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SEISMIC ANALYSIS OF IRREGULAR PLAN MULTISTOREY RESIDENTIAL RCC BUILDING USING SHEAR WALLS AND COMPARING WITH COMPOSITE STRUCTURE

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Abstract*— Reinforced concrete structures are mostly used in India since this is the most convenient & economic system for low-rise buildings. However, for medium to high-rise buildings this type of structure is no longer economic because of increased dead load, less stiffness, span restriction and hazardous formwork. So the Structural engineers are facing the challenge of striving for the most efficient and economical design solution. This paper is an attempt to evaluate and compare the seismic performance of G+ 15 storey Irregular plan multistory residential building made of RCC and composite structures using ETABS 2015 software. A total of 10 models have been analysed in ETABS software both RCC structures and composite structures located in the region of earthquake zone v on a medium soil. Equivalent static analysis (ESA) and response spectrum analysis (RSA) method is used. Storey displacement, Storey drift, self weight, Time period, Base shear , are considered as parameters. When compared to composite structures shows better performance than RCC.

Key words: Composite Structures, Storey drift ,Base shear ,Time period, ESA, RSA.

INTRODUCTION

Nowadays, the increase in population of Indian cities demands more houses and space of land for living. The Multistory residential buildings can provide higher number of houses and requires less space of land. Most buildings are constructed by irregular in both plan and vertical configurations. Buildings suffers much less damages in earth quake with regular configurations having simple regular geometry and uniformly distributed mass and stiffness in plan as well as in elevation. Irregularities in buildings causes eccentricity between the building mass and stiffness centers, give rise to damaging effect on building. Moreover to design and analyze an irregular building a significantly high level of engineering and designer effort are needed, whereas a regular building can be easily analysed and designed without much difficulties. In this work, an attempt was made to investigate the effect of Irregular plan configuration for multistoried reinforced concrete and composite building. This paper mainly emphasizes on analysis of a multi-storey building (G+15) which is irregular in plan. The modelling of G+15 storey R.C.C. and Composite building models will be done on the ETABS 2015 software. Post analyses of the structure such as Maximum Storey Displacement, Base Shear, Storey Drift, Self weight are computed and then compared for all the analysed cases.

1.1 COMPOSITE STRUCTURE

Composite Steel-Concrete structures are used widely in modern bridge and building construction. A composite member is formed when a steel component, such as an I-beam, is attached to a concrete component, such as a floor slab or bridge deck. In such a composite T-beam as shown in fig 1, the comparatively high strength of the concrete in compression and high strength of the steel in tension

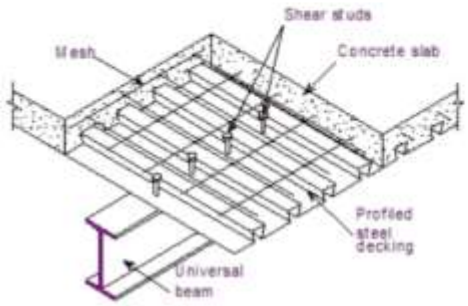

Fig 1: Typical composite beam slab details

Fig 2: Composite deck slab

1.2 Need of the Study

The RCC material is most commonly used construction material in India for multistory buildings Reinforced concrete structures are mostly used in India since this is the most convenient & economic system for low-rise buildings. However, for medium to high-rise buildings this type of structure is no longer economic because of increased dead load, less stiffness, span restriction and hazardous formwork. So the Structural engineers are facing the challenge of striving for the most efficient and economical design solution. The literature says that if properly configured, then composite steel-concrete system can provide extremely economical structural systems with high durability, rapid erection and superior seismic performance characteristics. This paper discusses comparison of G+15 storey R.C.C and Composite Building models in ETABS 2015 Software under the effect of earthquake loading. And it is an attempt to replace the RCC material with alternate building material such as steel concrete composite material. It proves that steel-concrete composite building with shear walls provided parallel to both X and Y axis is better option.

OBJECTIVES

The objectives of this study are:

1. To study the seismic behaviour of the G+15 multistory residential building and to obtain the Maximum Storey Displacement, Base Shear, Storey Drift, Self weight of structure.
2. To study the effect of providing shear walls in RCC and Composite framed building.
3. To study and compare the seismic behavior of RCC and composite building.
4. To identify the best building configuration from different models analysis.

METHODOLOGY

The methodology of the project is as follows:

Irregular plan multistory building (G+15)

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Modelling different models in etabs software

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1) Conventional building with beams and columns (Bare frame model). (ESA,RSA ,Zone V)
2) RCC bare frame model + Shear walls @ Core location of building. (ESA,RSA ,Zone V)
3) RCC bare frame model + Shear walls parallel to X axis. (ESA,RSA ,Zone V)
4) RCC bare frame model + Shear walls parallel to Y axis. (ESA,RSA ,Zone V)
5) RCC bare frame model + Shear walls parallel to both X and Y axis. (ESA,RSA ,Zone V)

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6) Composite bare frame model. (ESA,RSA ,Zone V)
7) Composite bare frame model + Shear walls @ Core location of building. (ESA,RSA ,Zone V)
8) Composite bare frame model + Shear walls parallel to X axis. (ESA,RSA ,Zone V)
9) Composite bare frame model + Shear walls parallel to Y axis. (ESA,RSA ,Zone V)
10) Composite bare frame model + Shear walls parallel to both X and Y axis. (ESA,RSA ,Zone V)

⇓

To get best model amongst all models

⇓

Resuts and comparison

⇓

Conclusions

NOTE:
ESA : Equivalent stastic analysis (Linear static)
RSA : Response spectrum analysis (Linear dynamic)
Zone V: Earth quake seismic zone

IV. ANALYTICAL MODELLING

4.1 BUILDING DETAILS:

Type of building	RCC Building	Composite Building
Type of frame	Moment Resisting Frame	Moment Resisting Frame
No of stories Total height of building	15 stories 53.15m	15 stories 53.15m
Thickness of walls	230mm (main wall) and 100mm (partition wall)	230mm (main wall) and 100mm (partition wall)
Live load	3KN/m2 – Balcony , Corridor 2KN/m2 – All rooms	3KN/m2 – Balcony , Corridor 2KN/m2 – All rooms
Grade of Concrete	M35	M25
Grade of reinforcing Steel	Fe550 , Fe415	Fe415
Density of brick masonry	8KN/m2 (AAC-Auto aeriated concrete blocks)	8KN/m2 (AAC-Auto aeriated concrete blocks)
Sizes of columns	C1=300mmX600mm C2=300mmX900mm C3=300X1050mm	C1=230mmX400mm with encased ISHB350 C2=300mmX450mm with encased ISHB350 C3=300X750mm with encased ISHB350
Thickness of slab	150mm	150mm
Sizes of beams	B1=230X530mm B2=300X600mm	B1=ISHB400 B2=ISMB150
Zone	V	V
Soil type	II	II
Importance factor	1	1
Response reduction	5	5
Seismic zone factor	0.36 for zone V	0.36 for zone V
Damping ratio	5%	5%

Table 1 : RCC and Composite Building details.

