EARTHQUAKE VIBRATION CONTROL USING SHEAR WALL

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Abstract : Earthquake damage reducing techniques have found their popularity after 26th January earthquake in Gujarat which was very dangerous. There were many structures which were affected heavily are found to be built as load bearing structures and there were not any special techniques used in building. Special techniques are necessary for making the building earthquake resistant because building is very much concerned with humans and its failure may results in loss of numbers of human lives and there are nothing to be more precious than a human life. Amongst all the techniques which can be used for making the structure earthquake resistant, the shear wall provision technique is the most effective and popular due to its easy understanding and economical construction. For making the multi-storey building earthquake resistant, shear wall is the best solution and it is maximum use now a days. In this article we are going to check the contribution of the shear wall to the structure during earthquake to behave safely and also we tried to find out the effective location of the shear wall.

***IndexTerms* – introduction, literature review, problem formulation and solution (analysis), shear wall, planwin, staadpro, conclusion.**

1. Introduction

1.1. What is earthquake?

An earthquake is the shaking of the earth surface, resulting from the sudden release of energy in the earth's outer most layer known as lithosphere that creates seismic waves which will pass through surface as well as through crust body. In general, the word earthquake is used to describe any seismic event whether it is natural or manmade that generates seismic waves.

1.2. How the building can be affected by earthquake?

Earthquake causes shaking of the ground; so a building resting on it will experience motion at its base. From Newton's 1st law of motion, even though the base of the building moves with the ground, the roof has a tendency to stay in its original position.

1.2.1. Inertia forces in the structure

The generation of the inertia forces is one of the seismic influences that affect the structure. When an earthquake causes surface shaking the base of the building would move with the wave propagation but the roof would be at rest. However, since the walls and columns are attached to it, the roof is dragged with the base of the building. (***Figure 1***). The tendency of the roof to maintain its original position is called **inertia.** The inertia force cause the shearing of the structure due to which the structure may fail.

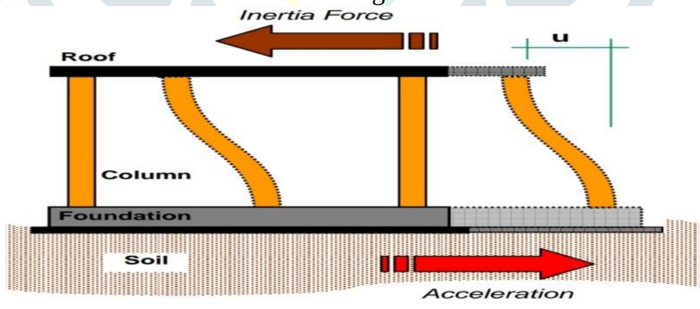

Figure 1 direction of inertia force

1.2.2. Horizontal and vertical shaking

Earthquake cause surface shaking in 3-directions (X, Y & Z); 2-horizontal (X & Y) & 1-vetical (Figure 2)

Traditionally the structures are designed to resist vertical loads and therefore the vertical motion created by earthquake can be resisted to few extent but the horizontal shaking could not be resisted properly.

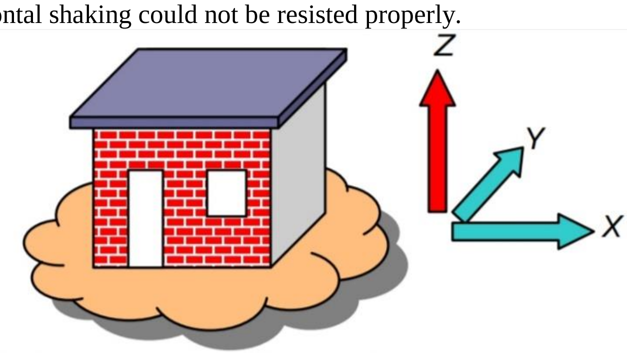

Figure 2 earthquake directions

1.2.3. Flow of seismic inertia forces to foundation

Due to horizontal shaking of the surface, horizontal inertia forces are generated at the level of the mass. These inertia forces are transferred by the slab to the walls/columns, to the foundation and finally to the soil below (Figure 3). So, each of these structural elements and the connections must be designed to safely transfer inertia forces through them to the soil below.

