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Design of Multistoried R.C.C. Buildings with and without Shear Walls

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Abstract

From the past records of earthquake, there is increase in the demand of earthquake resisting building which can be fulfilled by providing the shear wall systems in the buildings. Static Analysis is performed for regular buildings up to 90m height in zone II and III, Dynamic Analysis should be performed for regular buildings in zone IV and V above 40 m. Reinforced cement concrete (RCC) framed structures combined with shear walls has been widely used to resist lateral forces during earthquakes in tall buildings. Shear walls are generally provided for full height of the frame. Shear wall systems are one of the most commonly used lateral-load resisting systems in high-rise buildings. Shear walls have very high in-plane stiffness and strength, which can be used to simultaneously resist large horizontal loads and support gravity loads, making them quite advantageous in many structural engineering applications. An earthquake load is applied to a building for G+12, G+25, G+38 located in zone II, zone III, zone IV and zone V for different cases of shear wall position. An analysis is performed using ETAB v 9.0.7 software. Lateral displacement and story drift are calculated in all the cases. It was observed that Multistoried R.C.C. Buildings with shear wall is economical as compared to without shear wall.

Keyword: ETAB v 9.0.7, framed structure, Seismic analysis, Dynamic analysis, Shear wall.

Introduction

RC Multi-Storey Buildings are adequate for resisting both the vertical and horizontal load. When such building is designed without shear wall, the beam and column sizes are quite heavy, steel quantity is also required in large amount thus there is lot of congestion at these joint and it is difficult to place and vibrate concrete at these places and displacement is quite heavy which induces heavy forces in member. Shear wall may become imperative from the point of view of economy and control of lateral deflection. In RC multi-storey building R.C.C. lift well or shear wall are usual requirement. Centre of mass and stiffness of the building must coincide. However, on many occasions the design has to be based on the off centre position of lift and stair case wall with respect to centre of mass which results into an excessive forces in most of the structural members, unwanted torsion moment and deflection. Generally shear wall can be defined as structural vertical member that is able to resist combination of shear, moment and axial load induced by lateral load and gravity load transfer to the wall from other structural member. Reinforced concrete walls, which include lift wells or shear walls, are the usual requirements of Multi Storey Buildings. Design by coinciding center of mass and stiffness of the building is the ideal for a Structure. Providing of shear wall represents a structurally efficient solution to stiffen a building structural system because the main function of a shear wall is to increase the rigidity for lateral load resistance. The use of shear wall structure has gained popularity in high rise building structure, especially in the construction of service apartment or office, commercial tower. It is very important to note that shear walls meant to resist earthquake should be designed for ductility.

Forces acting on shear wall

Shear walls resist two types of forces: Shear forces and Uplift forces.
Shear forces are generated in stationary buildings by accelerations resulting from ground movement and by external forces like wind and waves. This action creates shear forces throughout the height of

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the wall between the top and bottom shear wall connections.

Uplift forces exist on shear walls because the horizontal forces are applied to the top of the wall. These uplift forces try to lift up one end of the wall and push the other end down. In some cases, the uplift force is large enough to tip the wall over. Uplift forces are greater on tall short walls and less on low long walls. Bearing walls have less uplift than non-bearing walls because gravity loads on shear walls help them resist uplift. Shear walls need hold down devices at each end when the gravity loads cannot resist all of the uplift. The hold down device then provides the necessary uplift resistance.

To form an effective box structure, equal length shear walls should be placed symmetrically on all four exterior walls of the building. Shear walls should be added to the building interior when the exterior walls cannot provide sufficient strength and stiffness.

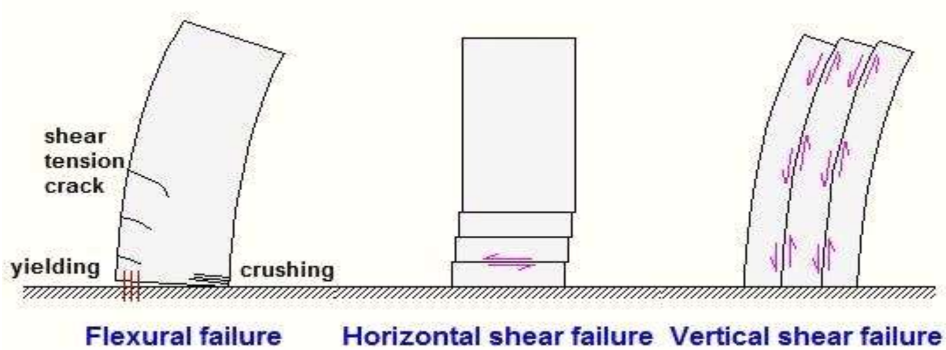

Figure 1. Failure of shear wall

Behaviour of shear wall

The behavior of shear walls, with particular reference to their typical mode of failure is, as in the case of beams, influenced by their proportions as well as their support conditions. Low shear walls also known as squat walls, characterized by relatively small height-to length ratios, may be expected to fail in shear just like deep beams. Shear walls occurring in high-rise buildings, on the other hand, generally behaves vertical cantilever beams with their strength controlled by flexure and than by shear. Such walls are subjected to bending moments and shear originating from lateral loads, and to axial compression caused by gravity.

Geometry and description

Details of structures

For this study, a G+12, G+25, G+38 building with 3.5 meters height for each storey, regular in plan is 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 are assumed to be fixed at the base and the floors acts as rigid diaphragms. The sections of structural elements are square and their dimensions are changed for different building. Storey heights of buildings are assumed to be constant including the ground storey.

The buildings are 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 are studied and dynamic analysis is 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.

The plan of the building model are given below

Model 1 – Floor plan of the bare framed structure.

