

Comparative Analysis of RCC and Steel-Concrete-Composite (B+G+ 11 Storey) Building

Mr. Nitish A. Mohite¹, Mr. P.K.Joshi², Dr. W. N. Deulkar³

^{1,2} Department of Civil Engineering, PVPIT, Budhgaon, Sangli, MS, India

³ Associate Professor, Department of Civil Engineering, DYPCOET, Kolhapur, MS, India

Abstract - Steel-concrete-composite buildings are formed by connecting the steel beams with concrete slab or profiled deck slab with the help of mechanical shear connectors so that slab and beam act as a single unit. In the present work, options of construction of (B+G+11storey) commercial building, situated in Kolhapur, with steel-concrete-composite and RCC are studied and compared with each other. Equivalent linear Static Method of Analysis explained in ETABS version 15 software is used and results are compared for different parameters. Comparative parameter includes roof deflections, base shear, storey drifts, for the building and axial forces and bending moments for column's and beams at different level. It is observed that steel-concrete-composite building is found to be more safe and economical and better option.

Key Words: Steel-concrete-composite, RCC, Shear connector, ETAB software, Equivalent linear Static Method

I. Introduction

In the past, structural engineers had the choice masonry building. Today multi-story buildings in India are constructed with R.C.C framed structure or Steel framed structure. Recently the trend of going towards composite structure has started and growing in us.

But the failure of many these buildings due to earthquake have forced engineer to look for the alternative method of construction. Use of composite or hybrid material remains the particular interest, due to its significant potential in improving the overall performance through modest changes in manufacturing and constructional technologies. In India, many consulting engineers are reluctant to accept the use of steel-concrete-composite structure because of its unfamiliarity and complexity in analysis and design. But literature shows that if properly configured, steel-concrete-composite system can provide economical structural systems to resist lateral load with high durability, rapid erection and superior seismic performance characteristics. As comparatively new and no updated design codes are available for the same[1], there is a need to study the composite analysis and design of the multi-story buildings keeping in view of the rapid development in this field. Hence same can be studied in Indian context.

In the present work, comparative study of RCC and Steel-Concrete-Composite (B+G+11Storey) Building is made. Comparative study includes roof deflections, base shear, storey drifts, for the building and axial forces and bending moments for column and beam, are compared for two buildings. Seismic behavior of building under seismic forces as per IS 1893-2002 are observed.

II. Composite Construction

Composite construction combines properties of concrete and steel. Steel-concrete-composite building has become now a day's quite popular because of its advantages over conventional In composite construction the two different materials are tied together by the use of shear studs at the interface having lesser depth which saves the material cost considerably. Thermal expansion (coefficient of thermal expansion) of both, concrete and steel being is nearly same. Therefore, there is no induction of different thermal stresses in the section under variation of temperature.

A steel concrete composite building consists of a composite column, structural steel beam, over which are reinforced concrete slab is cast with shear connectors between beam and slabs as shown in fig.1. The composite action reduces the beam depth. Rolled steel sections themselves are found adequate frequently for buildings and built-up girders are generally unnecessary. The composite beam can also be constructed with profiled sheeting with concrete topping or with cast in place or precast reinforced concrete slab.

A steel concrete composite column is conventionally a compression member in which the steel element is a structural steel section. There are three types of composite columns used in practice which are Concrete Encased, Concrete-filled, and Battered Section.

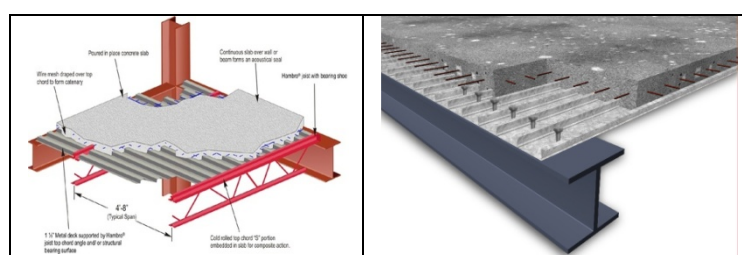


Fig1-Typical composite construction, column-footing (left) and beam-slab (right)

III. Linear static Analysis for Lateral load

IS 1893 gives procedure to satisfy the objectives[3]. This can be achieved by elastic structural response and limiting the storey drifts to minimize damage. The inelastic deformation demands are smaller than their deformation capacities on account of gravity loads and deterioration of stiffness and strength due to loading. Displacement is the key parameter for performance during earthquake rather than force or strength. Deformation can be classified in to three categories as roof displacement, Story drifts & other internal deformations and inelastic deformations for structural components and elements. These movements occur due to rigid body displacement and shear deformations.

