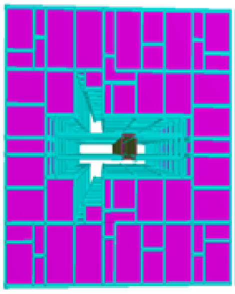


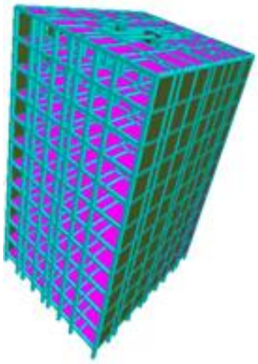
Fig. 1 Plan of the Building



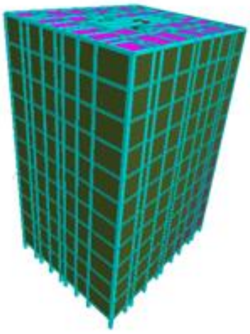
CASE 1- Without Shear wall



CASE 2- Shear wall at lift well

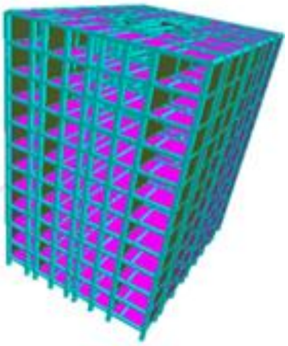


CASE 3- Shear wall parallel to X direction

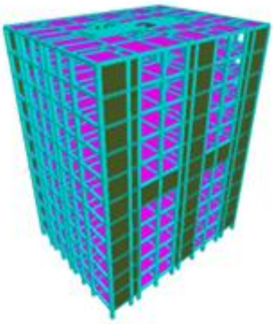


CASE 4- Shear wall on the periphery

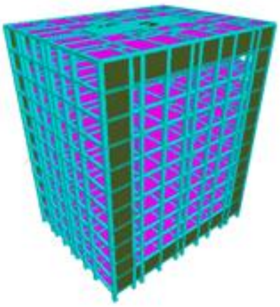
Loading consideration Dead Load (DL) and Live load (LL) have been taken. Seismic load calculation has been done based on the IS 1893 (Part 1) (2002)‟s approach. Load combination 1.5(DL+EQX) along X direction and 1.5(DL+EQZ) along Z direction has been consider.[5]



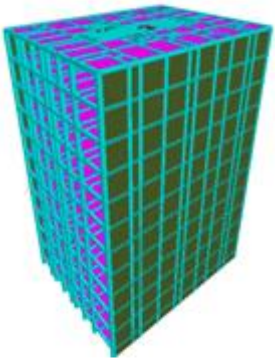
CASE 5- Additional Shear



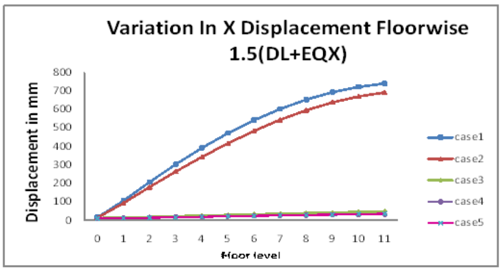
CASE 6-25% opening wall parallel to X direction in shear wall



CASE 7-50% opening in Shear wall



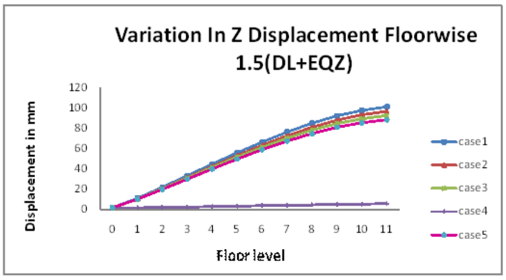
CASE 8- Shear Wall up to foundation



a) Column 1

Variation in Force Fx Floor wise

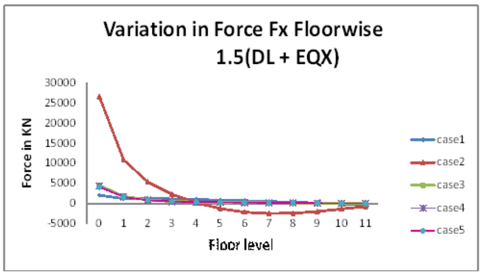
1.5(DL + EQX)