4.2 DESCRIPTION OF THE MODELS

Here in this study we have considered ten models for the study.

Model number	Description
1	Conventional RCC building with beams and columns (Bare frame model).
2	Bare frame model + Shear walls @ Core location of building.
3	Bare frame model + Shear walls parallel to X axis.
4	Bare frame model + Shear walls parallel to Y axis.
5	Bare frame model + Shear walls parallel to both X and Y axis.
6	Composite building with beams and columns (Bare frame model).
7	Composite Bare frame model + Shear walls @ Core location of building.
8	Composite Bare frame model + Shear walls parallel to X axis.
9	Composite Bare frame model + Shear walls parallel to Y axis.
10	Composite Bare frame model + Shear walls parallel to both X and Y axis.

4.3 PLAN OF THE RESIDENTIAL BUILDING

Fig 3: PLAN OF THE RESIDENTIAL BUILDING

4.4 Modelling different models in ETABS Software

1) Conventional RCC building with beams and columns (Bare frame model).

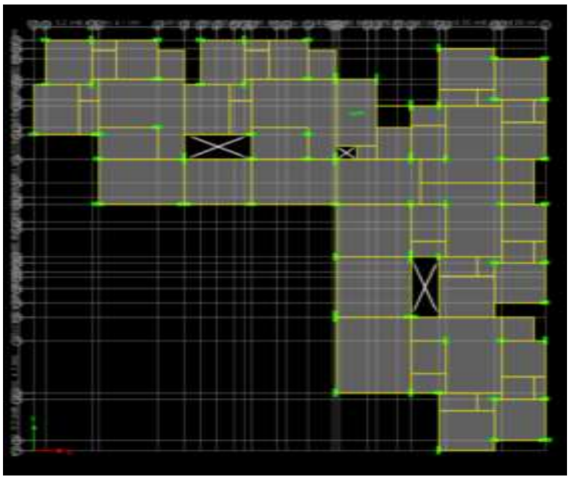


Fig 4: PLAN

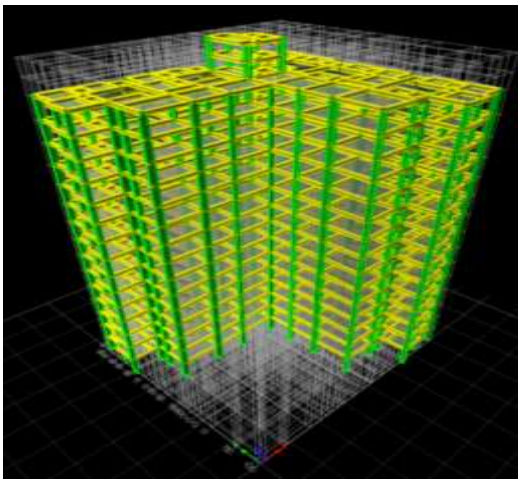


Fig 5:3D Elevation

2) Bare frame model + Shear walls @ Core location of building.

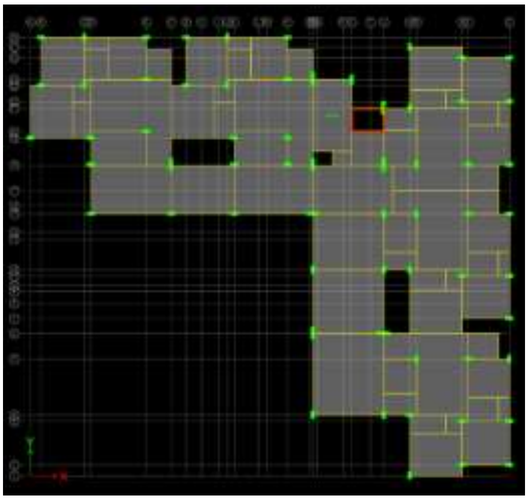


Fig 6: PLAN

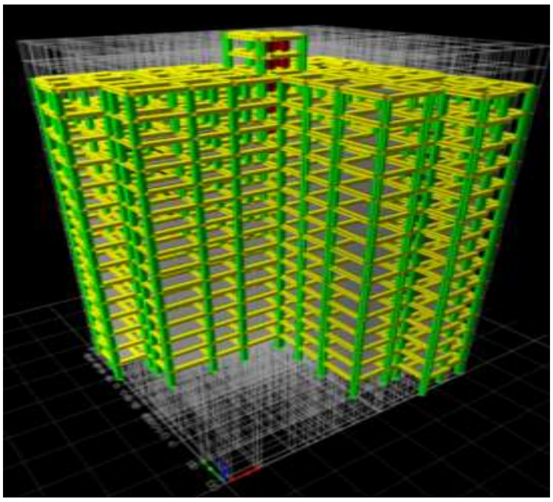


Fig 7:3D Elevation

3) Bare frame model + Shear walls parallel to X axis.