High base shear and moment can be avoided due to

- high shear capacity requirement,
- development of ductility in elements and structure under gravity and lateral loads and hence stresses, and
- controlling lateral displacement, story drifts , forces and moments in the structure

To study the above issues, composite and RCC model has been studied and compared for the parameters mentioned. This will give the idea about the behavior of the building. The static analysis of building model is performed using IS 1893 and software ETAB version 15. Models are analyzed for lateral load (earthquake) in two lateral X and Y direction. While performing the analysis, slab is considered as rigid diaphragm. RCC model was designed as per code IS 456: 2000 [4] and composite system was designed as per code AISC 360-10 [8].

IV. Project details of Architectural plan:

Architectural plan educational building with area 41.28 x 17.21m² is shown in fig.2, constructed at Kolhapur, Maharashtra. Other considered during analysis are as follows. Other details of educational complex and site conditions are mentioned in table 1.

- Live load : 4 kN / m²
- Super Dead Load : 3 kN/ m²
- Slab thickness : 150mm
- Lift shaft : 300 mm thick shear wall
- Earthquake Zone : III
- Soil type : Hard soil
- Importance factor : 1
- Time period : User Defined
- Reduction factor : 3
- Damping Ratio : 5%
- Wind Speed : 39 m/s

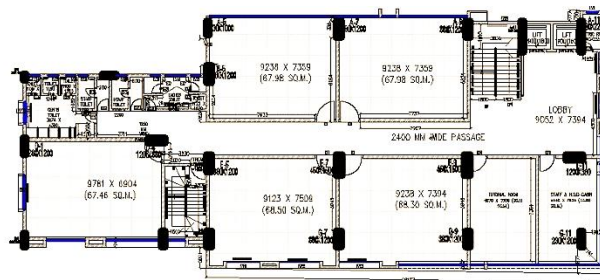


Fig 2- Typical floor Plan

Table 1-Project details

Particular	Details	Remarks
Depth of foundation	3m below GL	Basement provided
Number of stories	11	Story height - 3m
Thickness of walls	230mm	External walls
Tie at bottom level	3m interval	At 3 levels
Parking storey	2 stories	Basement and 1st floor
Parapet height	1.5m	
Type of foundation	Raft	Columns-fixed
Lift	Centre shaft	Machine roomat top
RCC water tank	Over staircase columns	At terrace level

Fig. 3 and 4 shows the typical structural plan and 3D elevation of the model respectively to be analysed.

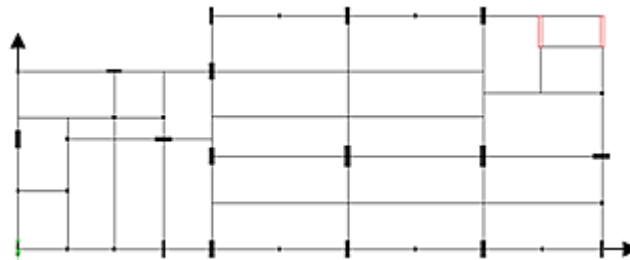


Fig3 - Typical plan for all floors of buildings in ETAB .

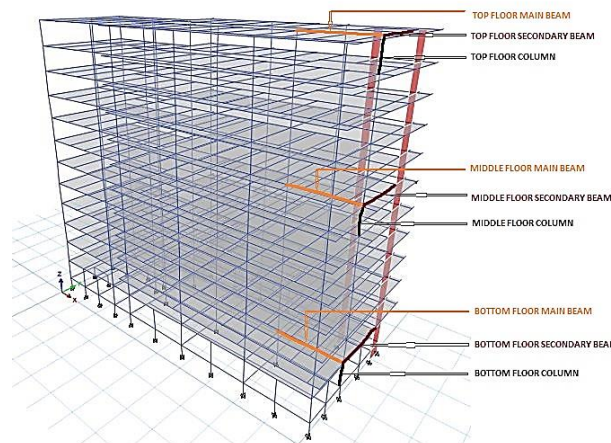


Fig. 4 – Typical 3D Model showing the selected elements.

With above data , the models were constructed, analysed and designed as per 456 and AISC code. The sizes of the different members in different model has been finalized as per strength as well as displacement requirements. The summary of final sizes for different elements are as follows. Table 2 shows of beam and column sizes used during design and analysis. Table 3 shows properties of materials used.