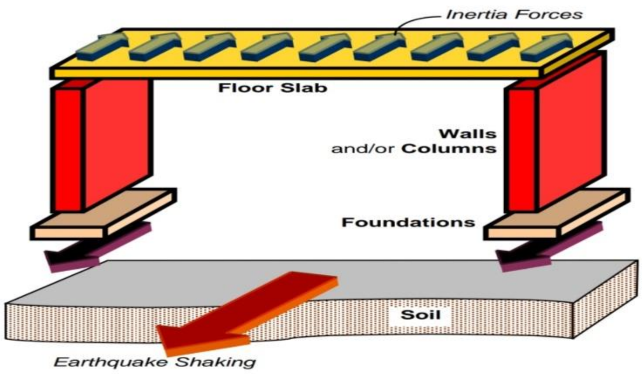

Figure 3 flow of seismic inertia forces

Walls or columns are the most vulnerable elements in transferring the inertia forces. But, in traditional construction, slabs and beam receive more attention during design and construction, than walls/columns. They are weak in carrying horizontal earthquake forces.

1.3. Earthquake resistant structure

Earthquake resistant structures are structures designed to protect building from earthquake. While no structure can be 100% immune from damage due to earthquakes, the goal of earthquake resistant construction is to erect structures that behave better during earthquake. According to the civil codes, earthquake resistant buildings are designed to withstand the largest earthquake of certain probability that is likely to occur at their location. This means the loss of life should be minimized by preventing collapse of the buildings for earthquakes while the loss of the functionally should be limited for more frequent ones.

1.4. Why earthquake resistant structure is important?

According to the National Information Centre, there is an average 20,000 earthquakes each year and 16 of them being major disasters. On January 26, 2001, an earthquake of magnitude 7.7 killed between 13,805 & 20,023 people, injured another 1,67,000 and destroyed nearly 4,00,000 homes. Hence due to earthquake there are lots of money loss and human lives may also get disturbed. Hence, it is very much required to consider the seismic forces during the design of the structure and make it able to withstand the earthquake loads up to few extent. Moreover high rise buildings are more trending now a days. Therefore, earthquake resistant structure is mostly required to ensure the safety of the people living inside the building and also surrounding to that structure and to reducing the heavy disaster. Over the past few decades, engineers have introduced new designs and building materials to better equip buildings to withstand earthquakes. Now a days more than one techniques are available to improve the seismic behavior of the building e.g.

- Create flexible foundation
- Counter force with damping
- Vibration control devices
- Providing shear walls and braces
- Pendulum power
- Shield buildings from vibrations
- Reinforced the building structure

Among all these available techniques the technique which is commonly adopted is the provision of **shear walls**.

1.5. Shear wall

Shear wall is a structural member positioned at different places in a building from foundation level to top parapet level, used to resist lateral forces. Shear wall is a continuous wall from foundation level to the parapet level. It is like a vertically oriented wide beam. (Figure 4) The thickness of shear wall can be as low as 150mm, or as high as 400mm in high rise buildings. Shear walls are generally provided along both length and width of the buildings.

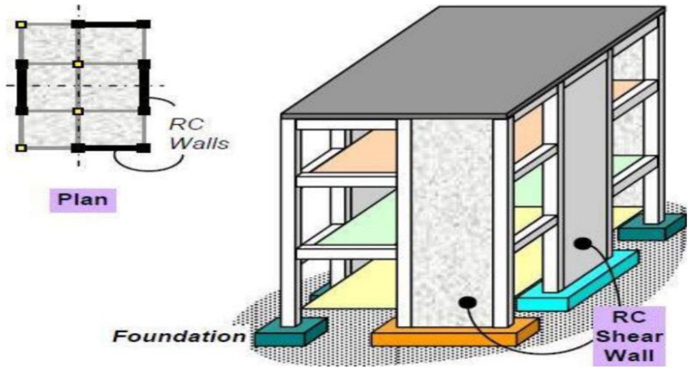

Figure 4 shear wall in building

These walls are more important in earthquake prone zones because during earthquake shear forces on the structure increases. Shear walls provide adequate strength and stiffness to reduce lateral displacements. Shear walls perform dual action that is they as lateral as well as gravity load bearing elements. Finally, shear wall is 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. When shear walls are designed and constructed properly, they will have the strength and stiffness to resist the horizontal forces. Shear walls are especially important in high rise buildings subjected to lateral wind and seismic forces.

1.6. Advantages of shear wall in RC building

- Shear wall resist horizontal lateral force.
- It provide earthquake resistance.
- It possess very large stiffness which resist lateral load.
- Shear walls are helpful in reduction of deflection.
- Shear walls are easy to construct.
- It minimizes earthquake damage.
- Well-designed shear walls not only provide adequate safety but also provide great measure of protection against costly non-structural damage during moderate seismic damages.