Model 2 – Floor plan of the dual system with shear wall one on each side.

Model 3 - Floor plan of the dual system with shear wall on corner with L = 5 m.

Model 4 – Floor plan of the dual system with shear wall in middle (core) with L = 6m.

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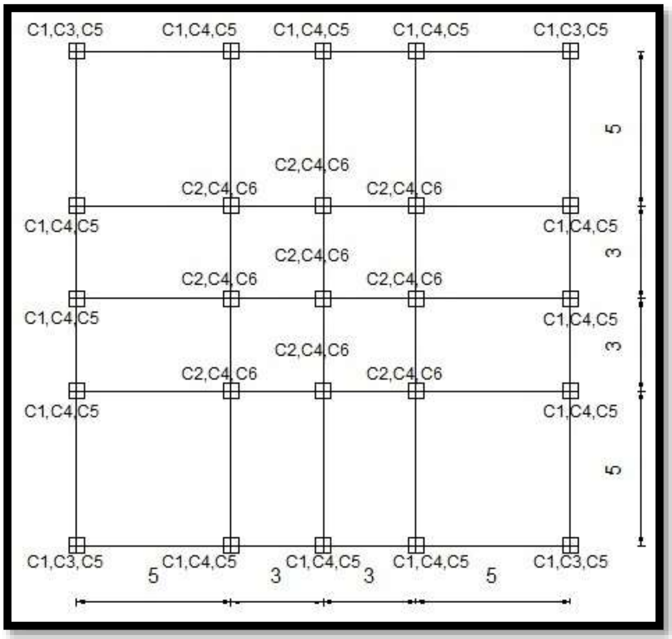

Figure 2. Model 1

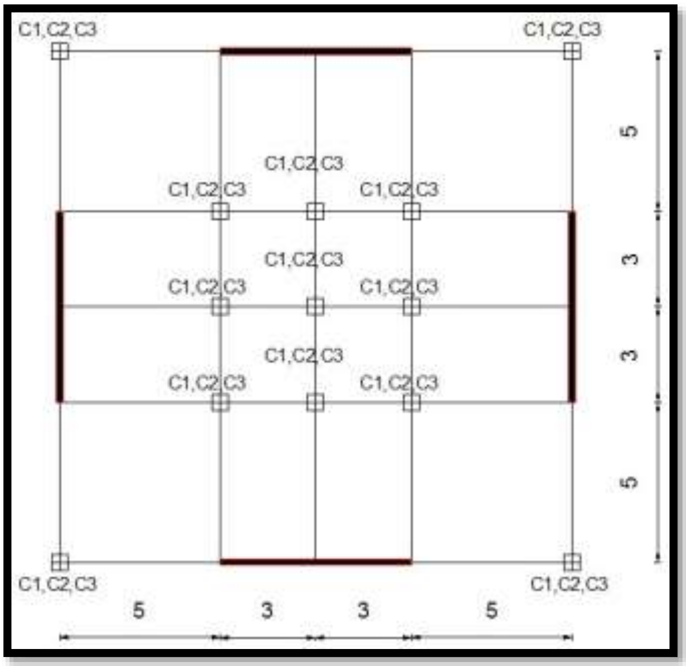

Figure 3. Model 2

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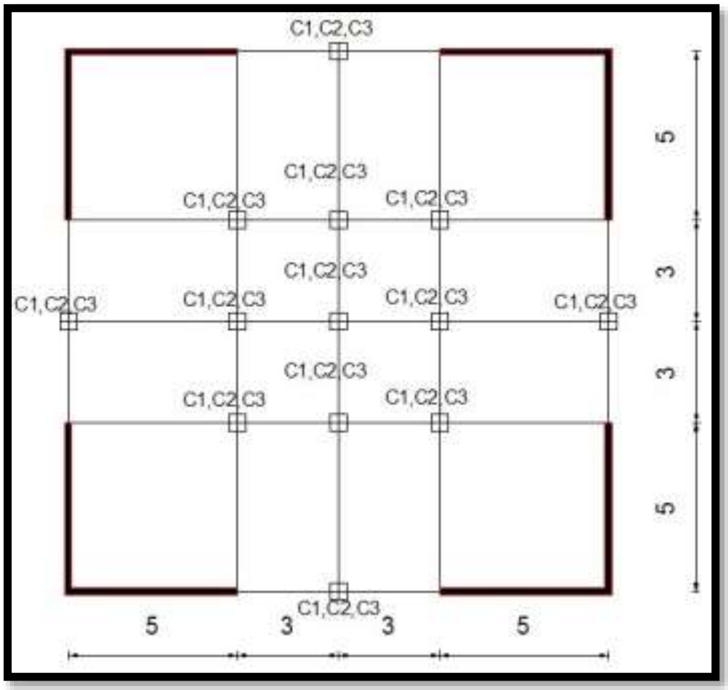