Table 2- Beam and column Sizes

Particular	RCC	Composite	Levels
Main beams	0.30m x 0.60m	ISMB300	Basement to 1 st Floor
Secondary Beams	0.23m x 0.60m	ISMB450	
Main beams	0.38m x 0.6m	ISMB 600	2 nd to 10 th Floor
Secondary Beams	0.3m x 0.6m	ISMB450	
Columns	0.38m x 1.2m	0.23m x 1 m with ISMB450 embedded	Basement upto 1 st Floor
	0.23m x 1 m	0.23m x 1 m with ISMB300 embedded	1 st to 10 th Floor

Table 3- Properties of material

Name of materials	E, MPa	v	α	G, MPa	Unit Weight, kN/m ³	F _c , MPa	F _t , MPa
M30	27386.13	0.2	9.9E-06	11410.89	25	30	-
STEEL	199947.98	0.3	1.17E-05	76903.07	76.8195	344.74	448.16

V. Results of analysis in two different models

Following are the results of analysis. Comparison of parameters mentioned is tabulated in following tables. Response of Storey displacement and Drift for earthquake in X and Y direction is shown in fig 5 and 6 respectively. Results are presented for load combination 1.5(DL + LL + EQX/WL). Mass source is from load, which is, lumped at story levels. Contribution of dead load was 100% and from live load was 50% as live load is more than 3 kN/m². In modal analysis, CQC method of combination was used and SRSS method was followed for directional combination. 12 modes were considered in modal analysis. Response spectrum method was used to apply earthquake load as per IS 1893 [5] and wind load as per IS 875[6].

Table 4-Roof displacement

Load combination	Parameter	Type of Model	
		RCC	COMPOSITE
DL+LL+EQX	UX, mm	213.6	102.1
	UY, mm	-13.7	-13.9

	UZ, mm	-14.1	-11.6
DL+LL+W LX	UX, mm	22	16.2
	UY, mm	-31.8	-18.4
	UZ, mm	-13.6	-11.5

Table 5- shows Base shear, base moment, torsional moment due to earthquake and wind loads for the load combination dead load plus live load plus, earthquake or wind load. It is seen that the base shear is more in case of RCC than Composite structure. Vertical reaction is same in all the cases irrespective of earthquake/wind load applied in x and y direction. The torsional moment is observed to be same in both model. Bending moment about the transverse axis of load applied is more than the moment about self-direction. These moment is little bit more in case of earthquake load combinations.

Table 5-Base shear, base moment, torsion due to earthquake and wind load

Load Combination	Parameter	Type of model	
		RCC	Composite
DLLLEQX	Base Shear (in kN)	-6,357.68	-5,807
	Base Moment (in kN-m)	11,05,462	10,11,275
	Torsion (in kN-m)	55,710.01	50,977.71
DLLLWX	Base Shear (in kN)	-940.072	-940.072
	Base Moment (in kN-m)	12,70,602	11,76,414
	Torsion (in kN-m)	8,806.779	8,806.779

Fig.5a and b shows the variation of drift along the storey height. It is seen that story drift is less in case of earthquake load and more in case of wind load.

Story drift in case of composite structure is less than RCC structure to both loads (earthquake and wind).

