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Comparative Analysis of RCC and Composite Hospital Building Subjected to Seismic Forces by Using National Disaster Management Authority of India Guidelines

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ABSTRACT

The National Disaster Management Authority of India (NDMA) guidelines on hospital Safety have been developed with the vision that all hospitals in India will be structurally and functionally safe from disasters, such that the risks to human life and infrastructure are minimized. In order to satisfy the proposed norms, G+6 storey reinforced concrete (RCC) and composite hospital building have been analyzed by NDMA guidelines. Response spectra method of analysis and earthquake zone III was considered. Various parameters like base shear, storey drift, story displacement, shear force, bending moment and axial force were worked out and compared. Analysis results shows RCC hospital building is having the less value of story drift and storey displacement as compared to the composite hospital building. The proposed approach for the analysis of hospital building by NDMA guidelines is useful to provide structurally safe solution from disasters.

Keywords*: Base shear, Hospital building, NDMA guidelines, Storey Drift, Storey Displacement.*

1. INTRODUCTION

The aim of the NDMA guidelines is to mainstream disaster prevention, mitigation, preparedness and response activities into the health sector in developing country, with specific focus on hospitals; such that hospitals are not just better prepared but fully functional immediately after disasters and are able to respond without any delay to the medical requirements of the affected community [1]. In high rise building the composite building is most suitable than steel and RCC building because it produces less displacement and resists more structural forces. It also seen that composite structures are resulted into lighter construction than traditional concrete construction as well as speedy construction [2]. For three storey RCC hospital building [3] having coefficient for importance 1.25, high seismic load requires the highest cross-sectional area of steel reinforcement compared to other loads and higher load will produce higher bending moment and shear force. The amount of story drift depends up on the amount of earthquake effect and also on the displacement of the story. For buildings, Earthquake zone factor for construction stages/period of a structure depending on its importance [4]. The hospital building analysed for various load cases [5] provided the solution for problem based on strengthening the weak columns by inserting reinforced concrete shear walls in the direction of y axis affected by seismic load. The dynamic analysis of composite frame structure done by non-linear time history analysis [6] indicated that the higher modes had greater influence on the 12-story Composite Special Moment Frames than the 6-story Composite Special Moment Frames, and also the maximum inter story drifts for both the 6- and 12-story high strength Composite Special Moment Frames were less than 1%, 1.5% and 3% when subjected to frequent occurrence earthquake, design basis earthquake and maximum considered earthquake ground motions. The comparative analysis of RCC and Steel-Concrete-

Composite of 11 storey building [7] showed the shear forces in main beams in composite structure are increased by average 39.43% as compared to R.C.C. framed structure while in secondary beams in composite structure are reduced by average 14.39 % as compared to RCC framed structure.

In this paper, the G+6 storey RCC and Composite hospital building was analysed by using NDMA guidelines. Comparison of story drift, story displacement, base shear, column and beam forces were carried out for both RCC and Composite building.

2. EARTHQUAKE ANALYSIS

In order to satisfy the proposed norms of NDMA guidelines, G+6 storey reinforced concrete (RCC) and composite hospital building have been analysed. Response spectra method of analysis and earthquake zone III was considered.

Structural elements of critical units of hospital buildings shall be designed to resist elastically the expected load action on them, including those due to earthquake effects. According to the guidelines of NDMA, the design horizontal acceleration coefficient A_h given in IS: 1893(1)-2016 [8] for design of structural elements shall be replaced by

$$A_h = \frac{ZI}{R}\left(\frac{S_a}{g}\right) \text{-----}(1)$$

where, Z is the Seismic Zone Factor,
I is the Importance Factor,
Sa/g is the Design Acceleration Spectrum for three different soil conditions and
R is the Response Reduction Factor
Various properties and earthquake parameters are represented in table1. Composite and R.C.C. model (Figure 1 and 2) has been developed with the help of commercially available software and different column and beam sizes were selected and represented in table 2, 3 and 4. The material properties like grade of concrete, steel, density and modulus of elasticity were defined initially and various loads like dead load, live load, super dead load and seismic loads were defined. The analysis was carried out with the help of commercially available software.