2. LITERATURE REVIEW

Concrete shear walls are the most common and useful type of shear wall for any multistoried building. Many researchers and scholars had researched on the shear wall configuration in any building and types of shear walls. The review on that some research papers are as follows;

I. **Nehal A. Bhavsar, Noopur A. Shah and Satyen D. Ramani** presented a paper on the study of effectiveness of the shear wall on different building aspect ratio. In that paper they checked the effectiveness of the shear wall on the different building aspect ratio, the three aspect ratio of building they have taken to study were ($R=H_b/L_b$) R=1, R=2 & R=3. For each of the aspect ratios, building of G+5, G+10, G+15, G+20, G+25 and G+30 storey with and without shear wall had been modelled. Rectangular type of shear was provided at the centre of the faces in both directions symmetrically. At the end of experiment they have concluded that; 1) The effectiveness of the shear wall does not depend on the building aspect ratio. 2) The effectiveness of the shear wall is maintained up to G+20 storey for shear wall at the centre of faces. 3) To achieve effectiveness beyond 20 storey the core shear wall or couple shear wall mechanism is required which increase the capacity of the building.

II. **J Tarigan, J Manggala and Tsitorus** presented a paper on the effect of shear wall location in resisting earthquake. In that paper seismic analysis had been performed using response-spectrum method for different model of structures: they were the open frame, the shear wall at core symmetrically, the shear wall at periphery symmetrically and the shear wall at periphery asymmetrically. The results were observed by comparing the displacement and story-drift. Based on that study, it had been observed that the utilization of shear wall can contribute in increasing stiffness of structure. It reduces the natural period of structure, lateral displacement and storey drift significantly, position of the shear wall need to be considered carefully because it gives difference performance to resisting earthquake load.

III. **P. Kalpana, R.D.Prasad and B.Kranthi Kumar** prepared a research article named as "Analysis of building with and without shear wall at various heights and variation of zone III and zone V". The problem considered in that paper is G+5 storey building with RCC elements as columns and beams, those building outside panels are provided with shear wall and the interior panels of the building are without shear wall are modeled of this problem. The model is prepared by using STAAD Pro analysis software. After analysis they have concluded that 1) The displacements are reduced in building with shear wall compared to building without shear wall. 2) The building with shear wall has more earthquake resistance compared to without shear wall. 3) There is no variation on wind effect for with and without shear wall buildings. 4) There is small variation on bending moment and axial force for with and without shear wall. 5) The axial forces are decreased with increasing structural height for all models.

IV. **Dr. Hadihosseini, Mahdi hosseini and Ahmed hosseini** also presented one paper about shear wall in **American Journal Of Engineering Research (2014)** and in that at the end they had concluded that 1) The shear wall makes the value of torsion very low. 2) The value of storey drift is very low because of adding the shear walls to the building.

V. **Kiran Tidke, Rahul Patil and Dr.D.R.Gandhe** conducted a test on various models having different locations of shear walls as, at center, at corner and parallel side, at corner and at periphery. In that study, response spectrum and time history analysis were performed for G+7 RC frame structure with shear wall frame at their different location. Some of main conclusions they have concluded that are as follows 1) RC frame with shear wall is having higher value of base shear than bare frame. 2) The presence of shear wall can affect the seismic behavior of frame structure to large extent and the shear wall increases the strength and stiffness of the structure. 3) From all different location of the shear wall, shear wall at the corner of the building gives better result. It shows greater base shear, less storey drift and displacement as compared to other shear wall locations.

VI. **Nanjma Nainan** et.al conducted analytical study on dynamic response of seismic resistant building. The effect of the change in height of shear wall on storey displacement in the dynamic response of the building were obtained. From the study it was concluded that it is sufficient to raise the shear wall up to mid height of the building instead of raising it up to entire height of the building.

VII. **Shahzad Jamil Sardar** et.al modeled a 25 storey building zone V and analysed by changing the location of shear wall to determine various parameters like storey drift, storey shear and dynamic analysis was done to determine and compare the base shear. Compared to other models, when shear wall placed at the center and four shear wall placed at the outer edge parallel to X & Y direction model showed lesser displacement and inter storey drift with maximum base shear in addition strength and stiffness of the structure has been increased.

