Analysis for seismic and wind effect on multistoried RCC and Steel-Concrete Composite Residential building using ETABS

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Abstract: In India, reinforced concrete structures are most widely used for construction as it is most convenient and economical system. Rcc is great for low rise structures but as height of structure increases such type of structures doesn't suffice economy due to increased dead load, unsubstantial stiffness and complex formwork. So, for this efficient and economical design solution is need of time. Steel concrete composite construction has gained wide acceptance worldwide as an alternative to pure steel and concrete construction. The High-rise structures of RCC are more bulky and less ductile as compared to composite structures. The use of steel in construction industry is very low in India compared to many developing countries. Composite construction combines the positive properties of both steel and concrete along with speedy construction, fire protection etc.

The objective of present research work is to determine the changes caused in building due to variation in the storey height, due to change in seismic zone, to find the effect of wind and seismic loading on the building and to compare the cost estimations of both buildings. All (G+10, G+20, G+30 and G+40) buildings are designed and analysed in Etabs software. Result is compared to find the best among the Rcc and Composite buildings. It is found that composite buildings are better than Rcc building but Rcc buildings are more economical.

***Index Terms* – ETABS, Composite beam, Composite column, Deck slab, Response Spectrum analysis, Wind analysis.**

I. Introduction

The Steel-Concrete composite system of construction has become quite popular in recent times because of its added advantages over the conventional Rcc construction system. Composite structures can be described as structural members that are made up of two or more different materials. The main benefit of composite elements is that the properties of each material can be combined to form a single unit that performs better overall than its separate constituent parts. The most common form of composite element in construction is a steel-concrete composite, however, other types of composites include; steel-timber, timber-concrete, plastic-concrete, and so on.

The Rcc structures are more suitable for low-rise structures but as the height of the structure increases, it becomes less efficient and economical due to increase dead load, less susceptibility, span restrictions, and complex formwork. Increasing population and less land area have led to the need for multi-story construction as it provides larger floor area in small land area. Therefore, it is essential to construct high-rise buildings. For high-rise buildings, many structural problems arise, such as lateral load effects, lateral stiffness, and displacements, etc. Generally, for high-rise structures wind and seismic effects are dominant. It is found that for high-rise buildings composite members over Reinforced concrete members are more efficient and effective.

II. Composite Construction

Structural members that are made up of two or more different materials are known as Composite elements. The main benefit of composite elements is that the properties of each material can be combined to form a single unit that performs better overall than its separate constituent parts. The most common form of composite element in construction is a steel-concrete composite, however, other types of composites include; steel-timber, timber-concrete, plastic-concrete, and so on.
As a material, concrete works well in compression, but it has less resistance in tension. Steel, however, is very strong in tension, even when used only in relatively small amounts. Steel-concrete composite elements use concrete's compressive strength alongside steel's resistance to tension, and when tied together this results in a highly efficient and lightweight unit that is commonly used for structures such as multi-storey buildings and bridges. There are Four Basic elements of Composite Structures

1. Composite Slab

   Composite slabs are typically constructed from reinforced concrete cast on top of profiled steel decking, (re-entrant or trapezoidal). The decking is capable of acting as formwork and a working platform during the construction stage, as well as acting as external reinforcement at the composite stage. Decking is lifted into place in bundles and distributed across the floor area by hand.

   Slab depths range from 130 mm upwards. Slabs are most commonly made of concrete because of their mass and stiffness which can be used to reduce the floor's deflections and vibrations, and achieve the necessary fire protection and thermal storage. Steel is often used as the supporting system underneath the slab due to its superior strength-weight and stiffness-weight ratio and ease of handling.

2. Shear connectors

   The total shear force at the interface between a steel beam and concrete slab is round about eight times the total load carried by the beam. Therefore, it is required to provide shear connectors steel-concrete interface. These connectors are designed to convey longitudinal shear along with the interface and to prevent separation of concrete slab and steel beam at the interface.

Thus, shear connectors are placed to pass on the horizontal shear between the concrete slab and the steel beam, ignoring the effect of any bond between the two. It also withstands uplift force acting at the steel interface.

3. Composite Beam

If the steel beams are connected to the concrete slab in such a way that the two acts as one unit, the beam is called the composite beam. Composite beams are similar to concrete T-beams where the flange of the T-beam is made of concrete slab and the web of the T-beam is made of the steel section subjected mainly to bending, consist of steel section acting compositely with reinforced concrete. To act together, shear connectors are provided to convey the horizontal shear between the steel beam and the concrete slab, neglecting the effect of any bond between the two materials. These resist uplift force also acting at the steel-concrete interface.

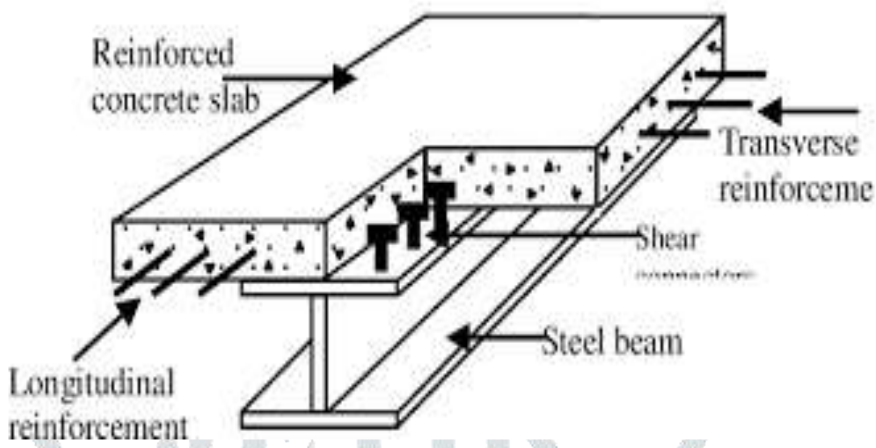


Figure 1.1: Composite Beam Section

4. Composite Column

Composite columns can have high strength for a relatively small cross-sectional area, meaning that use-able floor space can be maximized. There are several different types of the composite columns; the most common being a hollow section steel tube which is filled with concrete, or an open steel section encased in concrete. The concrete infill adds to the compression resistance of the steel section, preventing the steel from buckling. Its fire-resistant properties can permit the column to be left unprotected or only lightly protected.