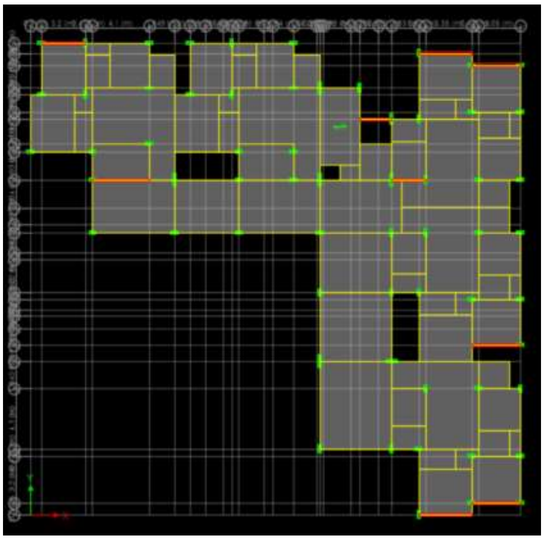


Fig 8: PLAN

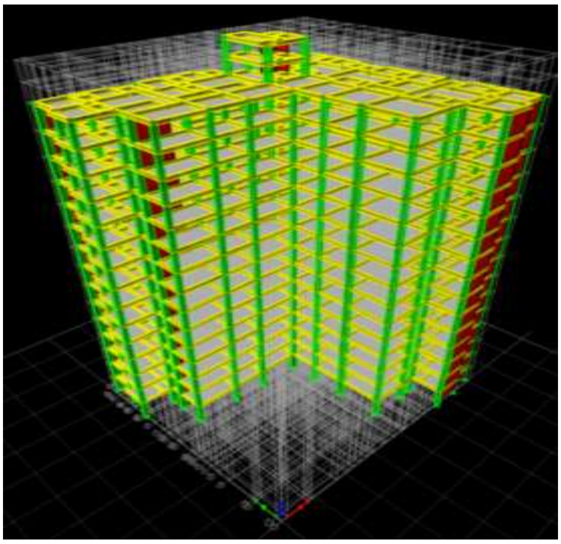


Fig 9:3D Elevation

4) Bare frame model + Shear walls parallel to Y axis.

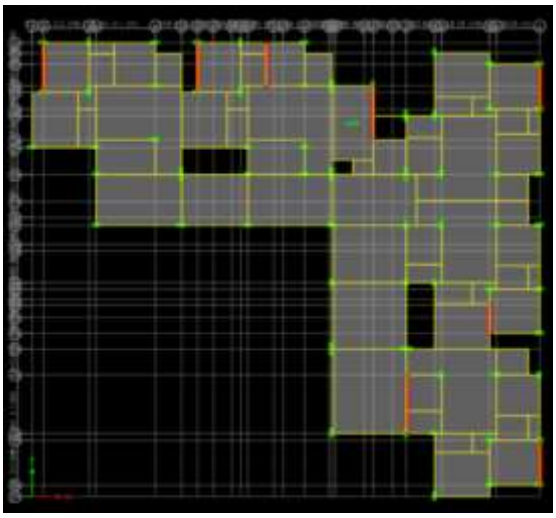


Fig 10: PLAN

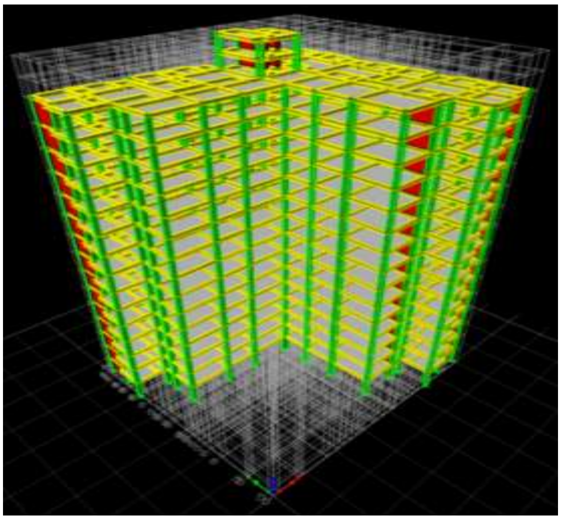


Fig 11: 3D Elevation

5) Bare frame model + Shear walls parallel to Both X and Y axis.

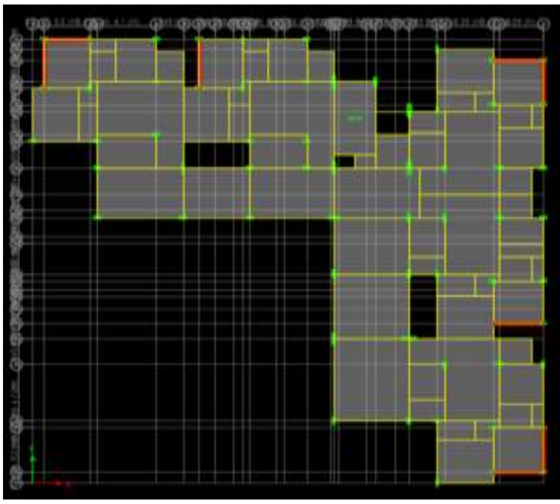


Fig 12: PLAN

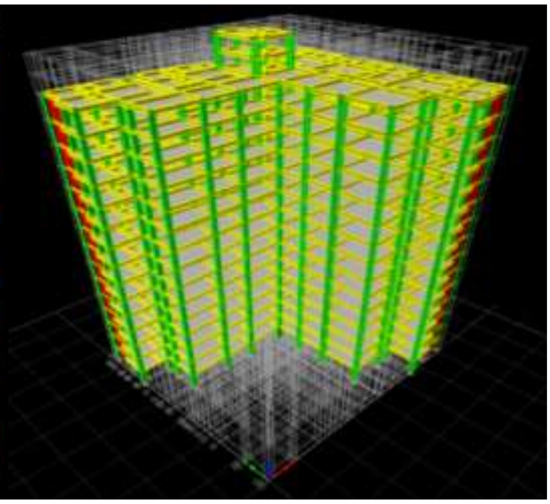


Fig 13: 3D Elevation

6) Composite building with beams and columns (Bare frame model).