- After studying all the literatures mentioned above we can conclude that the shear wall plays an important role to improve the seismic behavior of the building structure.
- It reduces the storey drift and displacement.
- It provides more strength and stiffness to the building structure.
- It is the most economical solution for making building as earthquake resistant building.

3. WORK DONE SO FAR

For analyzing the effectiveness of the shear wall a building with symmetrical plan having 3 bays in each directions is selected.

3.1. PROBLEM FORMULATION

- Plan : 15m X15m
- No. of storey : 30
- Height of each storey : 3 m
- Size of beam : 230mm x 450mm
- Size of column : 23mm x 230mm
- Thickness of slab : 150mm
- Shear wall thickness : 230mm
- Grade of concrete : M20
- Location : Rajkot
- Zone : IV

Consider the following cases for analysis;

I. Case 1 without shear wall
II. Case 2 shear wall at core
III. Case 3 L-shaped shear wall
IV. Case 4 shear wall at periphery
V. Case 5 Load combination 1.2DL+1.2LL+1.2EX
VI. Case 6 Wind load parameters

And generated the result files as follows;

I. Result1 comparing case 1 & 2
II. Result 2 comparing case 1, 2, 3 & 4
III. Result 3 Load combination 1.2DL+1.2LL+1.2EX
IV. Result 4 Wind load parameters
V. Result 5 support reactions

At very first we made a plan of 15m X 15m using **AUTOCAD 2018**
After that we import that file as **.dxf** file to the **planwin** file.

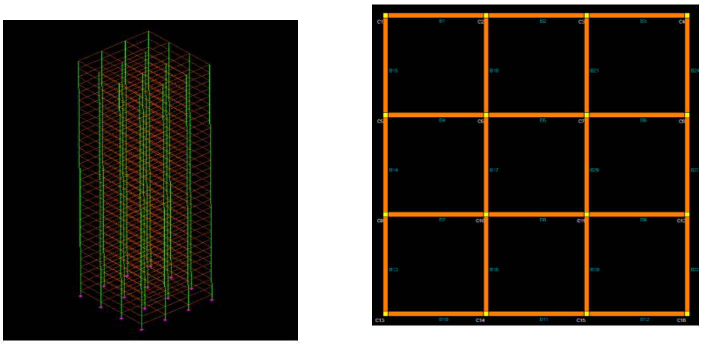

Figure 5 problem formulated

Then we created the beam column grid to the each storey of the structure. We assign the seismic parameters very first to the structure after finalizing the each storey plan. After assigning the seismic parameters we generated an analysis file for **STAAD Pro V8i** in planwin for analyzing the structure according to the **seismic coefficient method**. Then we analyze that structure in STADDPRO V8i and generate the repot for different load combinations and parameters.

3.2. Case 1 without shear wall

Load combination assigned is only the seismic load in X-direction. After that we generate a report about the storey (node) displacement due to applied seismic load. In 1st case we take the structure without shear wall (Figure 6).

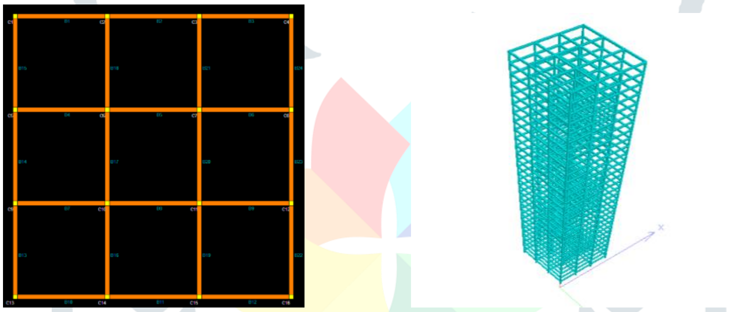

Figure 6 without shear wall

3.3. Case 2 shear wall at core

In this 2nd case we define the shear wall at the core of the building to the whole height of the structure (Figure 7).

Figure 7 with shear wall at core

Then after we compare the results of both the cases (1st and 2nd) and generate a comparative line graph about storey V/S displacement im mm as shown below(Figure 8).