Figure 4. Model 3

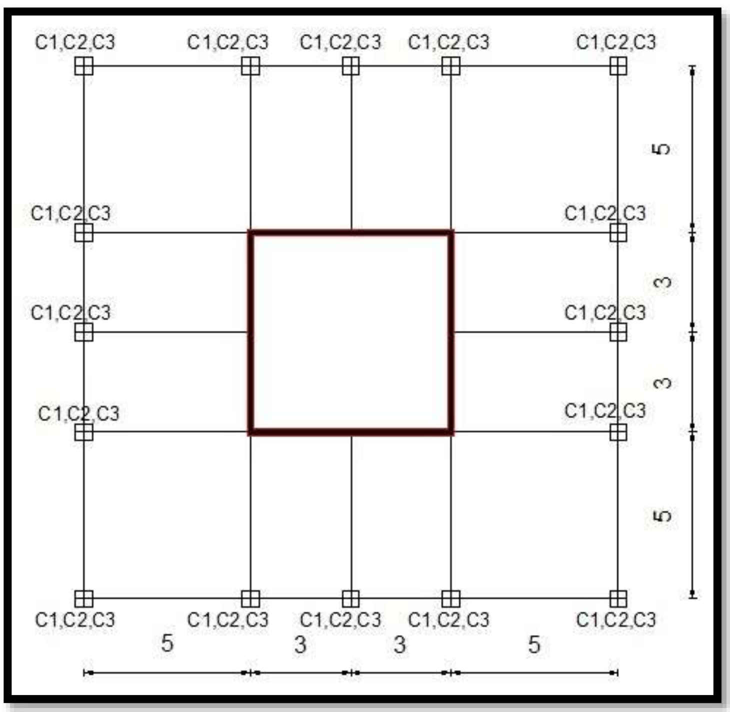

Figure 5. Model 4

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Table 1. Preliminary data

Sr. No.	Data	For 13 storey	For 26 storey	For 39 storey
1	No. of Stories	13 (G + 12)	26 (G + 25)	39 (G + 38)
2	Grade of Concrete and Steel	M25 and Fe415	M25 and Fe415	M25 and Fe415
3	Floor to Floor Height	3.5 m	3.5 m	3.5 m
4	Beam size B1: outer beam B2: inner beam	*300x300 mm²	*300x450 mm²	*300x450mm²
5	Column size C1,C2,C3,C4,C5,C6	*450x450 mm²	*500x500 mm²	*600x600 mm²
6	Thickness of slab	150 mm	150 mm	150 mm
7	Thickness of Shear Wall	200 mm	200 mm	200 mm
8	Thickness of External Wall	230 mm	230 mm	230 mm
9	Thickness of Internal Wall	115 mm	115 mm	115mm
10	Live load	3 kN/m²	3 kN/m²	3 kN/m²

Note:

* = sizes are changed according to requirement.

For Model 1 : Column notations are C1, C2, C3, C4, C5, C6.

For Model 2, 3, 4 : Column notations are C1, C2, C3.

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Results for G+12, G+25, G+38 story buildings