b)Column 1

variation in force fz floor wise

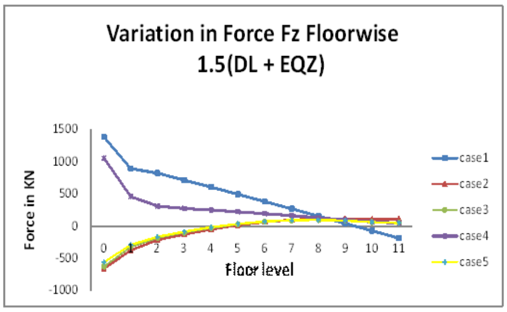
1.5(DL+EQZ)



c) Column 2

Variation in Moment Mx Floor wise

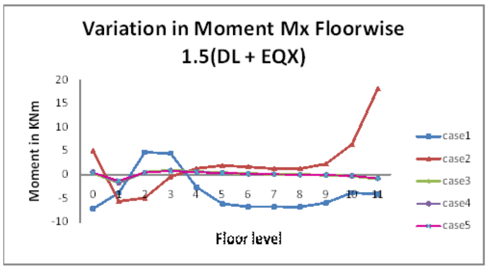
1.5(DL + EQX)



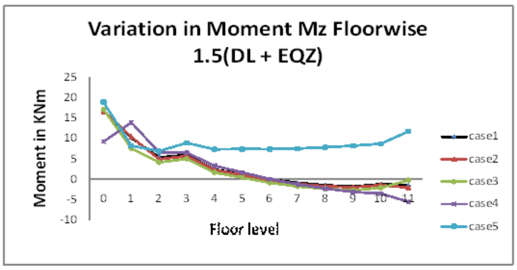
d) Column 2

Variation in Moment Mz Floor wise

1.5(DL + EQZ)

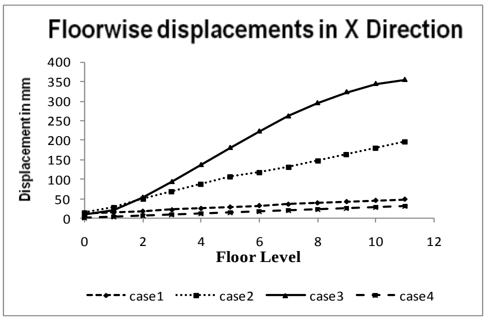


e) Column 3

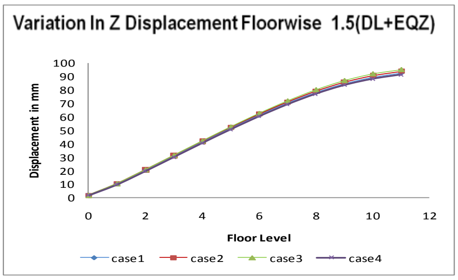


f) Column 3

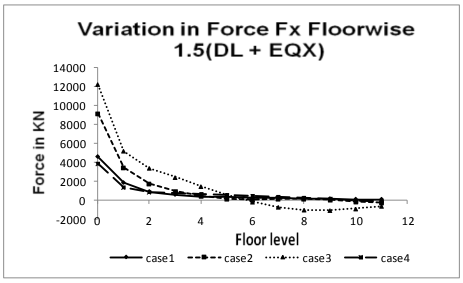
Fig. 2 Graphs corresponding to placement of shear wall