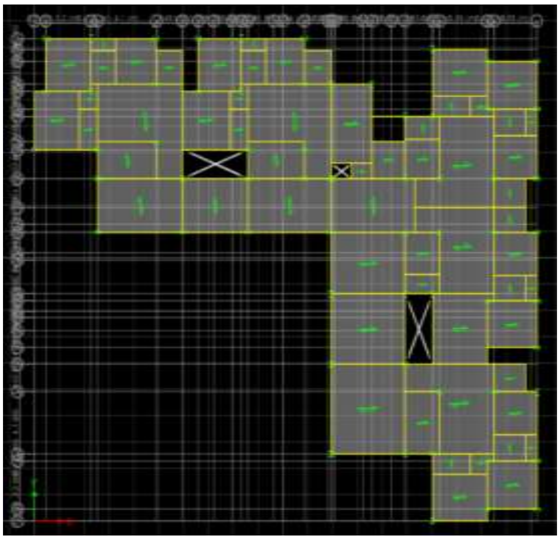


Fig 14: PLAN

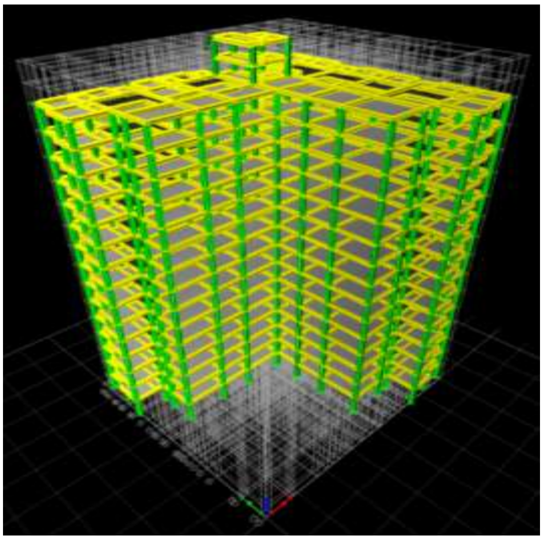


Fig 15 :3D ELEVATION

7) Composite Bare frame model with Shear walls @ Core location of building.

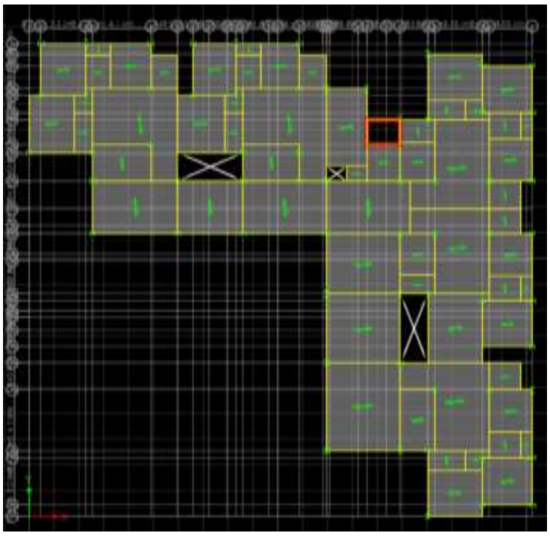


Fig 16: PLAN

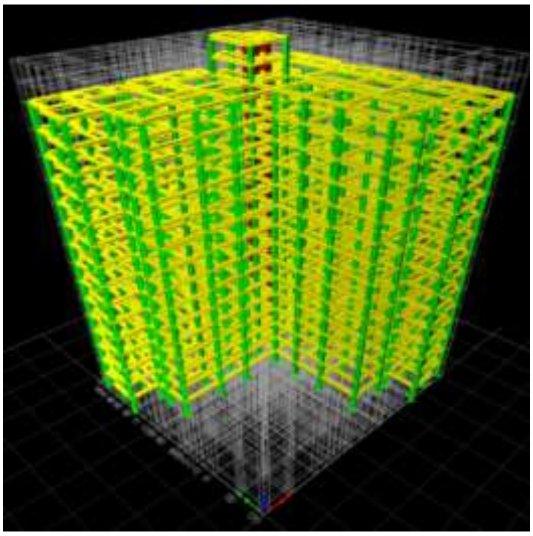


Fig 17: 3D ELEVATION

8) Composite Bare frame model with Shear walls parallel to X axis.

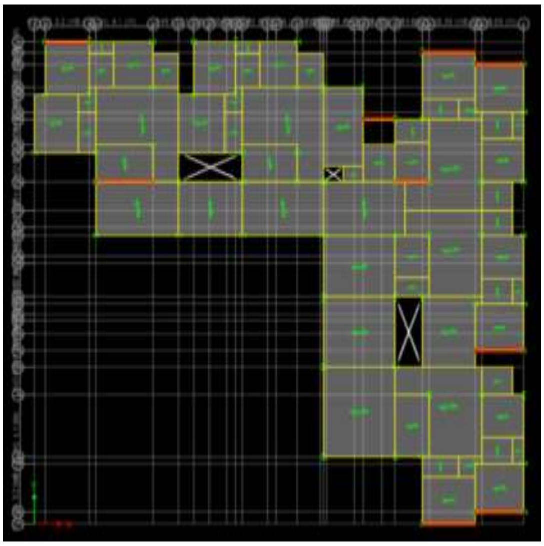
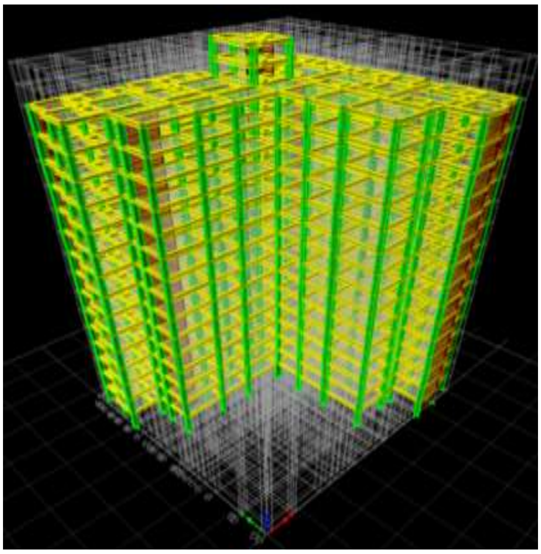



Fig 20 :PLAN

Fig 21: 3D ELEVATIION

9) Composite Bare frame model with Shear walls parallel to Y axis.