Table 1: properties and earthquake parameters

Parameter	Specifications
Number of stories	G+6
Height of each story	3.5m
Seismic Zone`	III
Zone factor Z	0.16
Importance factor I	1.5
Response reduction factor	5
Type of soil	Medium
Grade of concrete:	M30
Grade of steel for RCC	Fe415
Grade of steel for composite	Fe345
Modulus of elasticity	$2x10^5$ N/mm^2
Live loads	4 kN/m^2
Floor finish	1kN/m^2

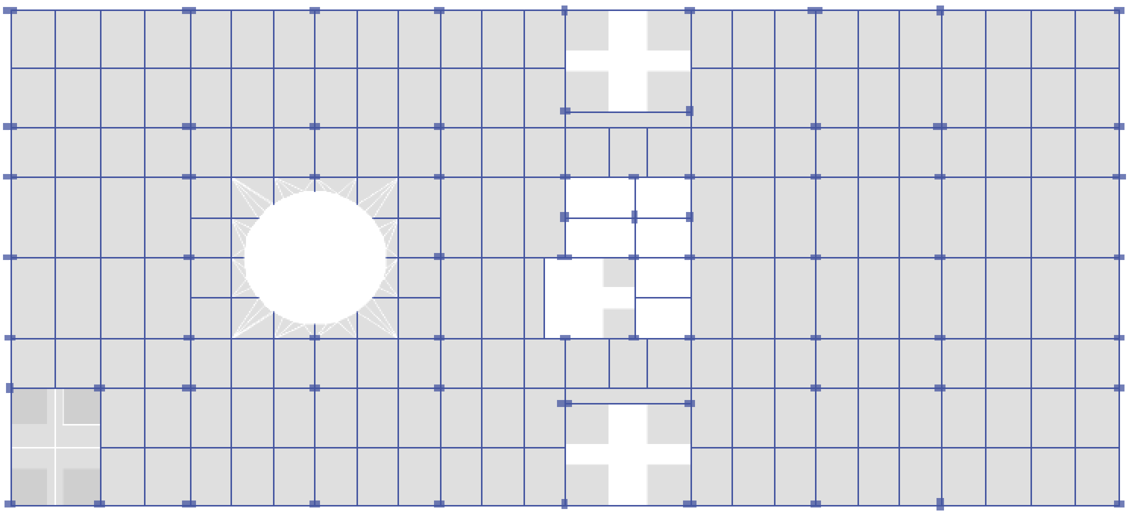

Figure 1. Plan of hospital building

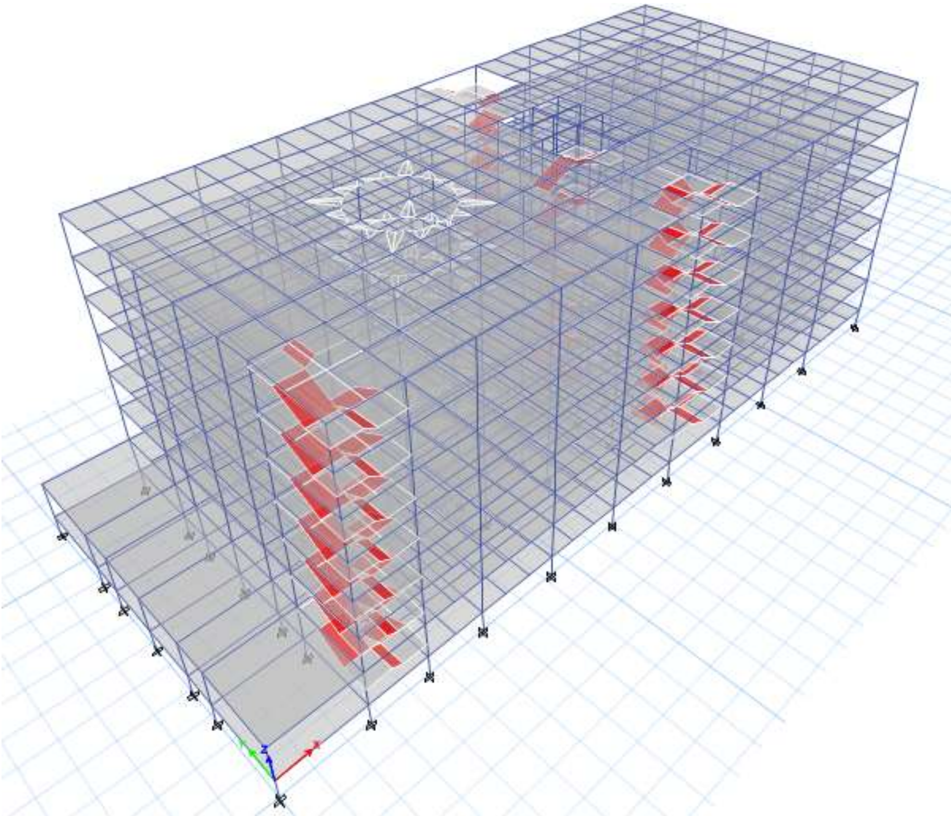

Figure 2. Three-dimensional view of hospital building

Table 2: Beam Size for composite section

Beam specification	T_f (mm)	T_w (mm)
ISMB600	20.2	12
ISMB550	19.3	11.2
ISMB500	17.2	10.2
ISMB450	17.4	9.4
ISMB400	16	8.9
ISMB350	14.2	8.1
ISMB300	12.2	7.5
ISMB200	10.8	5.7
ISMB175	8.6	5.5
ISMB150	7.6	4.8