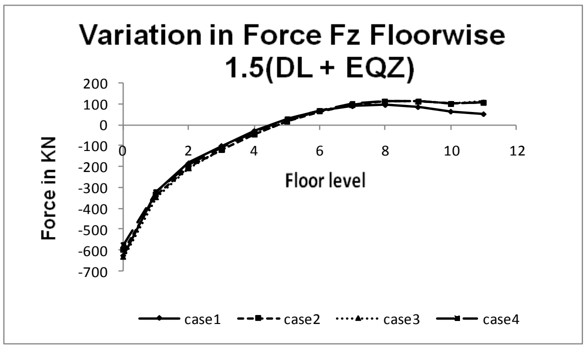
a) column 1



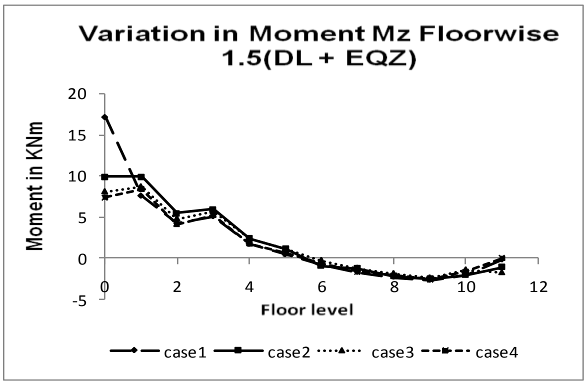
b) column 1



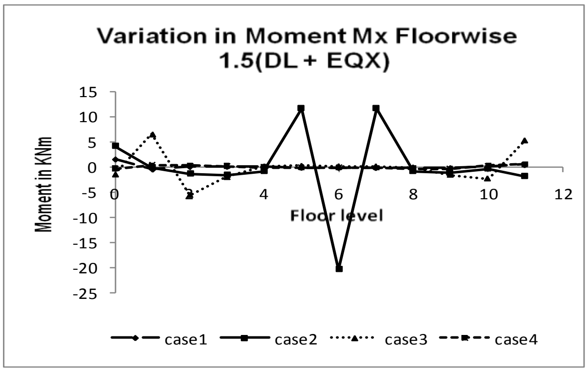
c) Column 2



b) Column 2



e) column 3



f) column 3

Architectural Aspects of Shear Walls

Most RC buildings with shear walls also have columns; these columns primarily carry gravity loads (i.e., those due to self-weight and contents of building). Shear walls provide large strength and stiffness to buildings in the direction of their orientation, which significantly reduces lateral sway of the building and thereby reduces damage to structure and its contents. Since shear walls carry large horizontal earthquake forces, the overturning effects on them are large. Thus, design of their foundations requires special attention. Shear walls should be provided along preferably both length and width. However, if they are provided along only one direction, a proper grid of beams and columns in the vertical plane (called a moment-resistant frame) must be provided along the other direction to resist strong earthquake effects.

Door or window openings can be provided in shear walls, but their size must be small to ensure least interruption to force flow through walls. Moreover, openings should be symmetrically located. Special design checks are required to ensure that the net cross-sectional area of a wall at an opening is sufficient to carry the horizontal earthquake force. Shear walls in buildings must be symmetrically located in plan to reduce ill-effects of twist in buildings (Figure 2). They could be placed symmetrically along one or both directions in plan. Shear walls are more effective when located along exterior perimeter of the building – such a layout increases resistance of the building to twisting.

Ductile Design of Shear Walls

Just like reinforced concrete (RC) beams and columns, RC shear walls also perform much better if designed to be ductile. Overall geometric proportions of the wall, types and amount of reinforcement, and connection with remaining elements in the building help in improving the ductility of walls. The Indian Standard Ductile Detailing Code for RC members (IS:13920-1993) provides special design guidelines for ductile detailing of shear walls.

Advantages of Shear Walls in RC Buildings

Properly designed and detailed buildings with shear walls have shown very good performance in past earthquakes. The overwhelming success of buildings with shear walls in resisting strong earthquakes is summarized in the quote:

"We cannot afford to build concrete buildings meant to resist severe earthquakes without shear walls.":: Mark Fintel, a noted consulting engineer in USA

Shear walls in high seismic regions require special detailing. However, in past earthquakes, even buildings with sufficient amount of walls that were not specially detailed for seismic performance (but had enough well-distributed reinforcement) were saved from collapse. 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 (like glass windows and building contents).

Reinforcement Bars in RC Walls: Steel reinforcing bars are to be provided in walls in regularly spaced vertical and horizontal grids (Figure 4a). The vertical and horizontal reinforcement in the wall can be placed in one or two parallel layers called curtains. Horizontal reinforcement needs to be anchored at the ends of walls. The minimum area of reinforcing steel to be provided is 0.0025 times the cross-sectional area, along each of the horizontal and vertical directions. This vertical reinforcement should be distributed uniformly across the wall cross-section.