Lateral displacement for G+12

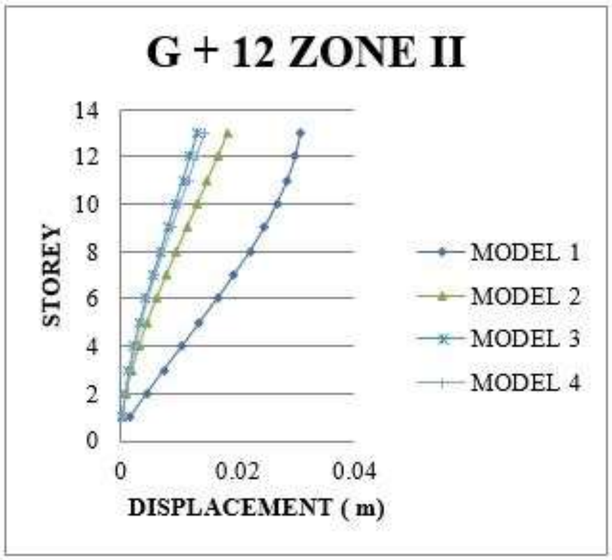

Figure 6. Displacement curve for Zone II

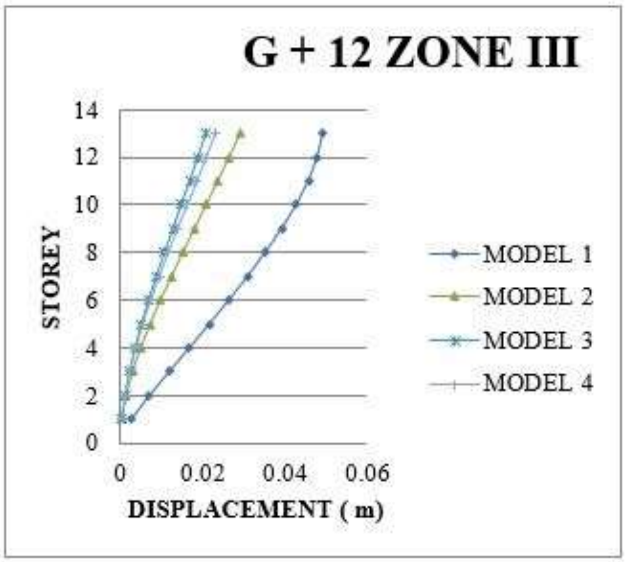

Figure 7. Displacement curve for Zone III

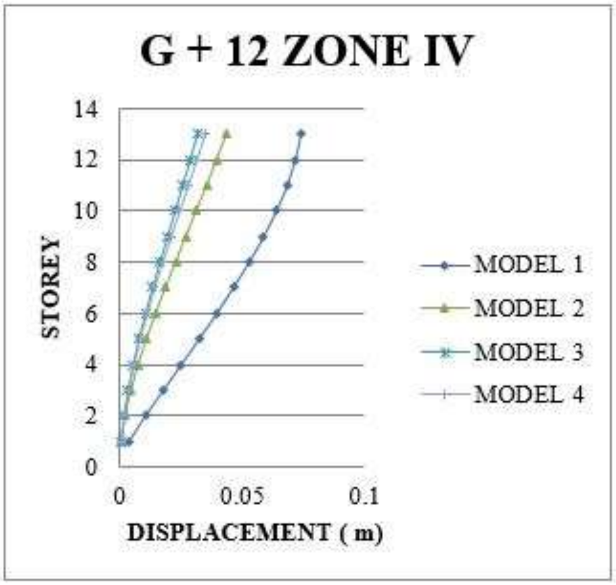

Figure 8. Displacement curve for Zone IV

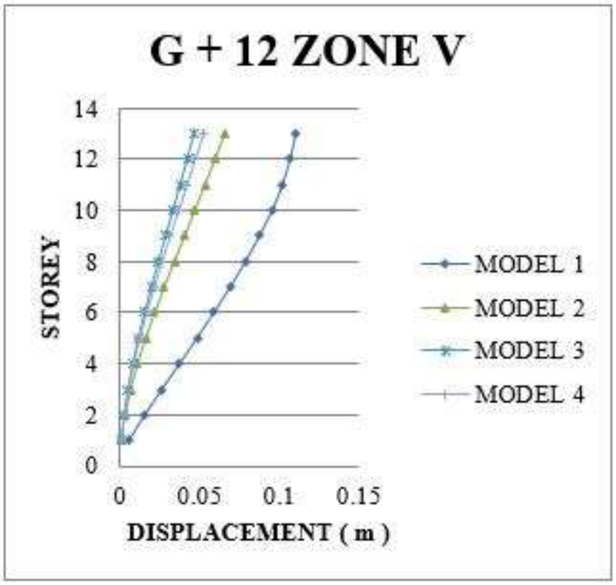

Figure 9. Displacement curve for Zone V

From results it is observed that the displacement of all models for G+12 in Zone II, III, IV and V is minimum for model 3.

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Lateral displacement for G+25