Table 3: Beam size for RCC section

Beam size (mm)	Additional Side Plate(mm)	Equivalent retrofitted beam size (mm)
300 X 600	20	820 X 600
400 X 600	16	784 X 600
400 X 600	16	784 X 600
500 X 800	20	1520 X 800

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Table 4: Column size for RCC and composite section

Composite Column (mm)	RCC (Retrofitted Column) (mm)
500 X 500 with ISMB350 embedded	700 X900 700X1000 900X1100

3. RESULTS AND DISCUSSION

In this study, the performance of G+6 RCC and composite hospital buildings subjected to seismic forces were examined by using NDMA guidelines. To study the effectiveness of RCC and composite hospital building, the various structural parameters like base shear, storey drift story displacement, shear force, bending moment and axial force of structure were worked out and are presented below.

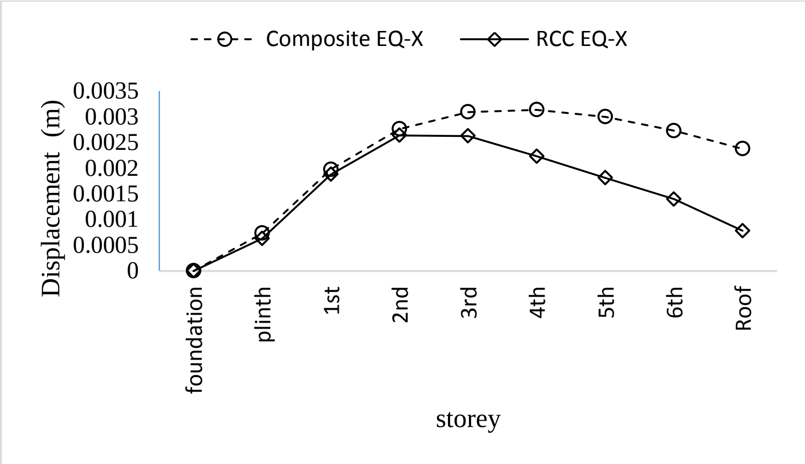

Figure 3: Storey drift in X-direction

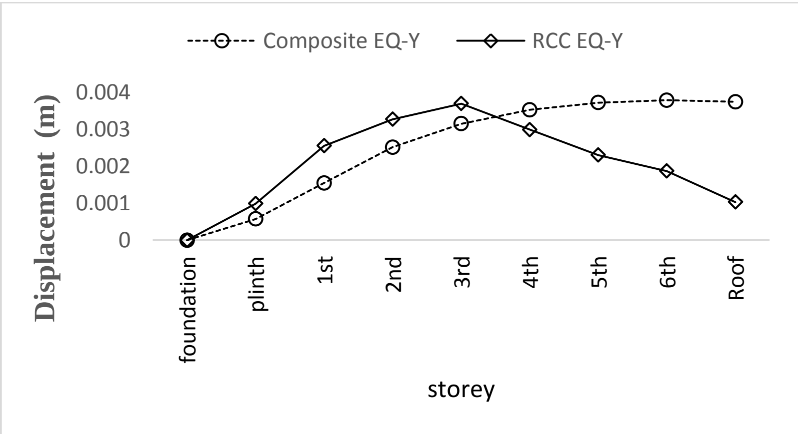

Figure 4: Storey drift in Y-direction

The figure 3 shows that RCC hospital building is having (41.5%) less value of story drift as compare to composite hospital building in X-direction due to the retrofitted cross-sectional area of RCC structural element. In Y-direction (figure 4) RCC hospital building is having the maximum value of story drift up to 3rd story and it decline consequently as the larger plan area in Y-direction. In case of composite building storey drift in Y-direction increases with storey height.