General discussion

In this part, the seismic effectiveness of structural system will be explored. It should be investigated if the structure has enough level of ductility, as a seismic system, to satisfy the assumptions of the codes. Also, effective contribution of coupled walls, which essentially depends on the behavior of coupling elements (beams interconnecting main wall and sidewalls), is of the prime importance Effect of axial load on shear wall ductility

According to the design codes, shear walls cannot be used as both gravity and seismic bracing systems; fact, very tight criterions should be satisfied. A seismic bracing system, conceptually, should have a level of ductility; therefore the decrements of the bracing elements ductility under axial loads should be considered in conceptual design. In this tower, it seems that designer assumed main walls as a seismic bracing system and sidewalls to carry gravity loads. This tower has a considerable behavior complexity because of its especial geometric specifications such as high aspect ratio of sidewalls (about 9), especial architectural plan form and some unknown facts about coupled wall system behavior. To quantify effects on gravity load distribution due to mentioned facts, numerical models of the tower assuming different number of stories over the foundation were developed.

Based on analysis results, main walls bear about 35% up to 60% of gravity loads varying with the story (Figure 3). It seems usual for a designer, to have an unreasonable judgment about gravity load distribution in the tower for example “main walls are a seismic bracing system and sidewalls are gravity load bearing system”, but as it is mentioned above, not only main walls are assumed to carry seismic loads, but also they are going to bear a significant percentage of gravity loads.

Effective contribution of coupled walls via coupling beams Theoretical and experimental studies show that in coupled wall structures, plastic hinges are formed in the coupling elements before the walls yield and that such plasticization can substantially increase the ductility of the structures. Within certain limits, the earlier the beams start to yield, the greater will be the increase in ductility. However, if the beams yield prematurely, the lateral strength of the wall structures might be severely impaired and the ductility of the beams might become exhausted when the walls start yielding. Thus for best overall performance, the beams should yield well before the walls do but not at so early a stage as to cause excessive reduction in lateral strength or breakage of the beams before the wall fails. Despite the fact that coupling beams are assumed to be cracked prematurely in earthquake, this event might take place under permanent gravity loads as a result of concrete time dependency. According to above, some coupling beams, connecting main wall to sidewall, were found to be cracked (Figure 7). It can be concluded that coupling beams are plasticized under fixed moments due to non-uniform vertical displacement. Level of axial stresses associated with floor loads on sidewalls and main walls were the same (Figure 3) and only probable cause, might be time-dependent effects based on self-weight of walls. All of the walls have at least 0.7% of reinforcement so the shrinkage effect will be negligible. Tertiary Evaluation of time-dependent effects with consideration of construction sequence loading According to ACI-209, followings are the most important parameters that should be considered in creep analysis

A. Displacement in X direction for loading 1.5 (DL+EQX)

1. It is observed that the displacements are very large at all floors for frames without shear walls.
2. Shear wall at lift well location partially reduces displacement in X direction .
3. Shear walls in X direction (case3) , on periphery (case4) and additional shear wall in X direction (case5) greatly reduces displacement in X direction .
4. Shear walls along the buildings in X and Z direction as well as periphery reduces this displacement at top level of building roughly between 93 to 96 % .Provision of extra shear wall in X direction is found to be redundant from reduction in displacement in X direction

B. Displacement in Z direction for loading 1.5 (DL+EQZ)

1. Shear walls in X direction only marginally contributes in the reduction of displacement in Z direction .However shear wall in Z direction as per case no.4 there is significant reduction in displacement z direction.

C. Force in X direction for loading 1.5 (DL+EQX)

1. It is observed that the force gradually decreases from ground floor to top floor without shear wall (case1) and when shear wall is located at lift well (case2) .
2. Provision of shear wall in X direction (case3) ,on the periphery (case 4) and additional shear wall in x direction (case 5) there is significant reduction in forces occur .
3. When column at lift well is observed then forces gradually decreases from ground floor to top floor when shear wall is located at lift well (case2) and significant reduction in forces occur for all other cases .