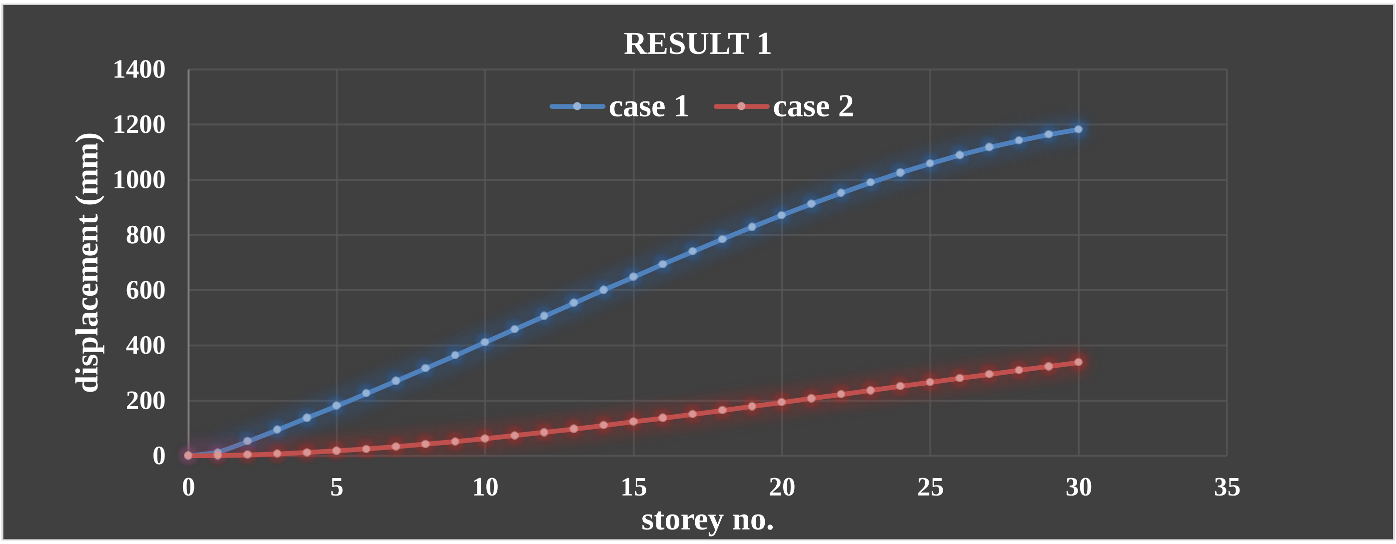

Figure 8 storey displacement graph for result 1

From above graph we can see that the storey displacement values are higher in case of the structure without shear wall and that for structure with shear wall is lesser. Hence we can conclude that the structure with shear wall is more stable and has more stiffness due to which the displacement of each storey is lesser than that for respective storey in without shear wall structure.

3.4. Case 3 L-shaped shear wall

Now in 3rd case we define the shear wall at each corners of the plan in L-shape (Figure 9).

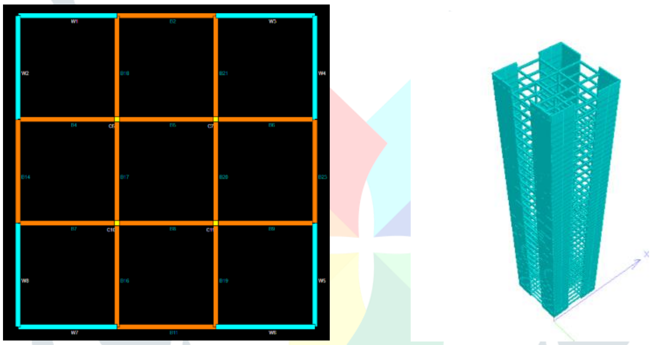

Figure 9 L-shaped shear wall

3.5. Case 4 shear wall at periphery

In 4th case providing shear walls at the periphery of the structure and assign the seismic parameters in X-directions only.(Figure 10)

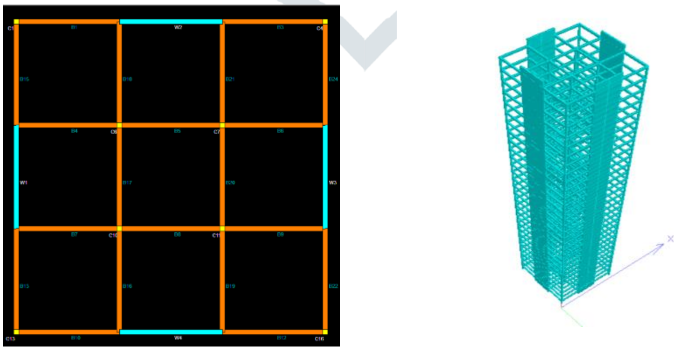

Figure 10 shear wall at periphery

Then after similar as above analysis we generate the graph for case 1, 2, 3 & 4. (Figure 11)