III. ANALYTICAL STUDY

The study is undertaken to carry out Response Spectrum analysis and Wind analysis for different buildings situated in different seismic zones.

In ETABS 2016, the models will be analyzed by defining Response Spectrum according to Indian Standard and Wind loads will also be analyzed according to Indian Standard.

With respect to change structural configurations the following parameters will be analyzed for the performance of R.C.C as well as Composite Building:

- Storey displacement
- Storey drift
- Storey shear
- Storey stiffness
- Base shear

IV. Structural Configuration

Structural data of the building model of G+10, G+20, G+30 and G+40 storey buildings are as follows

Table 1.1: Structural configuration details

Type of Building	Rcc	Composite
Plan area of the building	18.58m X 31.66m	18.58m X 31.66m
No. of bays in X- direction	11	11
No. of bays in Y- direction	12	12
Total height of the building	31.5m, 62.1m ,92.1m, and 122.1	31.5m ,62.1m ,92.1m, and 122.1
Height of each storey	3m	3m
No. of stories	G+10, G+20, G+30 and G+40	G+10, G+20, G+30 and G+40
Beam	250 mm X 450 mm	250 mm X 450 mm (ISWB 550)
Column	450 mm X 600 mm	450 mm X 600 mm (ISWB 550)
Thickness of Slab	200 mm	200 mm (Deck)
Thickness of wall	Partial wall (115mm), External wall (230)	Partial wall (115mm), External wall (230)
Thickness of Shear wall	Shear wall (200mm)	Shear wall (200mm)
Seismic zone	II, III, IV and V	II, III, IV and V
Zone factor	0.1, 0.16, 0.24 and 0.36	0.1, 0.16, 0.24 and 0.36
Risk coefficient (K1)	1	1
Topography coefficient (K3)	1	1
Importance factor	1	1
Basic wind speed	44	44
Grade of concrete	M25	M25
Grade of reinforced steel	Fe415	Fe415
Density of concrete	25 kN/m^3 (concrete), 20 kN/m^3 (brick)	25 kN/m^3(concrete), 20 kN/m^3 (brick)
Damping ratio	5%	3%

V. Load application details

Load application

1. Self-Weight of the Building
2. Slab load:
   Dead Load = 1 kN/m^2
   Floor finish = 1 kN/m^2
   Live Load = 2 kN/m^2 (Bath&Toilet, Living&Bed, Kitchen), 3 kN/m^2 (Corridor& Passage) and 1.5 kN/m^2 (roof)
3. Wall load on Beams:
   Dead Load = 15 kN/m (Main wall)

   = 7.5 kN/m (partition wall)
4. Earthquake load
   Seismic zone = II, III, IV and V
   Zone factor (Z) = 0.1, 0.16, 0.24 and 0.36
   Soil type II (Medium soil)
   Importance factor (I) =1
   Response reduction factor (R) =5
   Damping ratio = 5%
5. Wind load
   Basic wind speed = 44

Risk coefficient (K1) = 1

Topography coefficient (K3) = 1

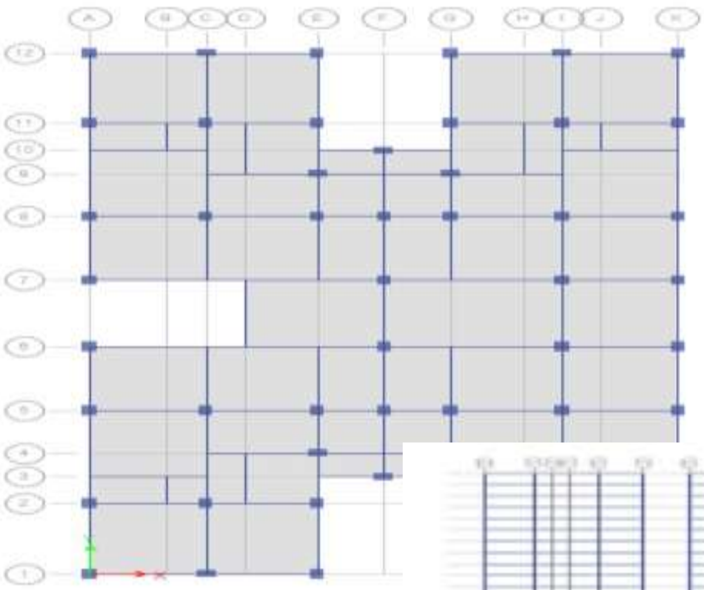
VI. Plan and Elevation of the model

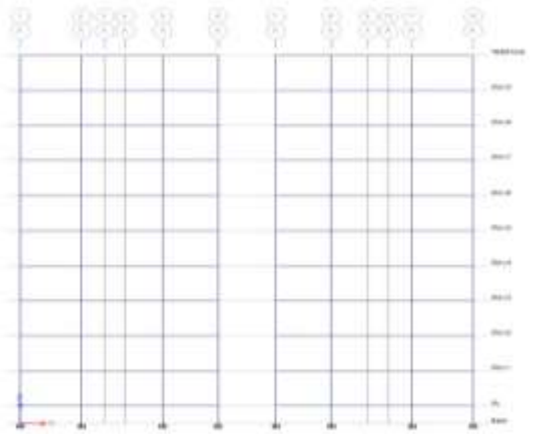
Plan and Elevation of the model from the software is shown below:

Figure 1.1: Beam and Column Plan of the Model

Figure 1.2: Elevation of the G+10 building

Figure 1.3: Elevation of the G+20 building





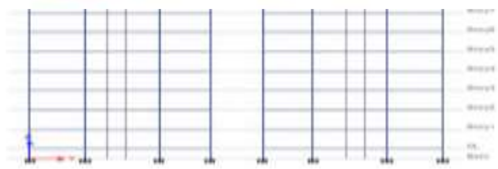


Figure 1.4: Elevation of the G+30 building

Figure 1.5: Elevation of the G+40 building

VII. Analysis Results

- **G+10 Building**

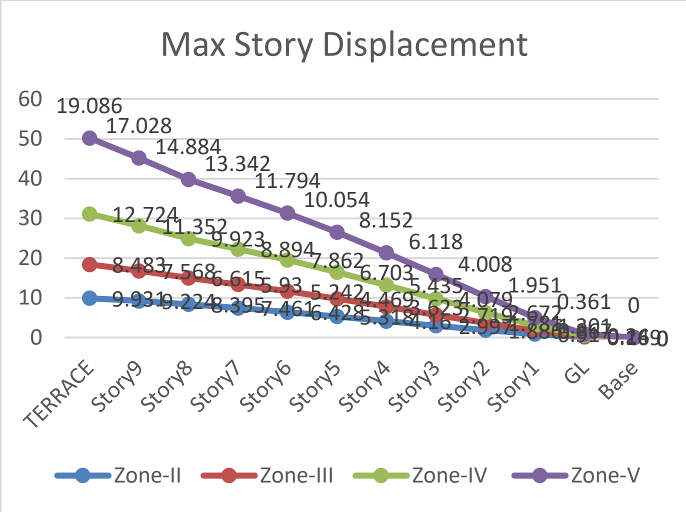


Figure 1.6: Max. Storey displacement due to Seismic effect (RCC building)

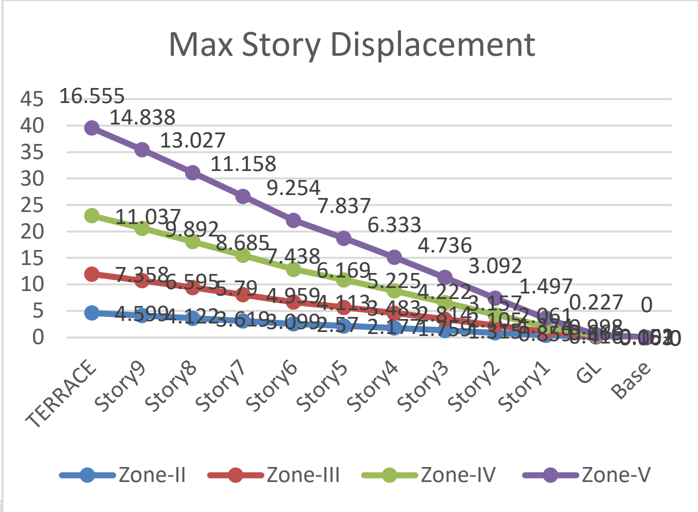


Figure 1.7: Max. Storey displacement due to Seismic effect (Composite building)

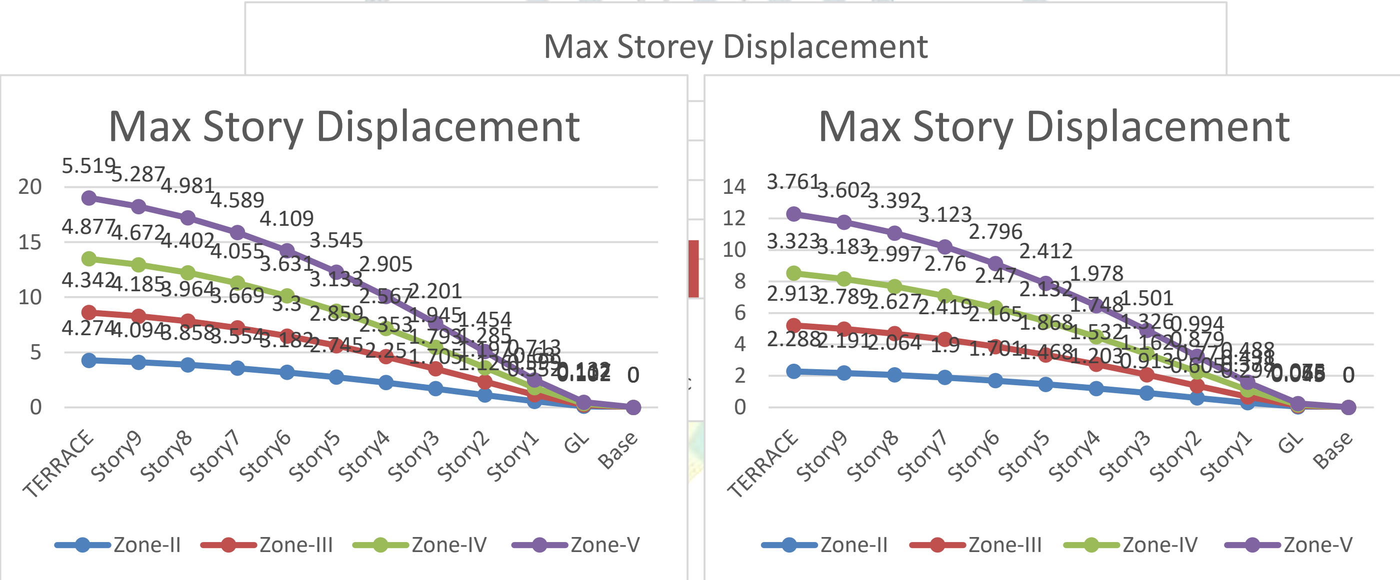


Figure 1.8: Maximum storey displacement of Rcc VS Composite G+10 building (seismic effect)

Figure 1.9: Max. Storey displacement due to Wind effect (RCC building)

Figure 1.10: Max. Storey displacement due to Wind effect (Composite building)