D. Force in Z direction for loading 1.5 (DL+EQZ)

1. It is observed that the forces gradually decreases from ground floor to top floor for all the cases along Z direction but by provision of shear wall on periphery force reduces certainly from ground to top floor .

E. Moment in X direction for loading 1.5 (DL+EQX)

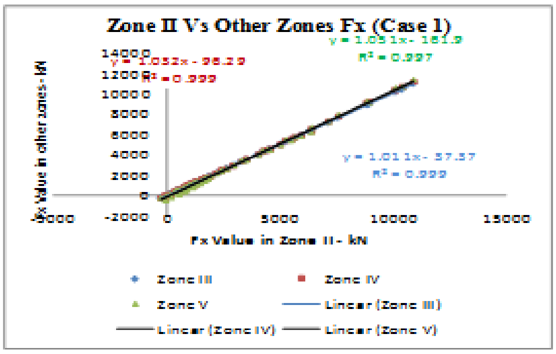
1. It is observed that torsion is negligible at all the floors without shear wall and by provision of shear wall (as per various cases) significant changes occurs.
2. When shear walls are provided in X direction sudden changes occurs in torsion , that is at ground floor it is very less , at intermediate floor very large and then suddenly decreases to zero at top floors .
3. When column at lift well is observed (for case 2) then sudden changes in torsion occurs .

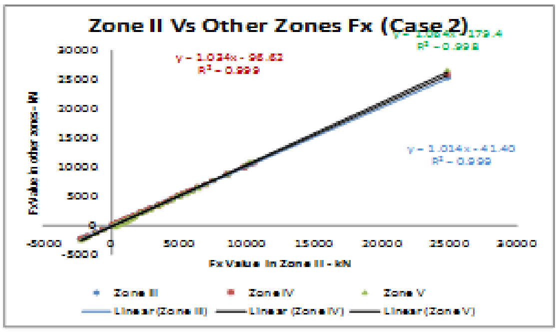
F. Moment in Z direction for loading 1.5 (DL+EQZ)

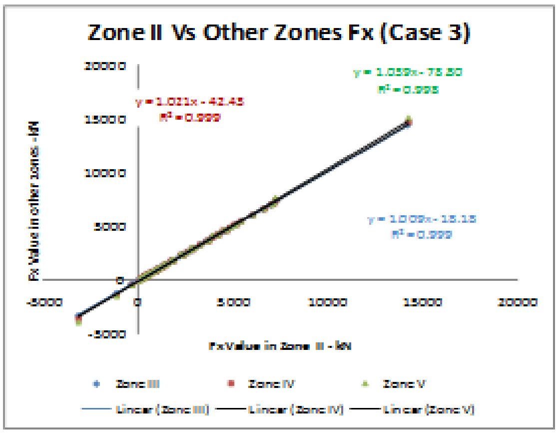
1. As we provide shear wall along X direction, torsion increases significantly along Z direction. When shear wall is provided on the periphery the torsion is very less at all the floors.
2. When column at lift well is observed (for case 2) then there is gradual decrease in torsion occur from bottom to top floor.
3. Development of Mathematical Models

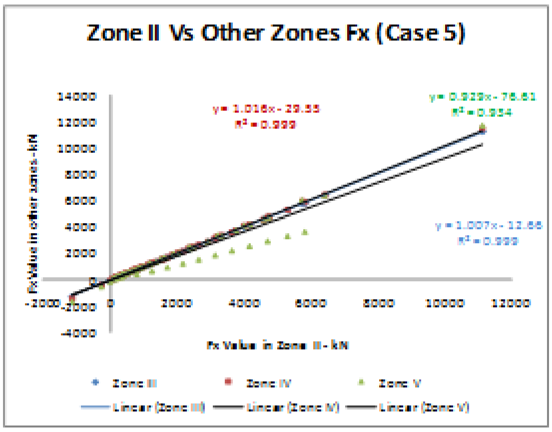
An attempt is made to determine relationship between parameters like displacements, forces, in various zones. Thus, data was compiled consisting of axial forces in all columns in zone II and similar data for zone III,IV,V the details are given in table no,5.103 to 5.108.