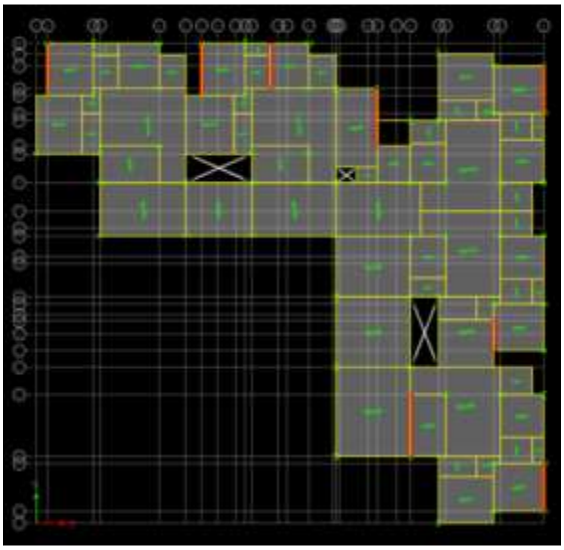
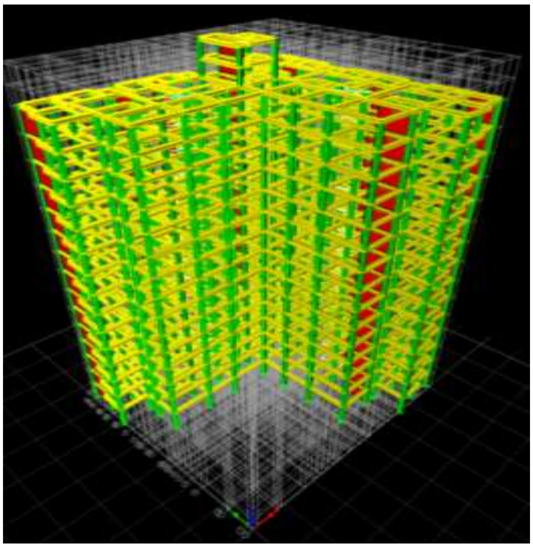



Fig 22 :PLAN

Fig 23: 3D ELEVATION

10) Composite Bare frame model with Shear walls parallel to both X and Y axis.

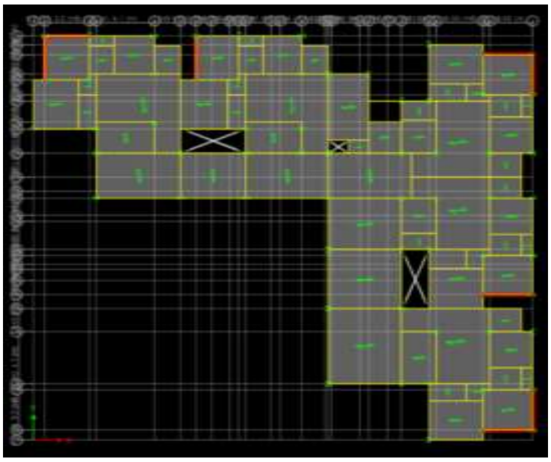
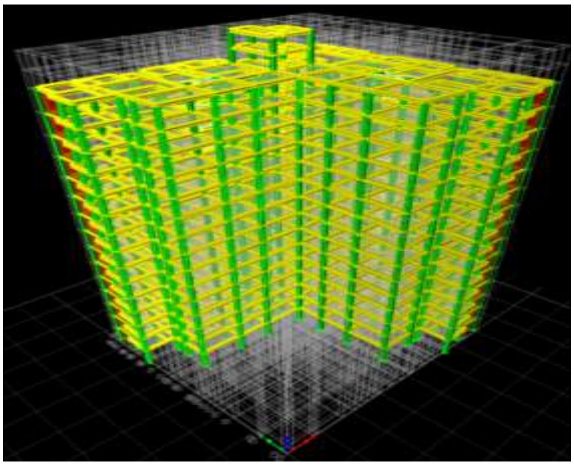



Fig 24: PLAN

Fig 25: 3D ELEVATION

V. RESULTS AND DISCUSSION

5.1 Fundamental Time period :

Time eriod in seconds	
Model No.	**ETABS Analysis**
1	3.327
2	3.14
3	2.792
4	2.8
5	1.305
6	3.073
7	2.94
8	2.692
9	2.582
10	0.5

Table 2 : Time period of Various RCC and Composite models.

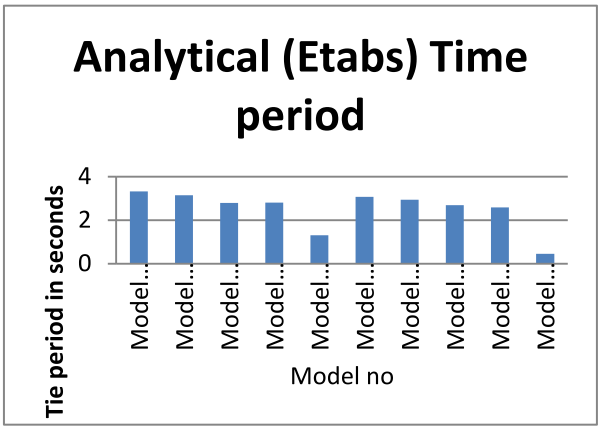


Chart 1: Time periods of various RCC and Composite models.

From the chart it is seen that, the Fundamental Time Period is highest for the bare frame model (Model 1) less for the model 10 i.e., Composite bare frame model with Shear walls provided parallel to X and Y direction. The Fundamental Time Period is found to be decrease when the influence of shear wall is considered. The Fundamental Time Period is highest for the RCC model 5 with shear walls parallel to X and Y axis and less for the Composite model 10 with Shear walls parallel to X and Y direction. The percentage decrease in Time period for model 10 is 61.68% when compared to model 5 (RCC Bare frame model with shear walls parallel to X and Y axis).

5.2 Maximum storey displacement .

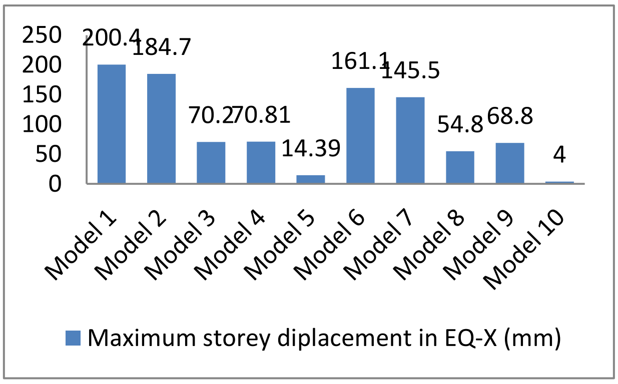


Chart 2: Maximum storey displacement of RCC & Composite models for ESA along EQ-X

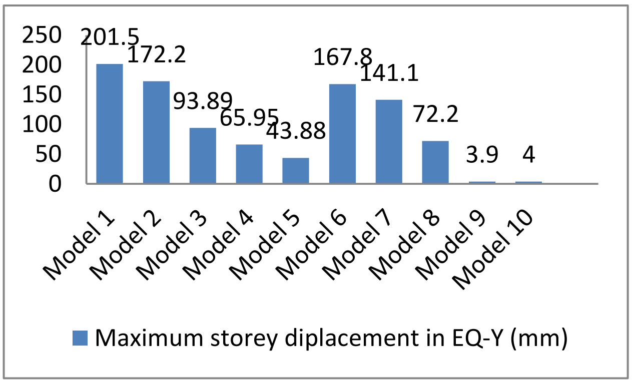


Chart 3: Maximum storey displacement of RCC & Composite models for ESA along EQ-Y