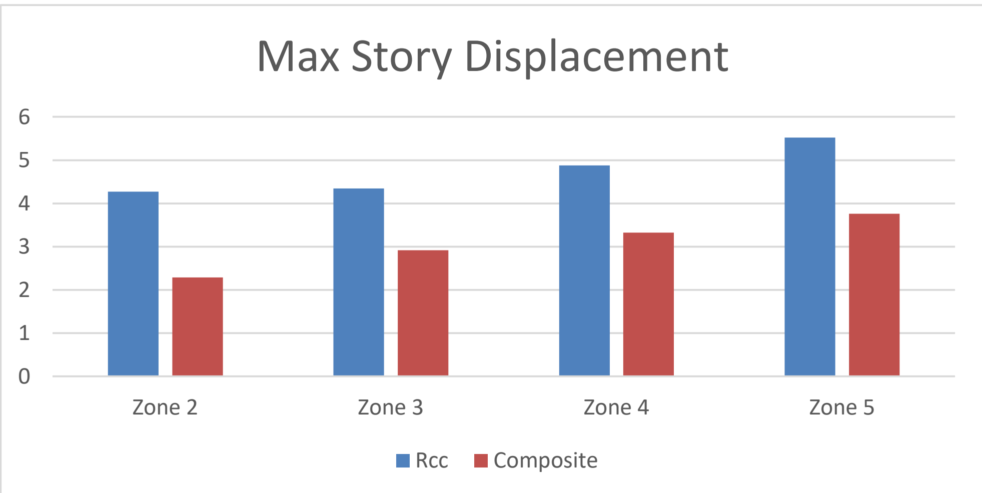


Figure 1.11: Maximum storey displacement of Rcc VS Composite G+10 building (wind effect)

- **G+20 Building**

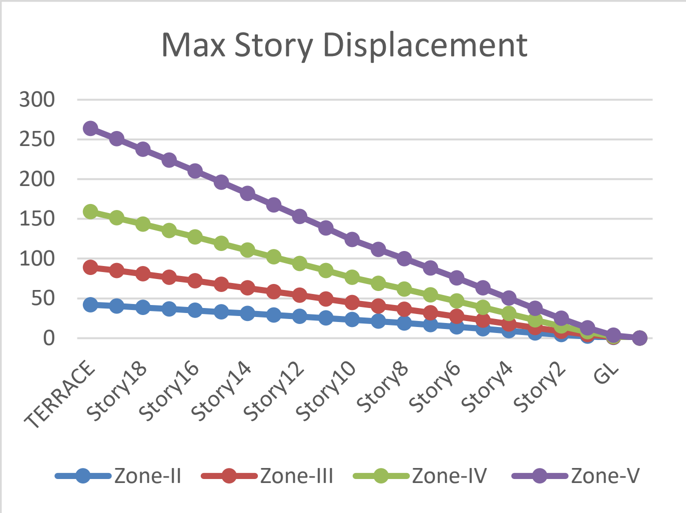


Figure 1.12: Max. Storey displacement due to Seismic effect (RCC building)

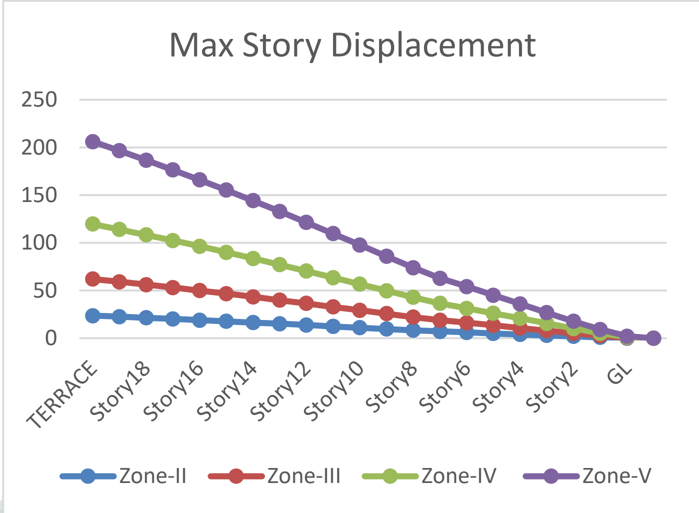


Figure 1.13: Max. Storey displacement due to Seismic effect (Composite building)

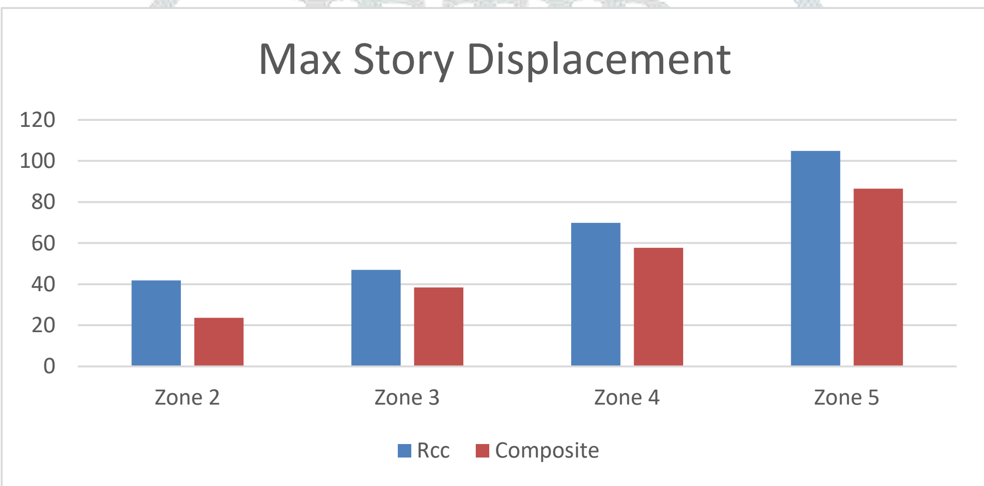


Figure 1.14: Maximum storey displacement of Rcc VS Composite G+20 building (seismic effect)