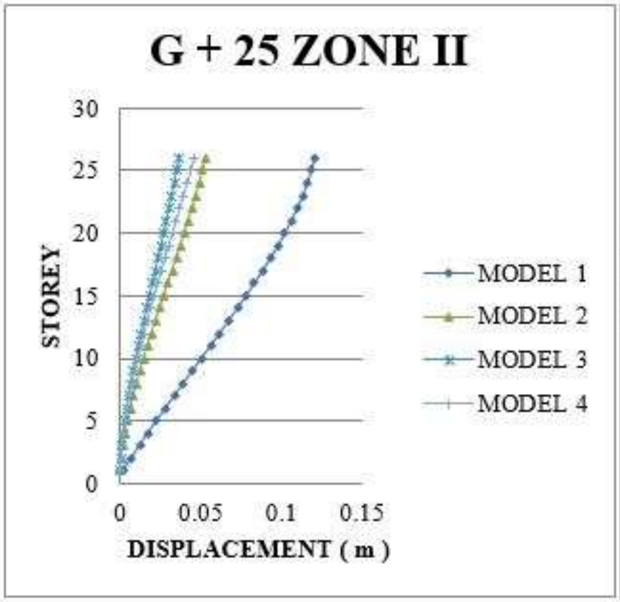

Figure 10. Displacement curve for Zone II

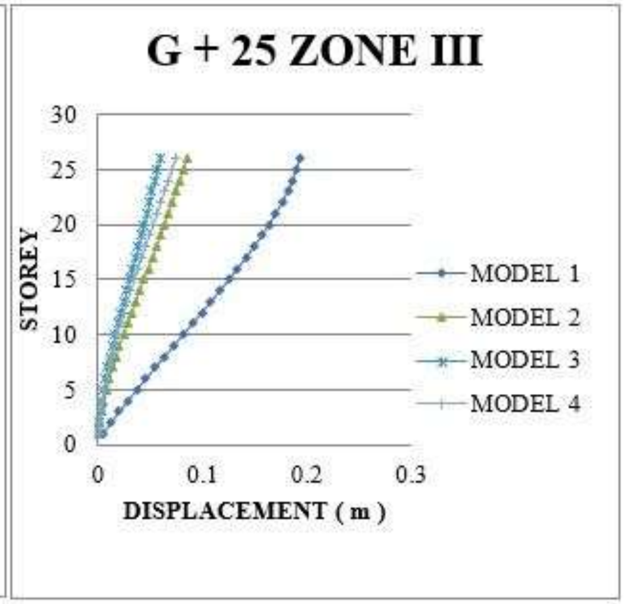

Figure 11. Displacement curve for Zone III

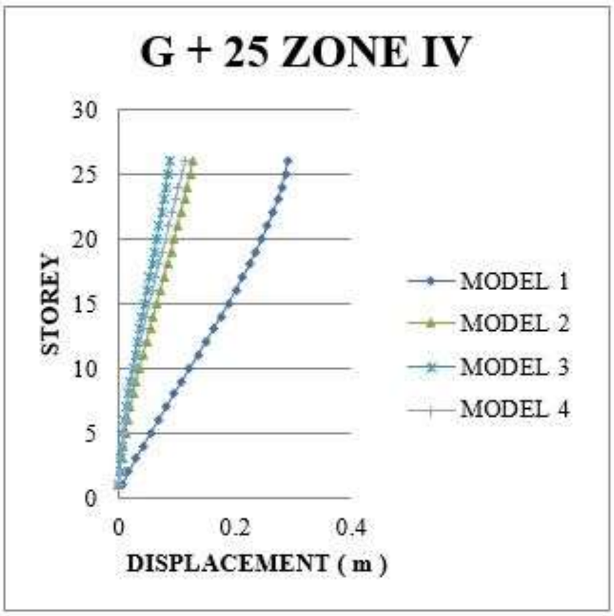

Figure 12. Displacement curve for Zone IV

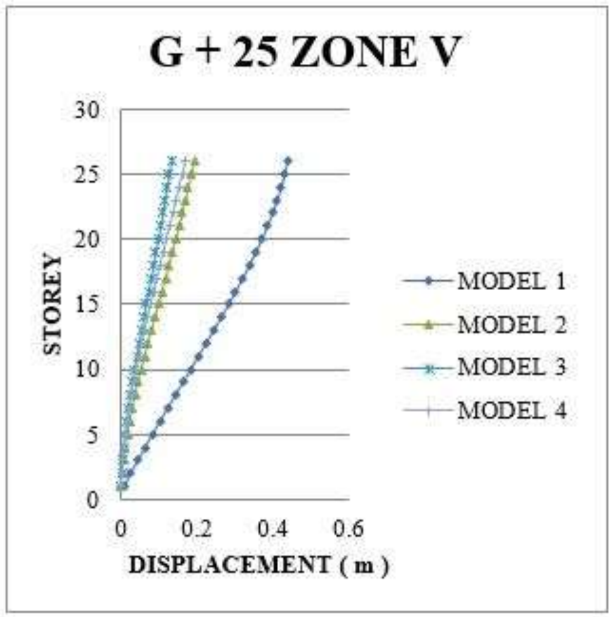

Figure 13. Displacement curve for Zone V

From results it is observed that the displacement of all models for G+25 in Zone II, III, IV and V is minimum for model 3.

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Lateral displacement for g+38