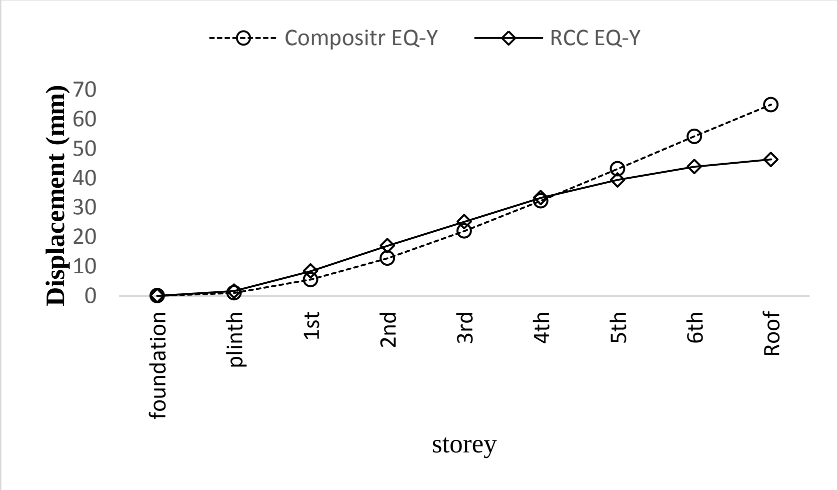

Figure 5: Storey displacement in Y-direction

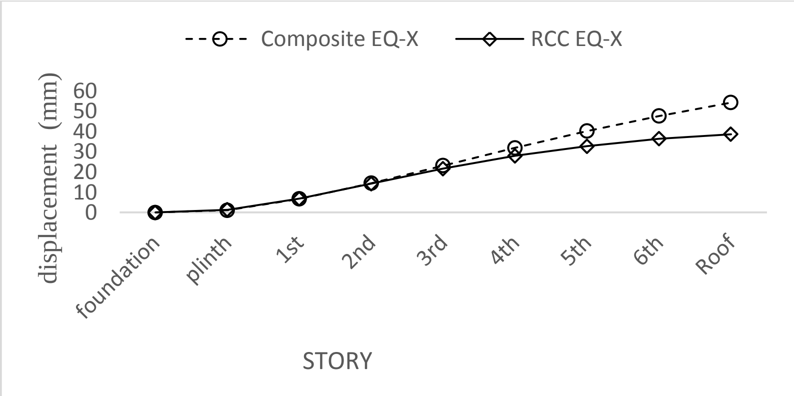

Figure 6: Storey displacement in X-direction

The figure 5 and 6 shows us that RCC hospital building is having (22%) and (10%) less value of story displacement as compare to composite hospital building in X-direction and Y-direction respectively as the composite structure is more flexible than RCC structure.

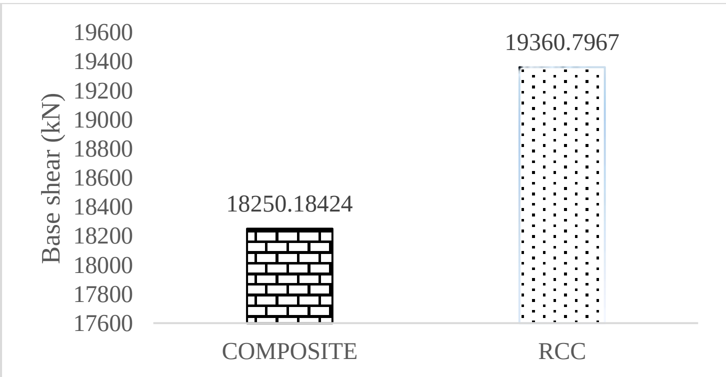

Figure 7: Base shear for RCC and composite hospital building

Base shear is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure, which is shown in the figure 7. The results noticed that base shear of composite hospital building was (6%) less than RCC hospital building, which indicates that less seismic weight which gives better seismic response during earthquake. The percentage reduction of seismic weight and self-weight was 6 % and 63 % respectively for composite hospital building as compared to RCC hospital building.