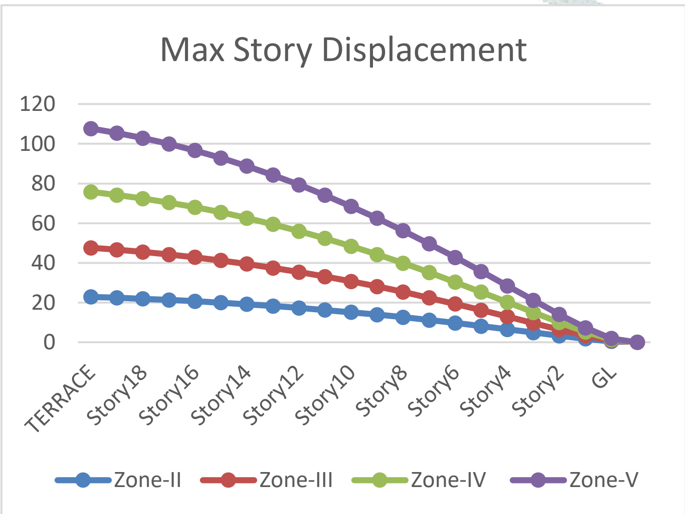


Figure 1.15: Max. Storey displacement due to Wind effect

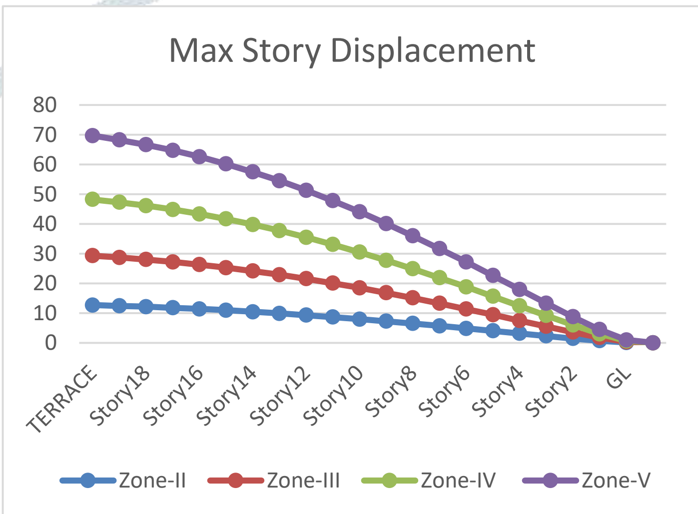


Figure 1.16: Max. Storey displacement due to Wind effect

(RCC building) *(Composite building)*

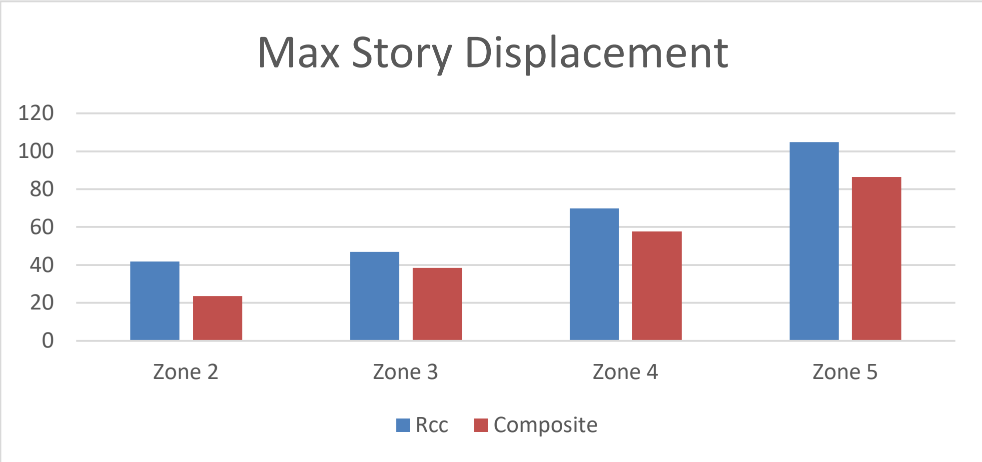
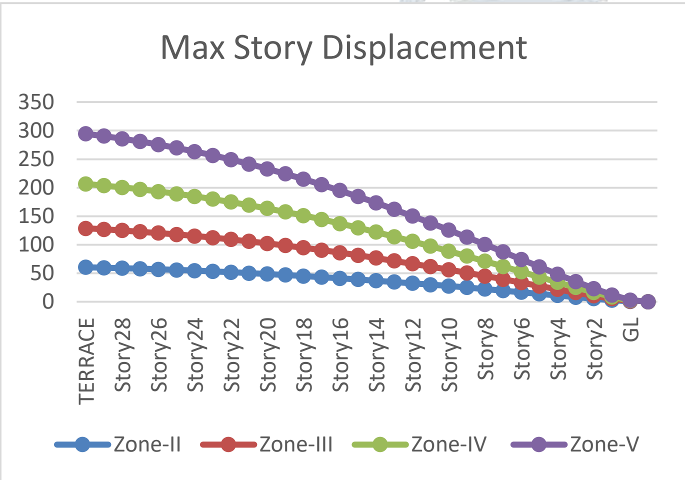


Figure 1.17: Maximum storey displacement of Rcc VS Composite G+20 building (wind effect)