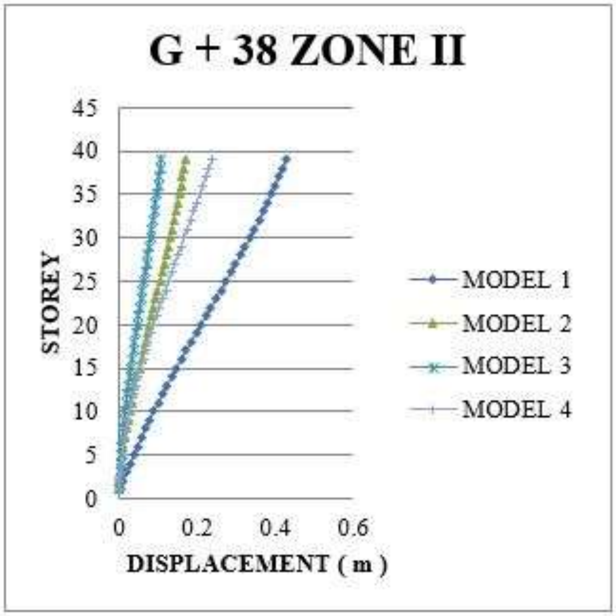

Figure 14. Displacement curve for Zone II

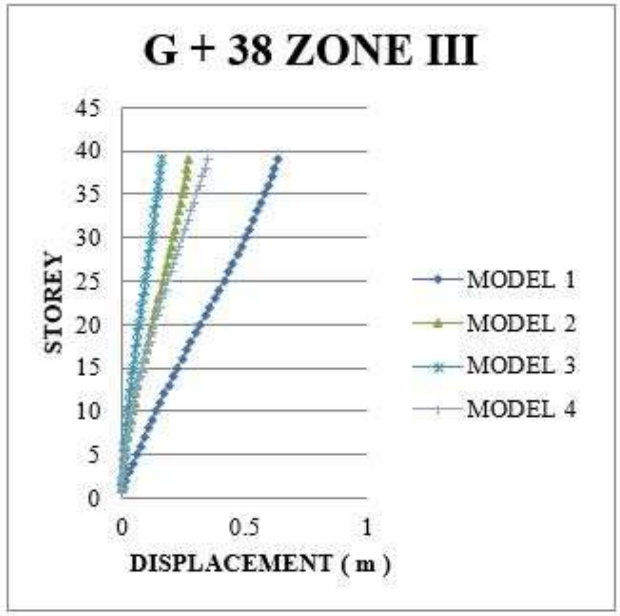

Figure 15. Displacement curve for Zone III

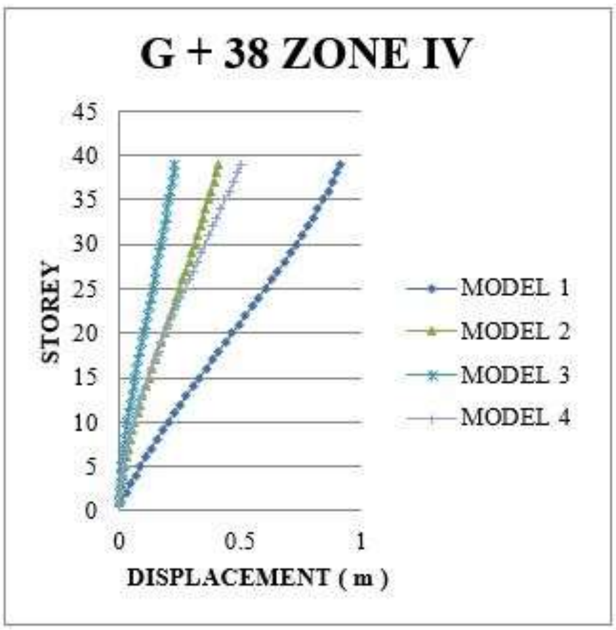

Figure 16. Displacement curve for Zone IV

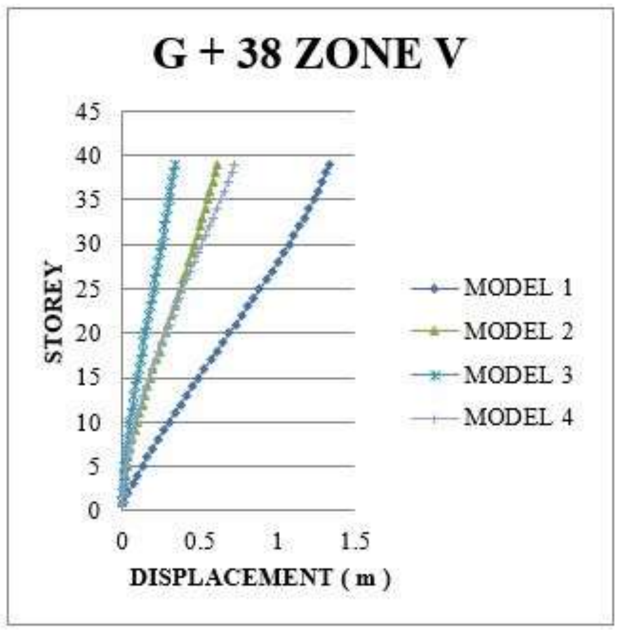

Figure 17. Displacement curve for Zone V

From results it is observed that the displacement of all models for G+38 in Zone II, III, IV and V is minimum for model 3.

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Design of multistoried building

After the analysis of various models it is cleared that by using shear wall at Corner location (Model 3) gives minimum displacement and drift. Hence design is done for corner location and for maximum height i.e. for G+38, so that dynamic analysis is applied for all zones and then comparison is done between Model 1 and Model 3 to find the steel and concrete quantity required for various zones.

For Model 1: Up to 14 storey column notation: C5, C6 = 700 mm x 700 mm.
15 to 27 storey column notation: C3, C4 = 600 mm x 600 mm.
Above 28 storey column notation: C1, C2 = 450 mm x 450 mm.

For Model 3: Up to 14 storey column notation: C3 = 650 mm x 650 mm.
15 to 27 storey column notation: C2 = 550 mm x 550 mm.
Above 28 storey column notation: C1 = 450 mm x 450 mm.

Methods of seismic analysis of structures

Various methods of differing complexity have been developed for the seismic analysis of structures. They can be classified as follows.

1. Static Analysis
2. Dynamic Analysis.

Methods of Static Analysis:

The method of static analysis used here is Equivalent Static Method.
According to clause 6.3.1.2 of IS 1893(Part1): 2000
Load combination used:

1) 1.5 (DL + LL)
2) 1.2 (DL + IL ± EL)
3) 1.5 (DL ± EL)
4) 0.9DL ± 1.5EL

Methods of Dynamic Analysis:

The method of dynamic analysis used here is Response Spectrum Method.

The word spectrum in seismic engineering conveys the idea that the response of buildings having a broad range of periods is summarized in a single graph. For a given earthquake motion and a percentage of critical damping, a typical response spectrum gives a plot of earthquake-related responses such as acceleration, velocity, and deflection for a complete range, or spectrum, of building periods. Thus, a response spectrum may be visualized as a graphical representation of the dynamic response of a series of progressively longer cantilever pendulums with increasing natural periods subjected to a common lateral seismic motion of the base.

Dynamic analysis is performed by Response Spectrum Method. In this method the design base shear VB is compared with a base shear VB1 calculated using a fundamental period Ta. Where VB is less than VB1, all the response quantity i.e. member force, displacements, storey forces, storey shears, base reactions are multiplied by VB1 / VB.

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Results for model 1 and 3 for G+38