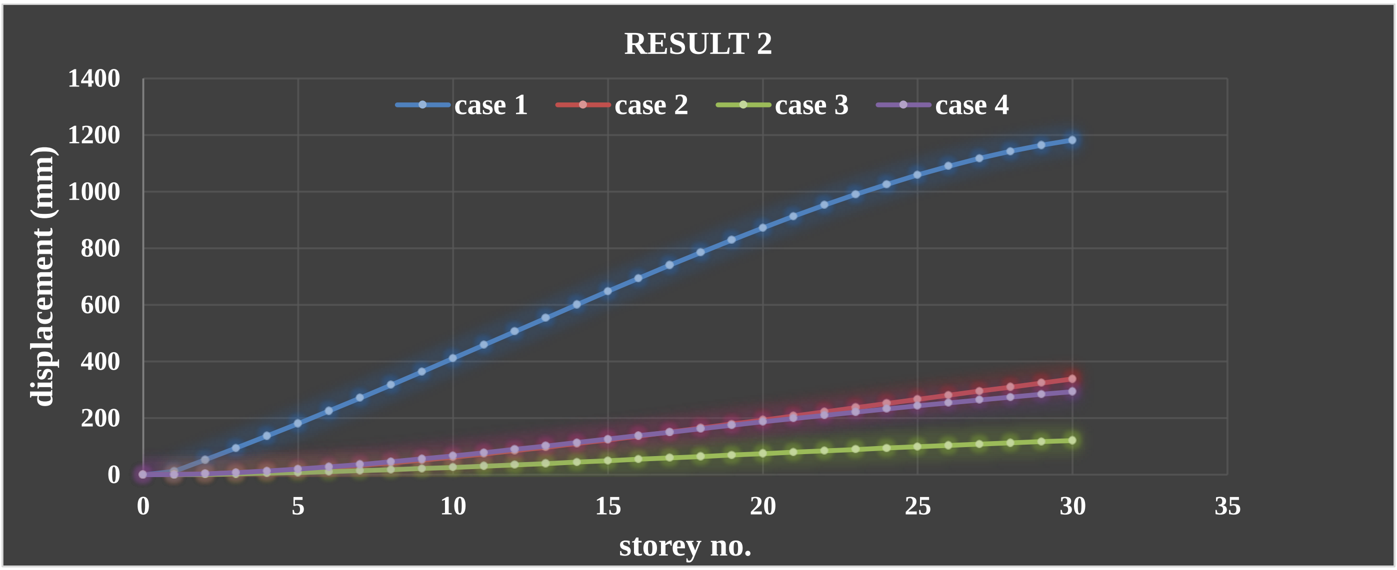

Figure 11 displacement graph for result 3

From above analysis we can perceive that in any case the shear wall structure gets lesser storey displacement value than that for without shear wall structure. Besides it can be seen from the above graph that the storey displacement is least when shear wall is provided at each corners in L-shape. There is no major difference in the results for shear wall at core and periphery but the periphery shear wall is more effective and gives lesser storey displacement then shear wall at core. Finally the storey displacement is highest in the structure without shear wall.

3.6. Case 5 Load combination 1.2DL+1.2LL+1.2EX

Previous all the analysis is only for the seismic load only in X-direction. Now we assign the load combination as 1.2DL+1.2LL+1.2EX and storey displacement graph is generated as below. (Figure 12)