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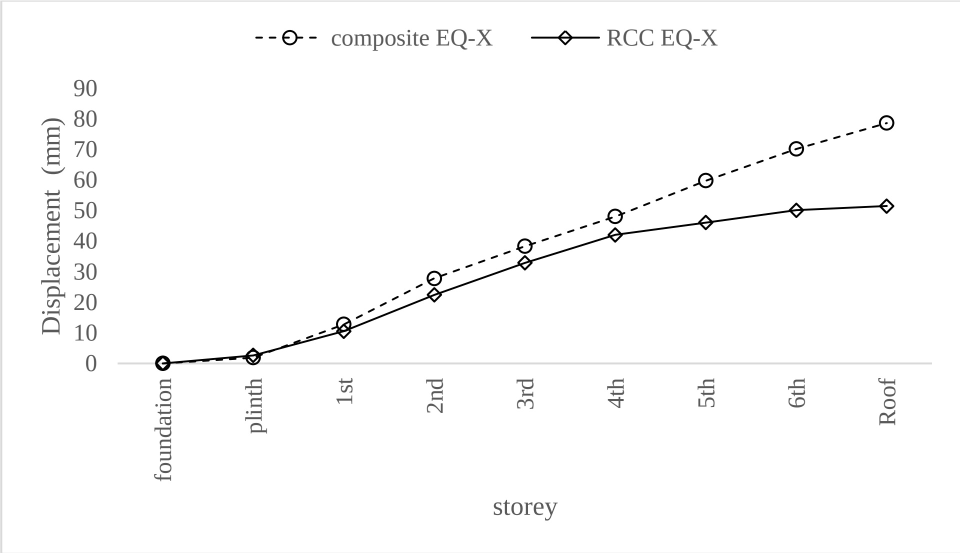

Figure 8: Joint displacement in X-direction

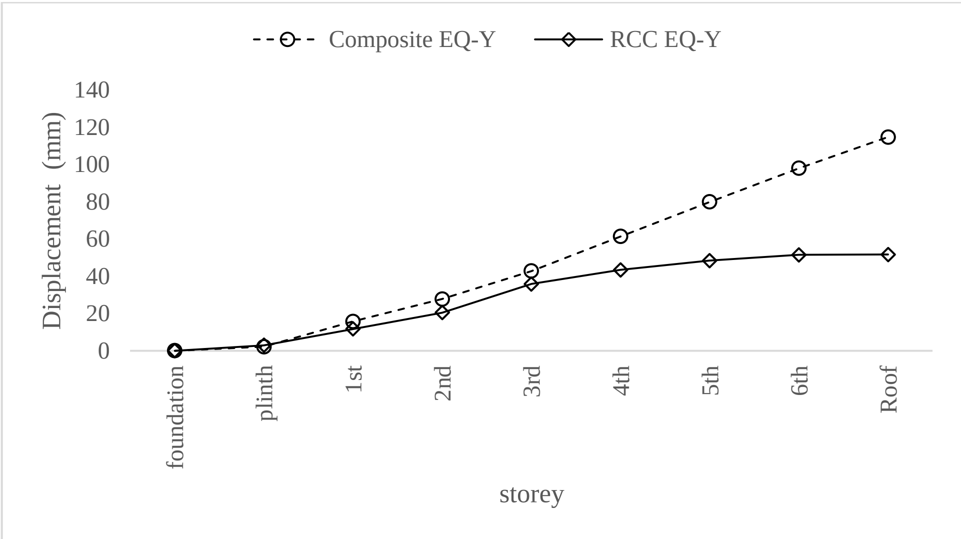

Figure 9: Joint displacement in Y-direction

The joint displacements (figure 8 and 9) in both X and Y direction in composite hospital building are 30.75% and 66.35% respectively more as compared to RCC hospital building as the composite structure is more flexible as compared to RCC structure.

Table 5: Comparison of resultant forces for composite and RCC hospital building

Storey	Shear force (kN)		Bending Moment (kN-m)		Axial force (kN)	
	Composite	RCC	Composite	RCC	Composite	RCC
plinth	1031.45	821.61	1051.84	735.14	16674.66	11256.40
1st	1700.72	1352.94	1675.58	1524.25	15433.32	8933.33
2nd	1994.32	1401.62	1997.73	1622.72	13269.24	7171.13
3rd	2010.71	1489.86	2037.70	1815.94	10714.23	6032.66
4th	1846.21	1336.86	1902.07	1767.41	8071.56	4886.34
5th	1593.43	1178.70	1656.54	1423.53	7056.06	3760.22
6th	1274.42	978.81	1359.04	1178.68	3265.48	2716.08
Roof	655.94	470.96	1126.49	930.68	1378.23	1294.62

The shear force, bending moment and axial force (table 5) values are more in case of composite hospital building as compared to RCC hospital building as it consist of large retrofitted cross-sectional area.

CONCLUSION

The various structural parameters for RCC and composite hospital buildings were analysed and compared. For both the proposed buildings having various properties and subjected to seismic loading, all the structural parameters are in the permissible limit. The result shows that storey drift and storey displacement are significantly less in RCC hospital building than composite as composite structures are more flexible. The reduction in the self-weight and seismic weight of the composite hospital building with respect to R.C.C hospital building is due to the retrofitted cross-sectional area. Composite structure is the better option as compared to RCC structures for high rise buildings as most of the structural parameters are predominant when it compared with RCC structures.

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