Displacement and drift comparison for model 1 and 3

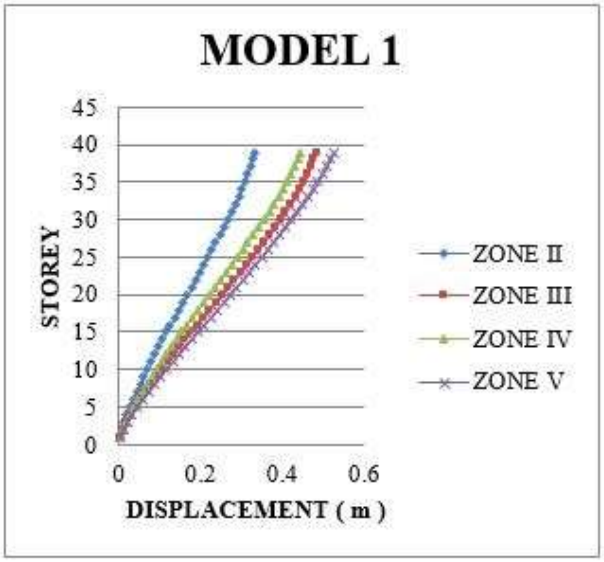

Figure 18. Displacement curve for Model 1

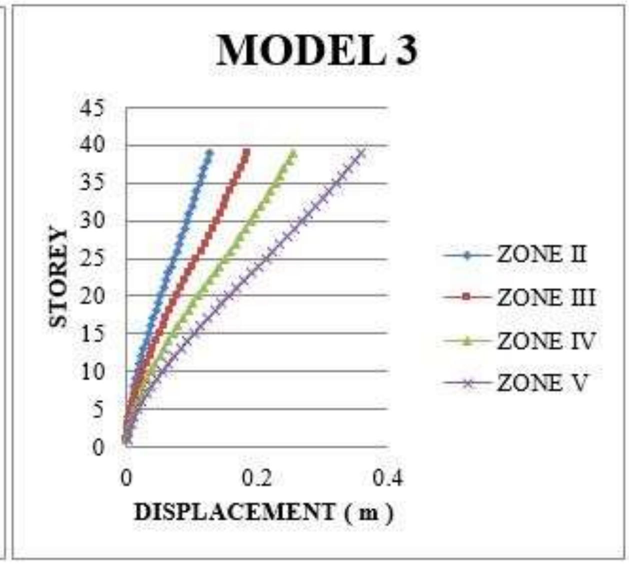

Figure 19. Displacement curve for Model 3

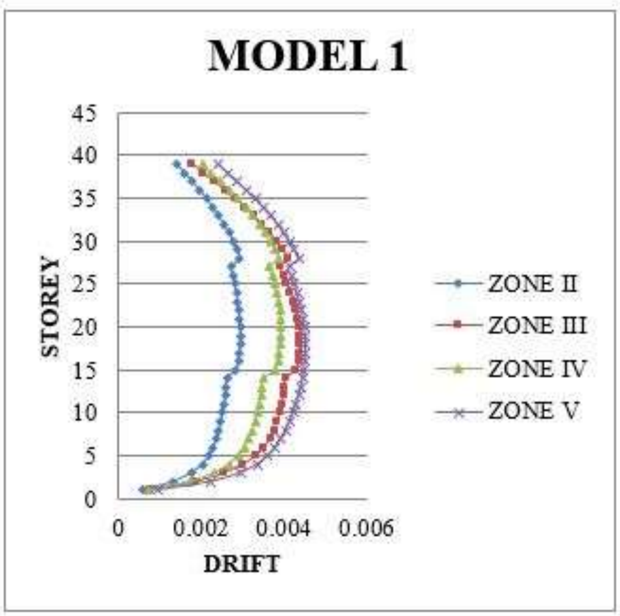

Figure 20. Storey Drift curve for Model 1

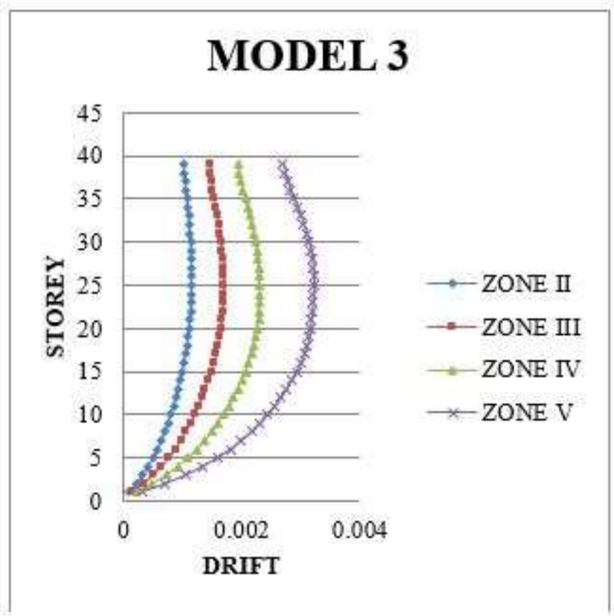

Figure 21. Storey Drift curve for Model 3

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Steel quantity and concrete quantity for model 1 and 3

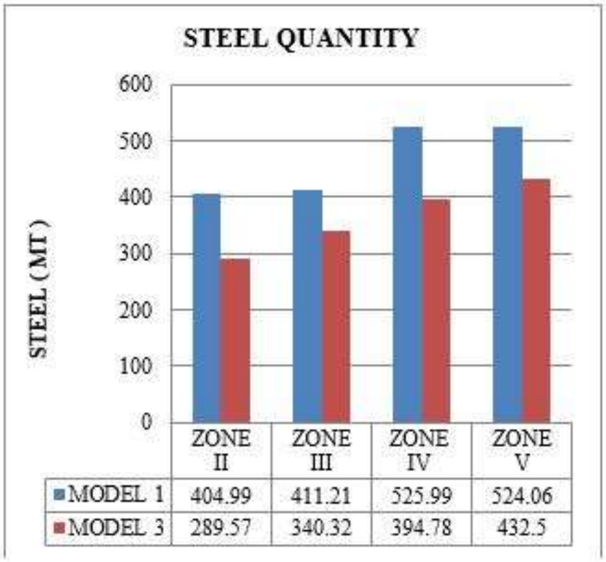

Figure 22. Steel quantity for Model 1 and Model 3.

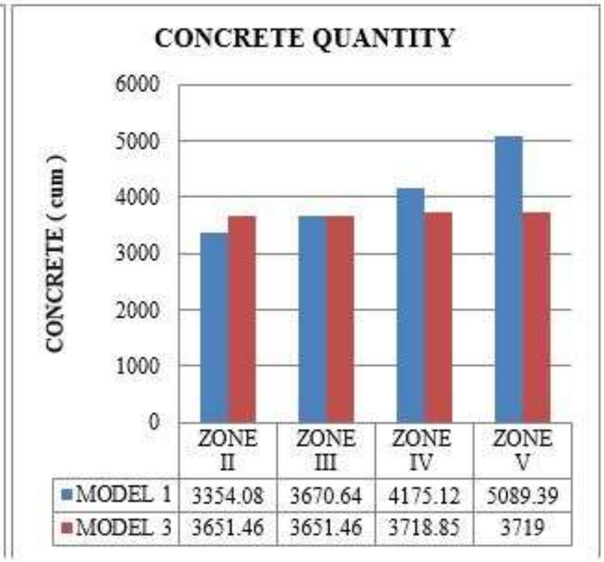

Figure 23. Concrete quantity for Model 1 and Model 3.