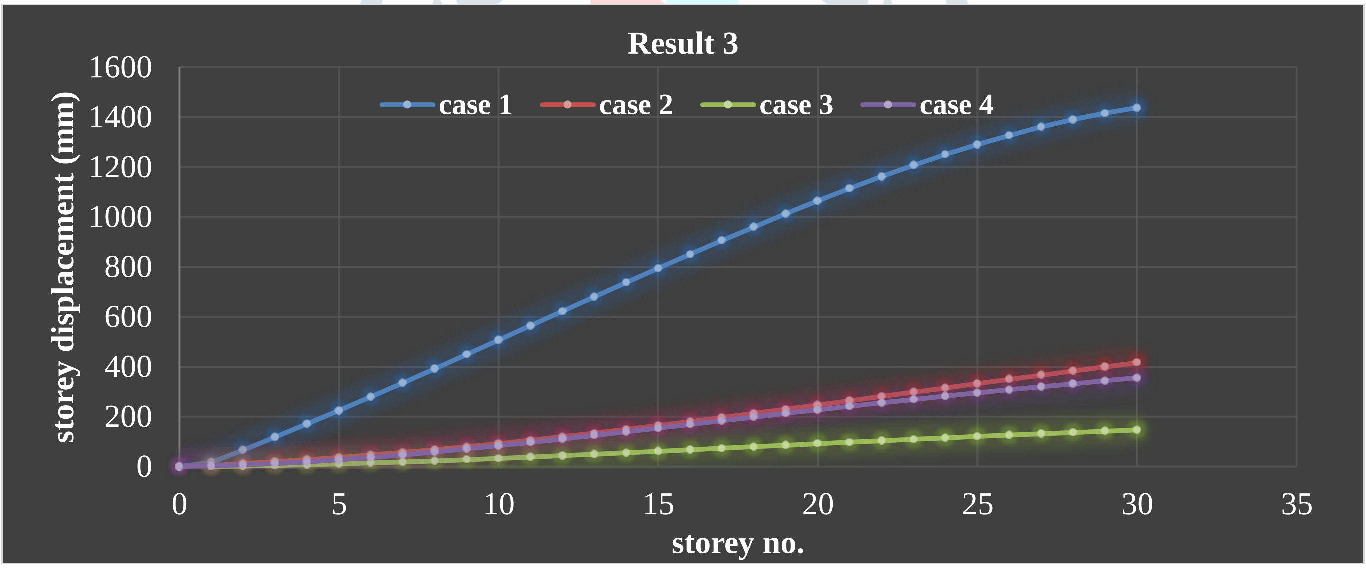

Figure 12 displacement graph for case 5

Therefor the final result had been observed that for any load combination the seismic behavior of the structure can be improved by providing shear wall. Moreover the l-shaped shear wall is the most effective one.

3.7. Case 6 Wind load parameters

During seismic analysis we also check the effectiveness of shear wall for impact of wind load also. For that we assign the wind load in X-direction only and the same analysis procedure had been followed. (Figure 13)

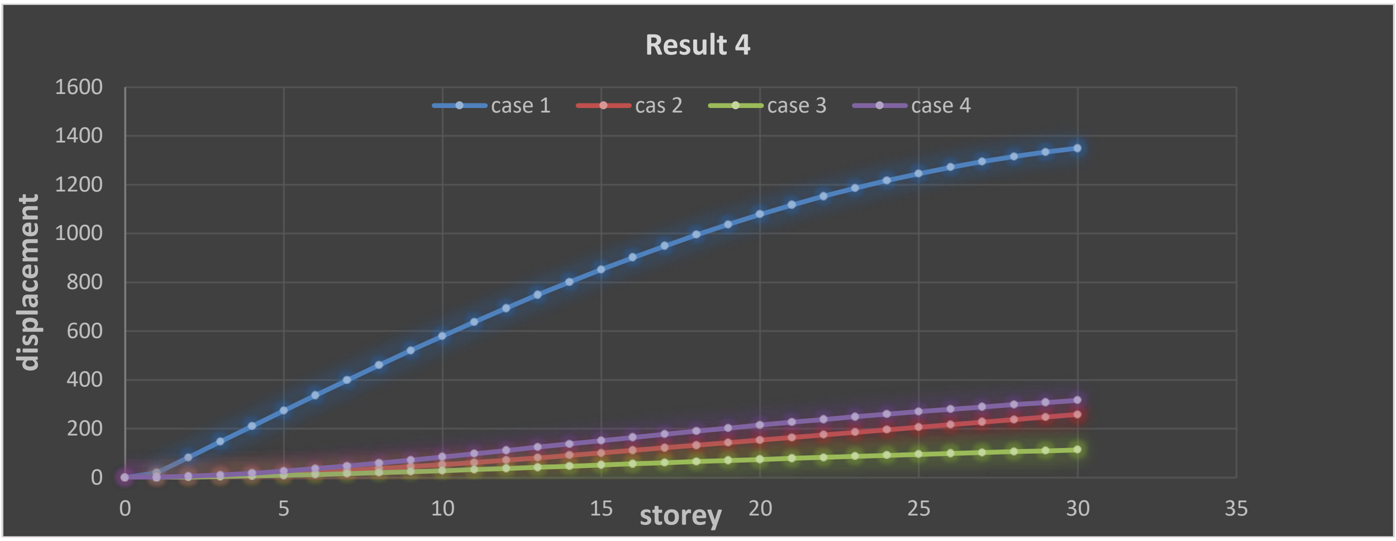

Figure 13 displacement graph for case 6

Hence shear wall is effective to resist the wind load also. And here also the L-shaped shear wall is the most effective and the structure without shear wall gets more storey displacement. (Figure 13)