- **G+30 Building**



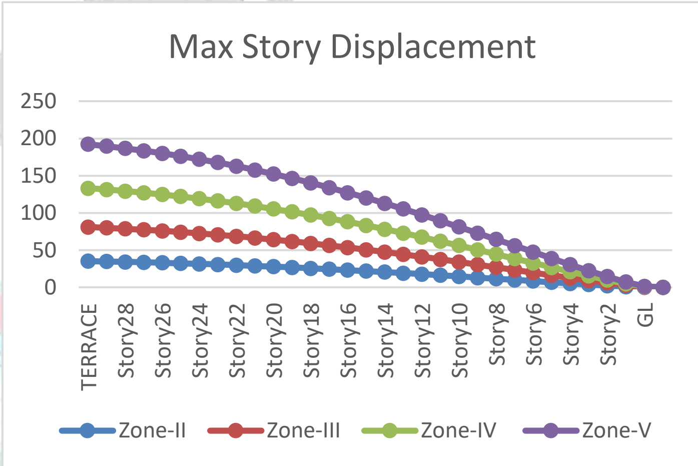


Figure 1.18: Max. Storey displacement due to Seismic effect (RCC building)

Figure 1.19: Max. Storey displacement due to Seismic effect (Composite building)

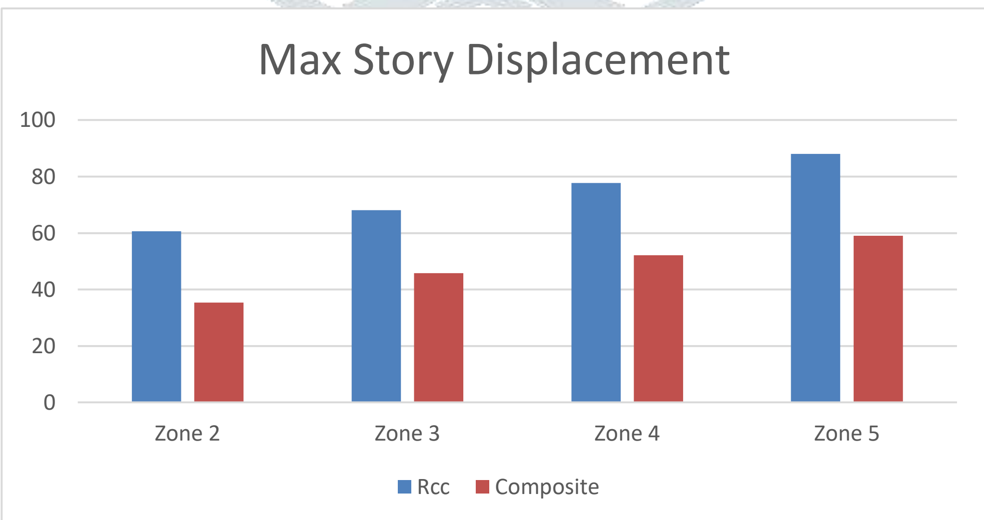


Figure 1.20: Maximum storey displacement of Rcc VS Composite G+30 building (seismic effect)

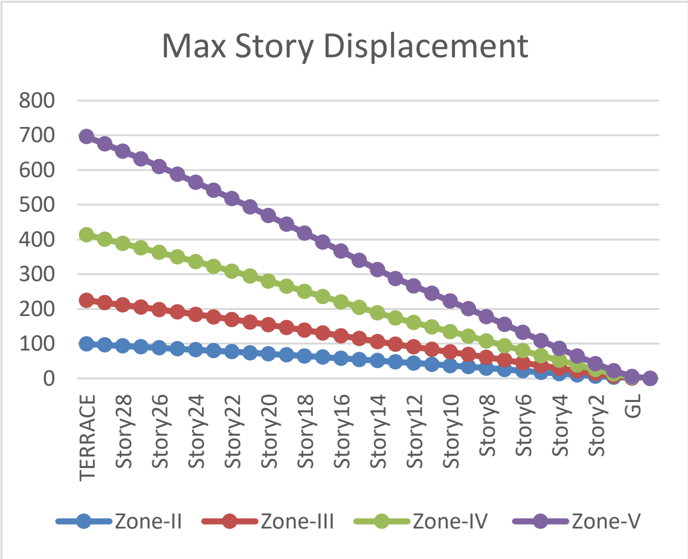


Figure 1.21: Max. Storey displacement due to Wind effect (RCC building)

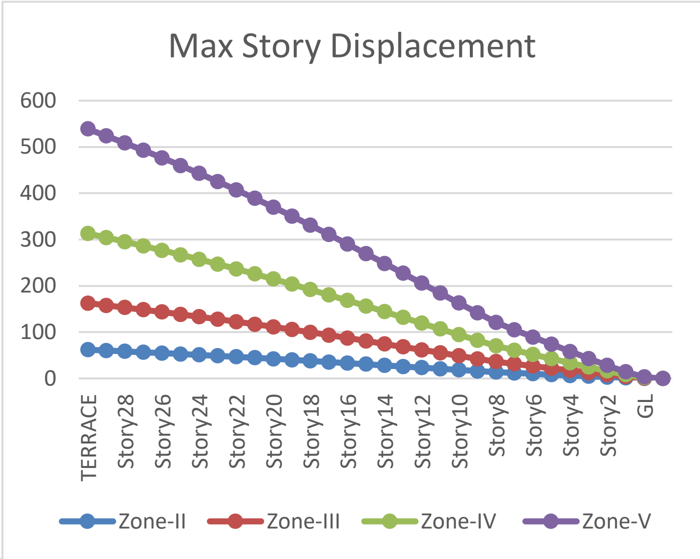


Figure 1.22: Max. Storey displacement due to Wind effect (Composite building)