Cost comparison for model 1 and 3

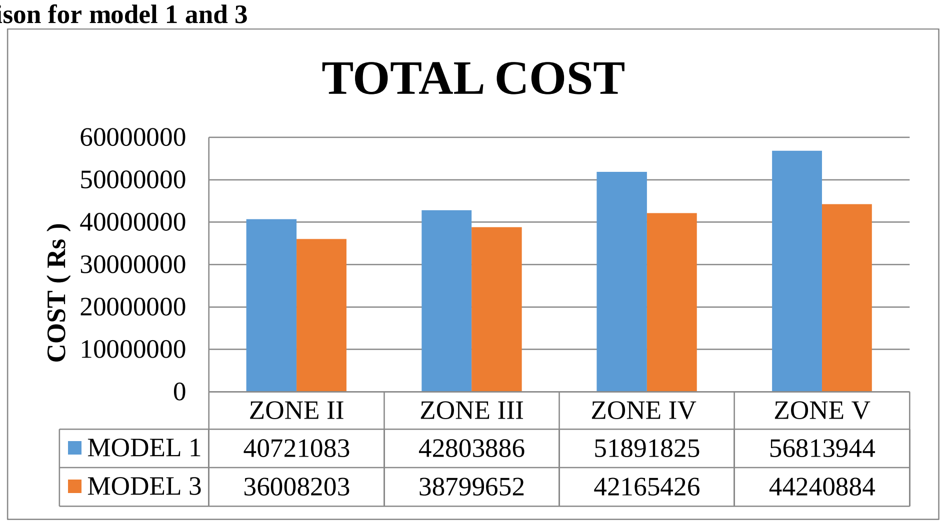

Figure 24. Cost for Model 1 and Model 3.

Discussion

Table 2. Displacement (m) for G+38 at the 39 storey

	Model 1	Model 3
ZONE II	0.3325	0.1262
ZONE III	0.4834	0.1857
ZONE IV	0.4454	0.2549
ZONE V	0.5252	0.3585

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$$\% = \frac{\text{Model 1} - \text{Model 3}}{\text{Model 1}} * 100$$

From the above result it is seen that,

- The displacement in Zone II for Model 1 is 62% greater than Model 3.
- The displacement in Zone III for Model 1 is 61.58% greater than Model 3.
- The displacement in Zone IV for Model 1 is 42% greater than Model 3.
- The displacement in Zone V for Model 1 is 31.74% greater than Model 3.
- The storey drift for model 1 (fig.20) shows the discontinuity of curve this is due to column size variation.
- The storey drift for all zones for model 1 is maximum up to 0.005 and that for Model 3 is maximum up to 0.0035.
- Fig.21 shows that by using shear wall with various sizes of column does not affect the storey drift. However fig.20 shows that the storey drift is affected where the column sizes are changing.
- According to clause 7.11.1 of IS 1893 (Part 1): 2000;
  Storey Drift Limitation:
  The storey drift in any storey due to the minimum specified design lateral force, with partial load factor of 1.0, shall not exceed 0.004 times the storey height, hence this clause is satisfied in this G+38 Building.

- Maximum displacement according to clause 7.11.1 of IS 1893 (Part 1): 2000;
  = 0.004*136.5 (total height)
  = 0.546 m
  = 546 mm
  Here maximum displacement is 0.5252 m for model 1.
- Maximum drift according to clause 7.11.1 of IS 1893 (Part 1): 2000;
  = 0.004*3.5 (floor to floor height)
  = 0.014
  Here maximum drift is 0.005 for Model 1.
- Fig. 22.
  Steel required for shear wall is less in Model 3 as compared to Model 1 for all Zones
  - For Zone II, 28.49 % of steel increases in Model 1 as compared to Model 3
  - For Zone III, 17.24 % of steel increases in Model 1 as compared to Model 3.
  - For Zone IV, 24.94 % of steel increases in Model 1 as compared to Model 3.
  - For Zone V, 17.47 % of steel increases in Model 1 as compared to Model 3.
- Fig. 23.
  - For Zone II, 8.14% of concrete increases in Model 3 as compared to Model 1, because of quantity of concrete increases in shear wall for this zone.
  - For Zone III, 0.52% of concrete increases in Model 1 as compared to Model 3, because quantity of column and beam sections are large.
  - For Zone IV, 10.93% of concrete increases in Model 1 as compared to Model 3, because quantity of column and beam sections are large.
  - For Zone V, 26.93 % of concrete increases in Model 1 as compared to Model 3, because quantity of column and beam sections are very large.
- Fig. 24.
  - For Zone II, 11.57 % of Cost increases in Model 1 as compared to Model 3.
  - For Zone III, 9.35 % of Cost increases in Model 1 as compared to Model 3.
  - For Zone IV, 18.74 % of Cost increases in Model 1 as compared to Model 3.
  - For Zone V, 22.13 % of Cost increases in Model 1 as compared to Model 3.

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Conclusion

- From above analysis, it is observed that in G+12, G+25, G+38 Storey building, constructing building with shear wall at corner (Model 3) location gives minimum drift and minimum displacement.
- From all the above analysis and design, it is observed that in G+38 Storey building, constructing building with shear wall at corner (Model 3) is economical as compared with bare frame structure (Model 1).
- Size of members like column can be reduced economically in case of structure with shear wall as compared to the same structure without shear wall.
- Variation in column size at different floors in Model 1 affects the storey drift while in case of Model 3 it does not affect the storey drift due to the presence of shear wall.
- More carpet area will be available in the building as the sizes of columns are reduced when shear wall is provided.
- Less obstruction will be there because of reduced size of column and provision of shear wall.
- As per analysis, it is concluded that displacement at different level in multistoried building with shear wall is comparatively lesser as compared to R.C.C. building Without Shear Wall.
- It is concluded that building with shear wall is constructed in lower cost as compared to structure without shear wall.
- For Zone II, 11.57 % of Cost increases for Model 1 as compared to Model 3.
- For Zone III, 9.35 % of Cost increases for Model 1 as compared to Model 3.
- For Zone IV, 18.74 % of Cost increases for Model 1 as compared to Model 3.
- For Zone V, 22.13 % of Cost increases for Model 1 as compared to Model 3.

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