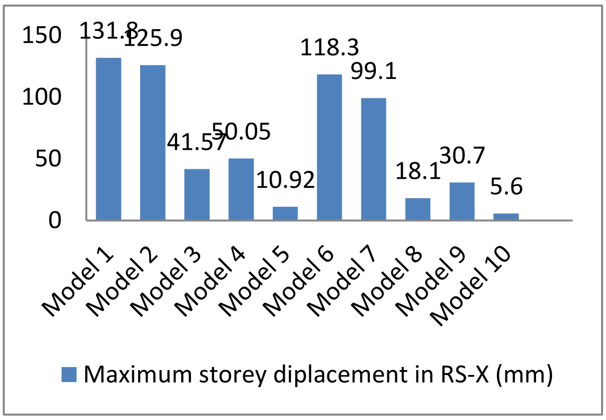


Chart 4: Maximum storey displacement of RCC & Composite models for RSA along EQ-X

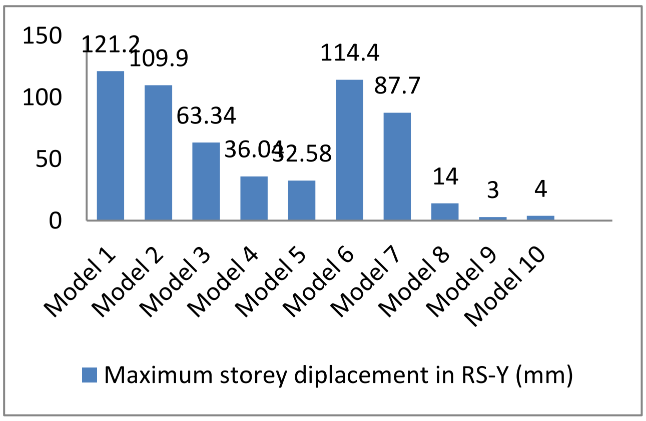


Chart 5: Maximum storey displacement of RCC & Composite models for RSA along EQ-Y

The story displacement results are summarized as follows.

	Equivalent Static Analysis (mm)		Response Spectrum Analysis (mm)	
Model No.	EQ-X	EQ-Y	RS-X	RS-Y
1	200.4	201.5	131.8	121.2
2	184.7	172.2	125.9	109.9
3	70.20	93.89	41.57	63.34
4	70.81	65.91	50.05	36.04
5	14.39	43.88	10.92	32.58
6	161.1	167.8	118.3	114.4
7	145.5	141.1	99.1	87.7
8	54.8	72.2	18.1	14
9	68.8	3.9	30.7	3
10	4	4	5.6	4

Table 3 : Maximum storey displacement of RCC and Composite models.

From the chart it is observed that, the maximum storey displacement is more for model 1 and less for model 10. The permissible Maximum displacement as per IS code is given by L/500=53130/500=106.26mm where L is total height of the building.Model 1,Model 2 exceeds permissible limits in ESA and RSA. whereas other 3 models are within the permissible limits**.** The Storey displacement is maximum for model 5 i.e., RCC bare frame model with shear walls provided parallel to X and Y axis compared to Composite Bare frame model with shear walls parallel to X and Y axis (model10). The percentage decrease in displacement for ESA and RSA are 72.22% and 90.88% in X direction and Y directions respectively for model 10 when compared to model 5. The reduction in storey displacement shows that the model 10 is stiff and less flexible.

5.3 Base shear

	Equivalent Static Analysis (ESA)		Response Spectrum Analysis (RSA)	
Model No	EQX	EQY	RSX	RSY
1	3787	3787	3222	3220
2	3944	3944	3353	3353
3	4021	2411	3453	2050
4	2359	4976	2005.15	4229.6
5	6396	6396	5505.28	5474.14
6	2629	2629	2234.75	2234.8
7	2708	2708	2301.8	2301.83
8	2890	2890	2456.45	2456.23
9	3013	3013	2561.07	2561.13
10	3034	3034	2578.41	2579.21

Table 4 : Base shea values of RCC and Composite models.