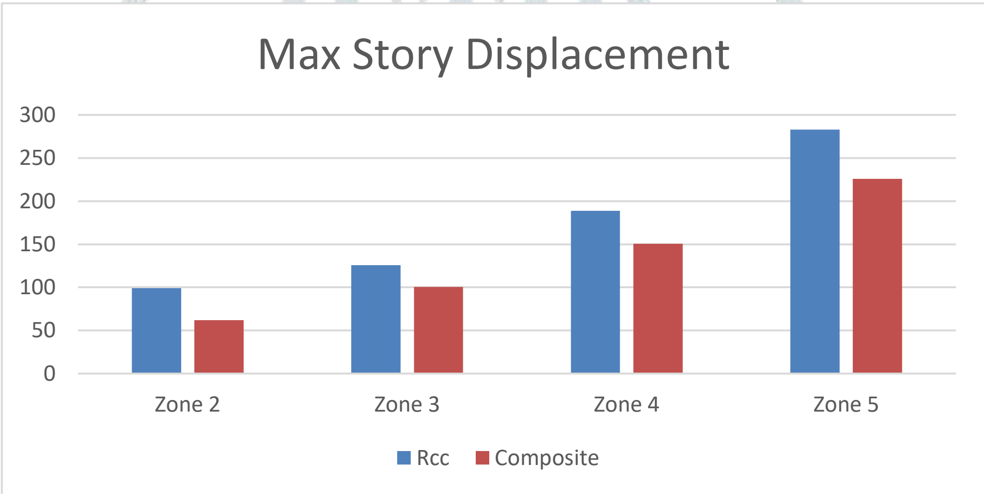


Figure 1.23: Maximum storey displacement of Rcc VS Composite G+30 building (wind effect)

- **G+40 Building**

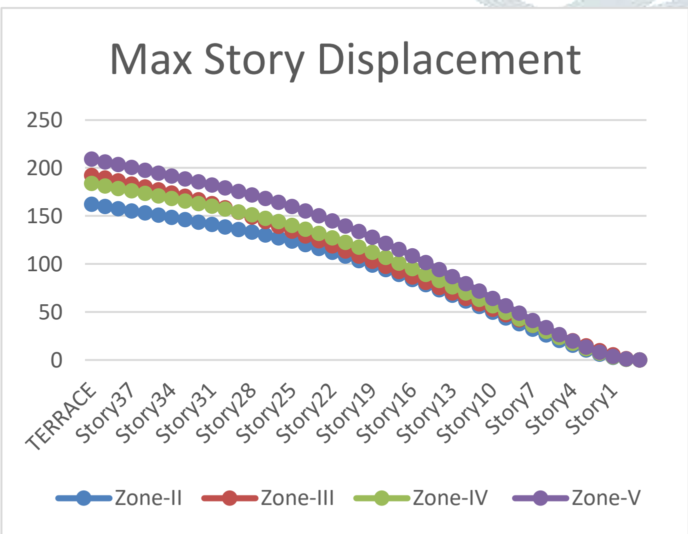


Figure 1.24: Max. Storey displacement due to Seismic effect

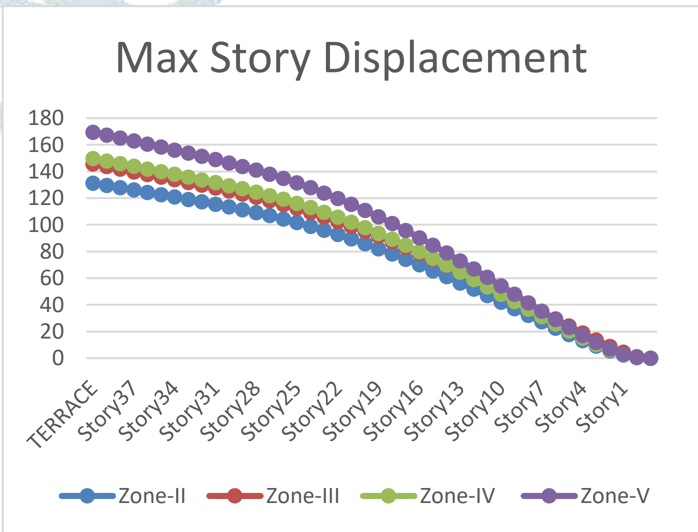


Figure 1.25: Max. Storey displacement due to Seismic effect

(RCC building) *(Composite building)*

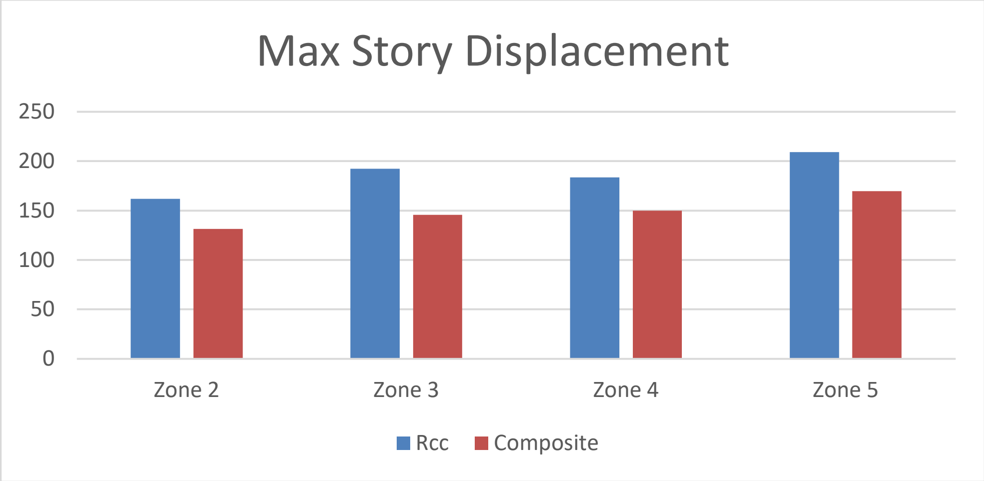


Figure 1.26: Maximum storey displacement of Rcc VS Composite G+40 building (seismic effect)