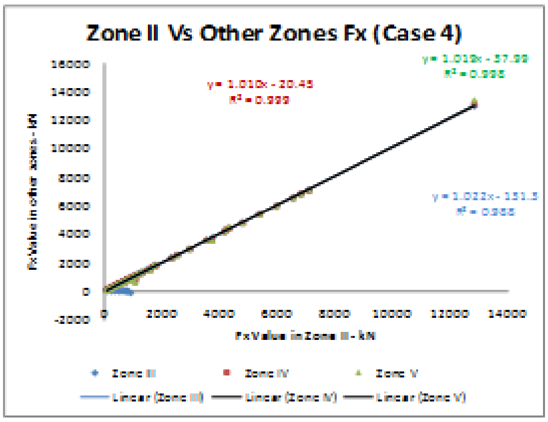
An attempt is also made to understand relationship between displacements in Z direction for the structure without shear wall with shear wall on all sides ,the relationship is demonstrated in the following figs.

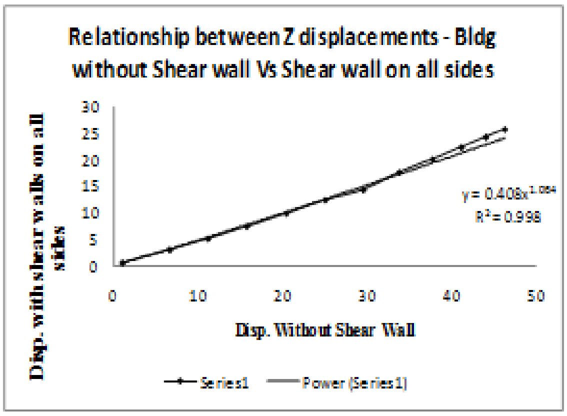












RC frame buildings with open first story's are known to perform poorly during in strong earthquake shaking .The large opening on the lowest floor causing the stiffness is relative low compare to the stiffness at the story above thus there is need of immediate measure to prevent to indiscrimate use of soft story in building which are design without regard to increase the displacement ,ductility and force demand in the first story this paper highlight the various factors which are responsible for failure of high rise building under seismic forces and also argues the importance of shear wall as a one of the efficient approach to eliminate seismic failure of soft story high rise building

This paper has tried to discuss various aspects regarding shear wall discussed by many of the investigators on adding shear wall to the building in different arrangement in order to reduce soft story effect on structural seismic response in earthquake excitation. It was found that location, number and curtailment of shear wall acts an important factor for the soft story structures to displace during earthquake.

From the review of literature its shows that use of shear wall is a good way to provide more level of ductility and getting more stable behavior and appear to be an novel approach to reduce effect of soft story in

Observations are as follows

1. It is observed that the displacements are very large at all floors for frames without shear walls.
2. Shear walls in X direction only marginal contributes in the reduction of displacement in Z direction. However shear wall in Z direction as per case no.4 there is significant reduction in z direction.
3. When column at lift well is observed then forces gradually decreases from ground floor to top floor when shear wall is located at lift well (case2) and significant reduction in forces occur for all other cases.
4. When shear walls are provided in X direction sudden changes occurs in torsion , that is at ground floor it is very less , at intermediate floor very large and then suddenly decreases to zero at top floors. Graphical representation of shear wall with 25%, 50% openings and shear wall up to foundation in zone V for load combination of 1.5 (DL+EQX) along Z direction and 1.5(DL+EQZ) along Z direction for parameters like lateral displacement, axial displacement and moment.

Conclusions

1. Introduction of shear wall greatly reduces lateral displacements in structures due to application of earthquake forces.
2. Shear walls must be placed in both the directions as shear wall in one direction may result in increase in moment in the transverse direction.
3. Shear wall at periphery is found to be beneficial from reduction in displacement point of view.
4. Provision of additional shear walls above the optimum requirement may not be useful in restricting displacements; however it may results in higher cost and unwanted gravity forces.
5. There is marginal reduction in lateral displacement if the shear walls are extended beyond plinth level up to foundation level.
6. Careful analysis of structures is necessary, if shear wall is provided only at lift well as it may result in unnecessary increase of forces in various columns.
7. With the increase in openings in shear wall lateral displacement increases to greater extent.
8. If openings are required in shear wall detailed analysis of structure is essential as it may lead to erratic increase in forces on columns.

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