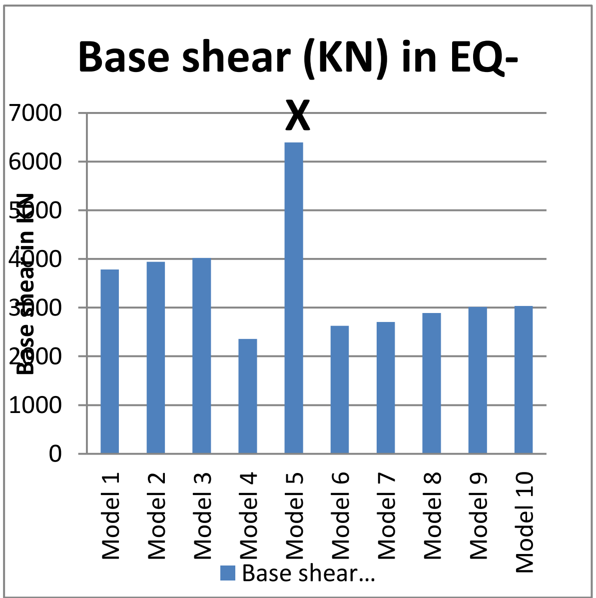


Chart 6 : Base shear of RCC and Composite models for ESA along X- direction

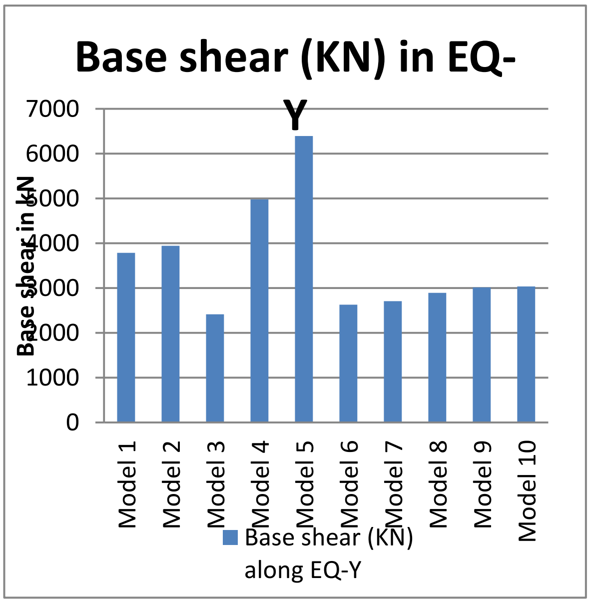


Chart 7 : Base shear of RCC and Composite models for ESA along Y- direction

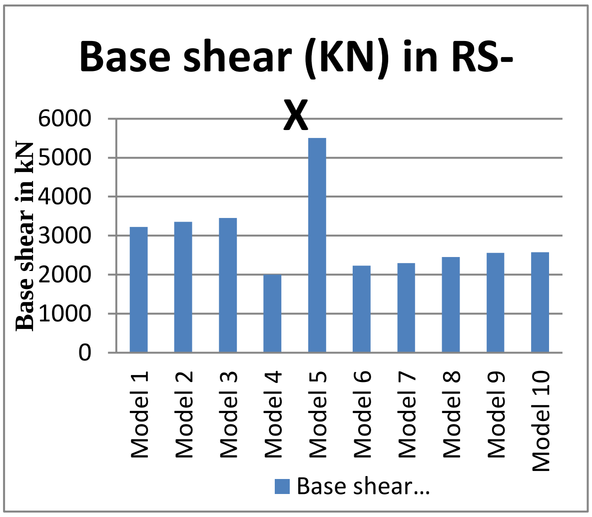


Chart 8 : Base shear of RCC and Composite models for RSA along X- direction

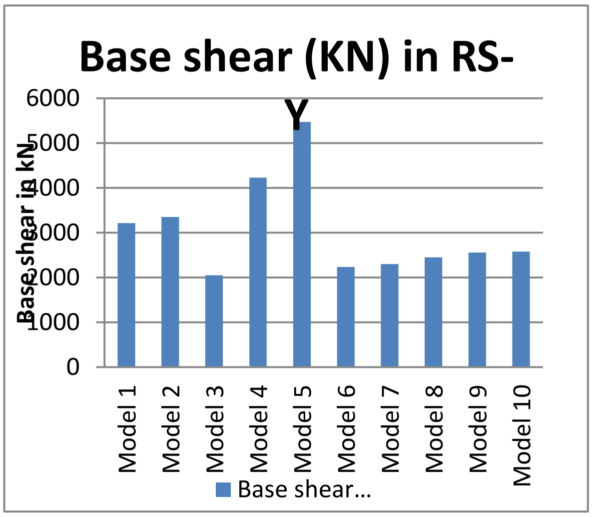


Chart 9: Base shear of RCC and Composite models for RSA along Y- direction

From the chart it is seen that , the base shear value is minimum for model 1 i.e., Bare frame model and maximum for model 5 i.e., Bare frame model with shear walls parallel to both X and Y axis for equivalent analysis (ESA). It is observed that the Composite bare frame model with shear walls parallel to X and Y axis (model 10) has minimum base shear value compared to model 5 in Equivalent static analysis (ESA) and response spectrum analysis (RSA) in X- direction, The percentage decrease in Base shear for model 10 in X direction is 52.56% for ESA and 53.16% for RSA when compared to model 5.

5.4 Storey Drift

	Equivalent Static Analysis (ESA)		Response Spectrum Analysis (RSA)	
Model No	EQX	EQY	RSX	RSY
1	0.003555	0.006144	0.004937	0.005042
2	0.003802	0.003339	0.003814	0.002168
3	0.005321	0.002723	0.000067	0.002007
4	0.001947	0.00143	0.00257	0.00022
5	0.000674	0.00067	0.000141	0.000142
6	0.00389	0.00427	0.00257	0.00275
7	0.00322	0.003043	0.001365	0.000787
8	0.000946	0.001995	0.000458	0.001204
9	0.00259	0.00009	0.00194	0.000084
10	0.000097	0.000101	0.000079	0.000085