3.8. Support reactions

We check the shear wall effect for the support reactions also. In this case we assign the seismic load in X-direction only. The graph generated is as follows. (Figure 14)

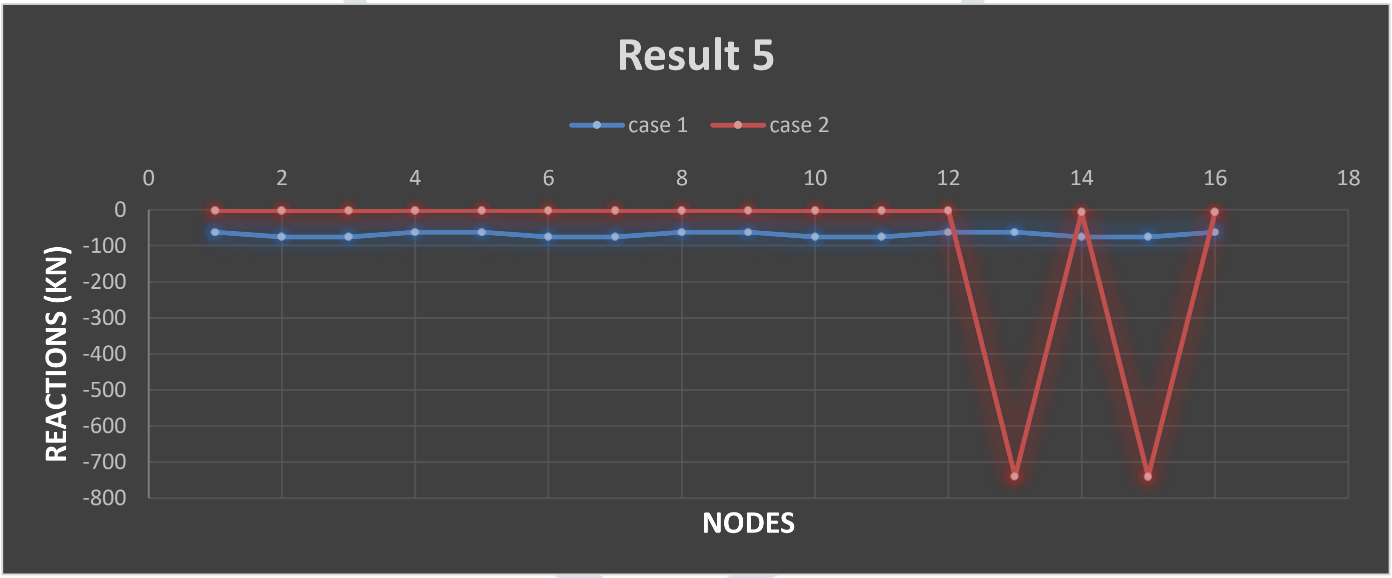

Figure 14 support reactions

From this analysis it can be seen that the is in –X direction (-ve) which is very obvious. While comparing both the data it had been observed that the reactions for the supports in with shear wall structure is lesser than that of the same support in the non-shear wall structure except the support no. 13 & 15 which are the supports of the shear wall oriented in the parallel direction to the seismic load assigned because they resist the major amount of the seismic load assigned. It is observed that the base shear is more for structure with shear wall than that for the structure without shear wall. Hence it has been concluded that the seismic load can be easily resisted by providing shear walls.

4. CONCLUSION

- ✓ From all the analysis result obtained it had been seen that the shear wall is the best provision to improve the seismic behavior of the building structure.
- ✓ The presence of shear wall can affect the seismic behavior of the building structure to large extent, and the shear wall increases the strength and stiffness of the structure.
- ✓ Whether the lateral load is due to earthquake (seismic load) or wind load; the shear wall provision is the most effective solution for multi-storey building structure.
- ✓ Shear wall location also affects the seismic behavior of the building structure.
- ✓ The best location for shear wall provision is at all the corners in L-shape as two (double) side stiffness can be provided by one single wall.
- ✓ The storey displacement values in the building with shear wall is lesser compared to the building without shear wall.

- ✓ The base shear is more for building with shear wall than that for the building without shear wall; hence the building will behave more fare during earthquake.
- ✓ The structure provide more earthquake resistance by providing shear wall.

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