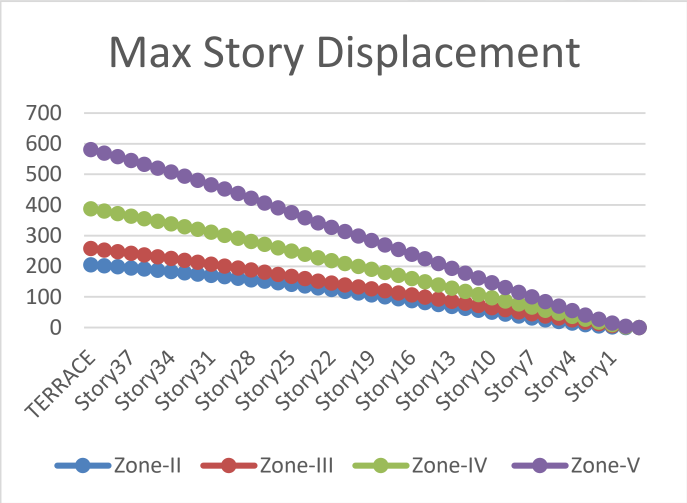


Figure 1.27: Max. Storey displacement due to Wind effect (RCC building)

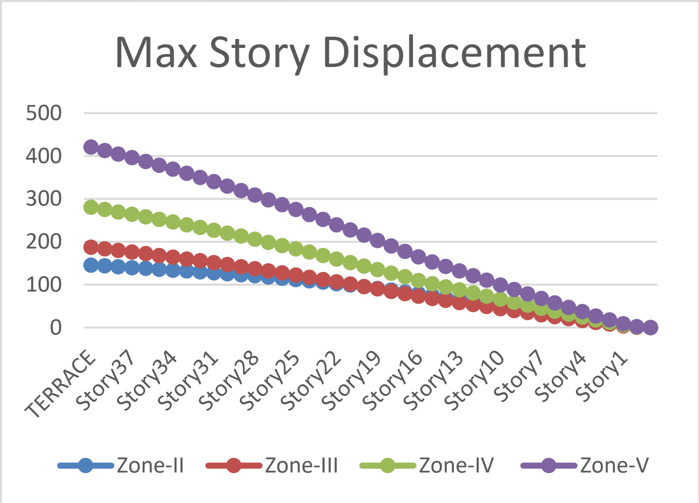


Figure 1.28: Max. Storey displacement due to Wind effect (Composite building)

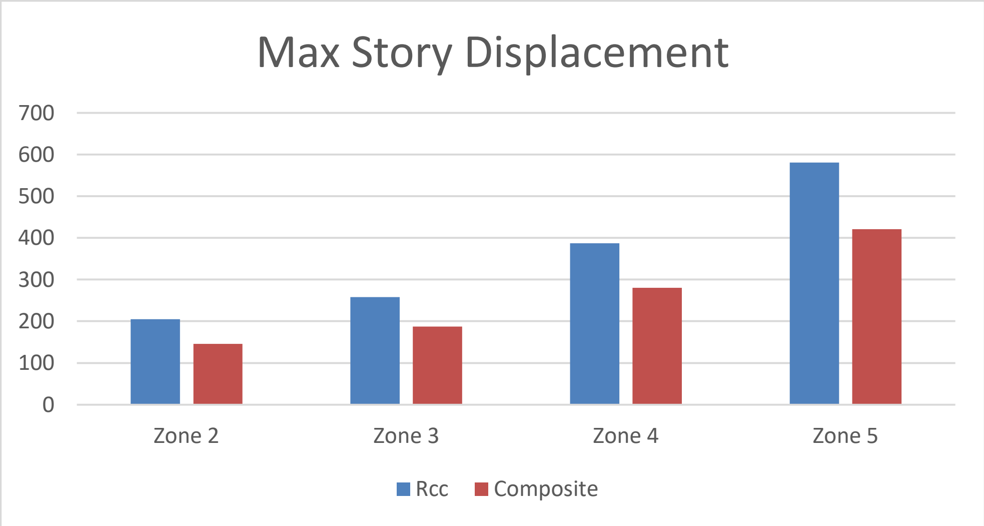


Figure 1.29: Maximum storey displacement of Rcc VS Composite G+40 building (wind effect)

VIII. Conclusion

- In case of Composite buildings, it is observed that it shows less storey displacement as compared to Rcc buildings. Composite buildings are more effective in resisting wind forces as compared to Rcc buildings.
- For G+10 building 13% to 25%, for G+20 building 17% to 36%, for G+30 19% to 35% and for G+40 building 27% to 35% reduction in storey displacement is observed for Composite building as compared to Rcc building.
- For G+10 building 22% to 39%, for G+20 building 22% to 36%, for G+30 23% to 32% and for G+40 building 18% to 28% reduction in storey displacement is observed for Composite building as compared to Rcc building.
- Maximum storey drift in G+10 was between storey 5, 6 and 7, in G+20 was between storey 11, 12 and 13, for G+30 it was between storey 13, 14 and 15, and for G+40 it was between storey 23, 24 and 25 for seismic effect.
- Maximum storey drift in G+10 was between storey 2 and 3, in G+20 was between storey 4, 5 and 6, for G+30 it was between storey 13, 14 and 15 and, for G+40 was between storey 28, 29 and 30 for wind effect.
- Base shear forces are slightly more in the Composite building as compared to Rcc building.
- In G+10 and G+20 buildings earthquake forces are governing and in G+30 and G+40 wind forces are governing.
- In G+10 not much of variance was observed between composite and Rcc building were as in G+20, G+30 and G+40 quite a variance was observed.
- Storey Drift in all the buildings is well within permissible limit i.e., 0.004h.
- Storey Displacement in all the buildings are within permissible limit i.e., H/500.
- The cost of Composite building is 30% to 40% more as compared to Rcc building.

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Standard code:

- IS: 456:2000 Plain and Reinforced Concrete- Code of Practice
- IS:1893:2016 (Part 1) Criteria for Earthquake Resistant Design of Structures
- IS: 456:2000 Plain and Reinforced Concrete- Code of Practice
- IS: 800:2007 General Construction in Steel - Code of Practice
- IS: 11384:1985 Code of Practice for Composite Construction in Structural Steel and Concrete
- IS: 1893:2016 (Part 1) Criteria for Earthquake Resistant Design of Structures
- IS: 875 part 3 :2015 Design loads (Other than Earthquake) for Building and Structures – Code of Practice