Table 5 : Storey Drift of RCC and Composite models

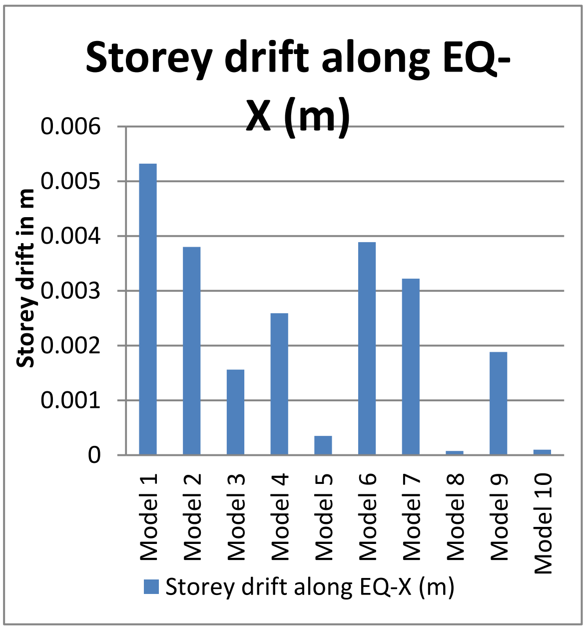


Chart 10 : Storey drift of RCC and Composite models for ESA along X- direction

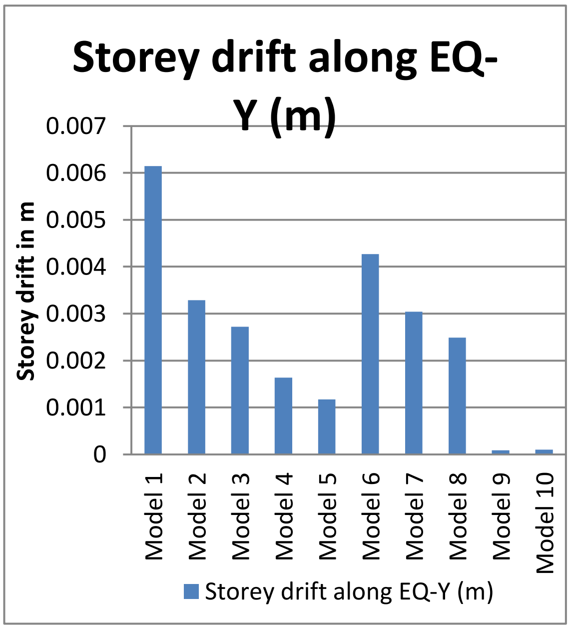
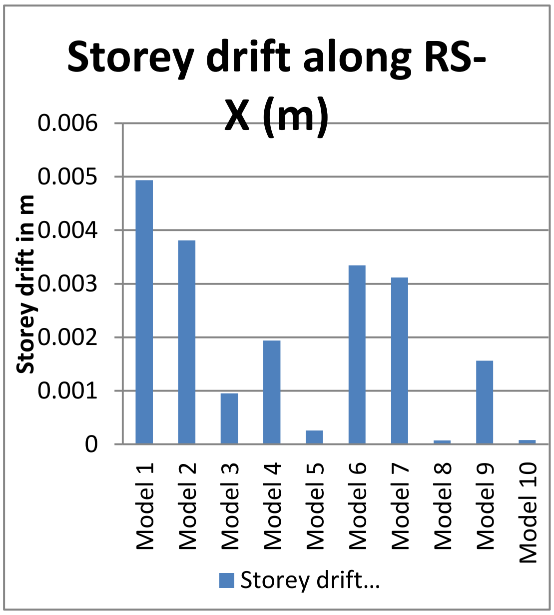


Chart 11 : Storey drift of RCC and Composite models for ESA along Y- direction



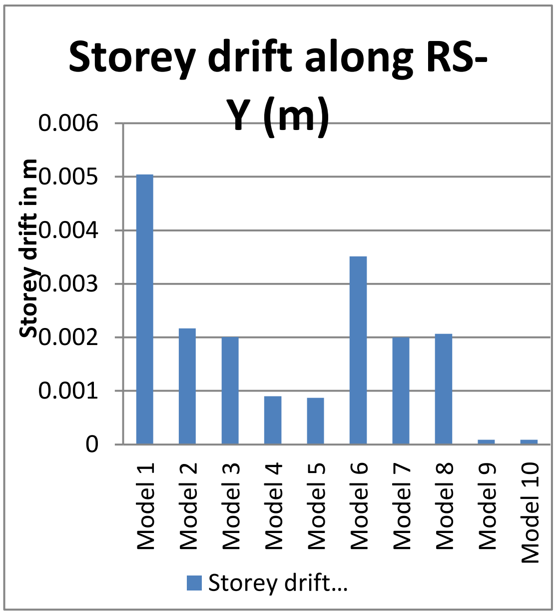


Chart 12 : Storey drift of RCC and Composite models for RSA along X- direction

Chart 13: Storey drift of RCC and Composite models for RSA along Y- direction

From the charts it is seen that ,the storey drift is maximum for RCC bare frame model (model1) and minimum for model 10 i.e., Composite bare frame model with shear walls provided parallel to X and Y axis. All the storey dift values are within the permissible limits i.e.,0.004times the height of each storey
0.004x3.35=0.0134m=13.4mm.
The percentage decrease in storey drift for model 10 is 72.20% and 91.39% For ESA in X and Y directions respectively when compared to model 5.

5.5 The self weight of RCC and Composite building

The self weight includes Dead load, lift load, wall load, floor finish and parapet wall load. The Self weight of RCC Bare frame model is 116877.8 kN and the Self weight of Composite Bare frame model is 89574.76kN.The results are obtained from ETABS Software. The results shows that the Composite structure is 23.36% lighter than the RCC structure. As a result the foundation cost of composite structure decreases as compared to RCC structure,

The RCC Structure member sizes gets reduced when the same RCC plan is analysed using Composite structure. The reduction in member sizes is shown below:

l	RCC BUILDING	COMPOSITE BUILDING
Column sizes	C1=300X600mm C2=300X900mm C3=300X1050mm	C1=230mmX400mm with encased ISHB350 C2=300mmX450mm with encased ISHB350 C3=300X750mm with encased ISHB350
Beam sizes	B1=300X600mm (primary beam) B2=230X530mm (secondary beam)	B1=ISHB400 (primary beam) B2=ISMB150 (secondary beam)
Grade of Concrete	M35	M25

Table6 : RCC and Composite structure member sizes

5.6 COMPARISON OF SALEABLE AREA IN RCC AND COMPOSITE STRUCTURE:

Carpet area covered by the RCC columns
C1=(300X600)mm
C2=(300x900)mm
C3=(300x1050)mm
Quantity of C1=54x0.3x0.6 = 9.72m2
Quantity of C2=5X0.3X0.9 = 0.9m2
Quantity of C3=3X0.3X1.05 = 0.945m2
Total Quantity = 11.565m2

Carpet area covered by Composite columns
C1=(230x400)mm
C2=(300x450)mm
C3=(300x750)mm
Quantity of C1=54x0.23x0.4 = 4.968m2
Quantity of C2=5X0.3X0.45 = 0.675m2
Quantity of C3=3X0.3X0.75 = 0.675m2
Total Quantity = 6.318m2

Assuming the minimum market rate as 4000sqft
Reduction in carpet area covered by RCC to Composite Columns =11.565-6.318=5.247m2.

The cost of carpet area saving per floor = 5.247x(3.28x3.28)x4000
= 225797Rs
The total cost of carpet area saving for 15 floors = 225797x15
= 3386959Rs

CONCLUSIONS

1) The maximum storey displacement ,storey drift, Base shear and Time period is more for the RCC Bare frame model when compared to the Composite bare frame model.
2) The maximum storey displacement,Storey drift , Base shear and Time period is more for model 5 i.e., RCC Bare frame model with shear walls provided parallel to X and Y direction and less for model 10 i.e., Composite Bare frame model with shear walls provided in both X and Y directions.
3) The Fundamental Time Period, maximum storey displacement ,Storey drift and Base shear for model 10 is less compared to all other models which shows that the model 10 is stiff ,less flexible to vibrate against lateral force.
4) The self weight of Composite structure is less as compared to RCC structure which helps in reducing the foundation cost.
5) The Base shear for composite structure is less as compared to RCC structure because the self weight of RCC structure is more as compared to composite structure.
6) The model 10 i.e., Composite bare frame model with shear walls provided parallel to X and Y axis is best economical model due to reduction in frame sizes, increase in floor area , less displacement, less storey drift ,less base shear and less time period.

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