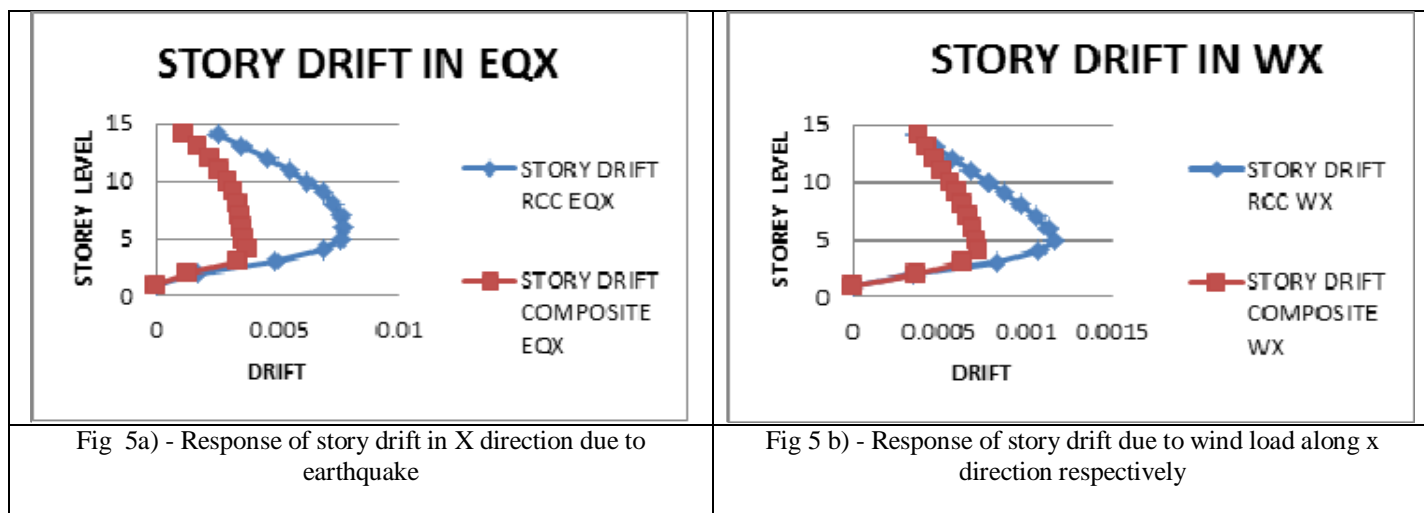


Fig 6a and b shows variation of story shear along story height. Story shear is more in case of earthquake load than wind load. Story shear is less in case of composite structure.

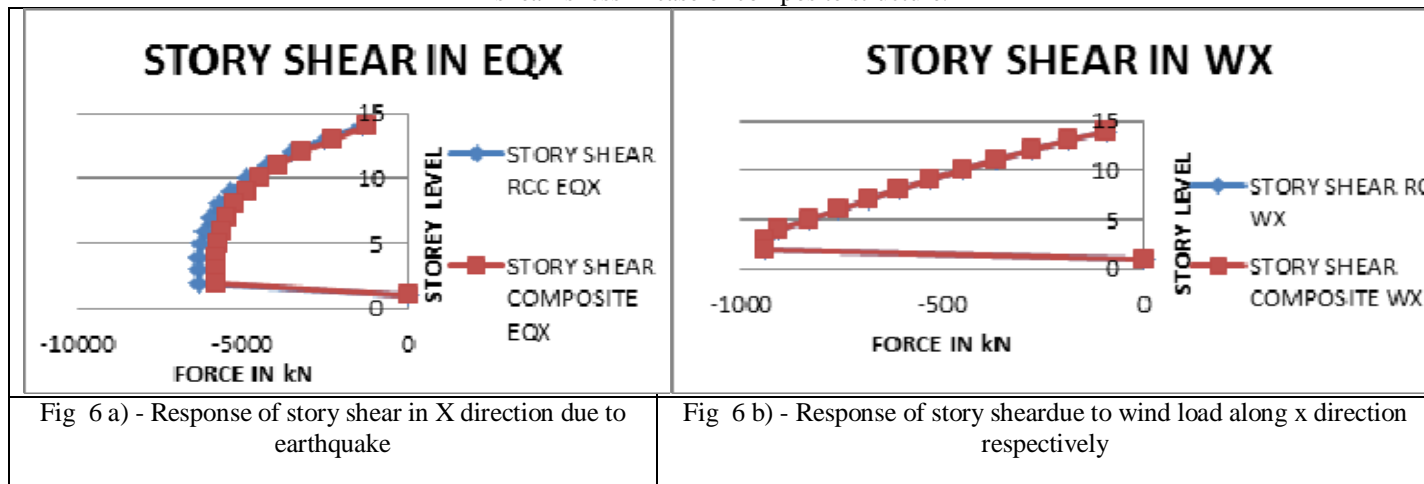


Table 6 : Max. values of different action of AF,SF, BM and TM for main beams at different story for RCC and Composite

Action	Level	Max value for RCC		Max value for Composite		Remark
		End 1	End 2	End 1	End 2	
AF	Top	0	0	0	0	Axial force in beam is absent.
	Middle	0	0	0	0	
	basement	8.53	8.53	53.97	54.14	
SF	Top	-161.14	227.76	-156.21	211.51	Shear force decreases from top to bottom.
	Middle	-49.72	340.46	-18.77	345.53	
	basement	47.57	87.21	120.64	141.42	
BM	Top	-160	-344.37	-197.96	-380.58	BM is higher in middle level beams . In top level beam , BM is less.
	Middle	266.89	-736.45	281.51	-917.99	
	basement	234.60	-260.07	446.23	-537.42	
TM	Top	30.10	-36.66	0.085	-0.099	TM is negligible for Bottom beams and max. for top level beam
	Middle	31.88	-38.53	0.0685	-0.099	
	basement	-0.16	-0.16	-0.0213	-0.0074	
All action are less for Composite structure						

Table 7 : Max. values of different action of AF,SF, BM and TM for secondary beam at different story for RCC and Composite

Action	Level	Max value for RCC		Max value for Composite		Remark
		End 1	End 2	End 1	End 2	
AF	Top	0	0	0	0	Axial force in beam is absent.
	Middle	0	0	0	0	
	basement	-23.51	-23.51	-15.71	-15.71	
SF	Top	-145.80	169.32	-133.51	181.33	Shear force decreases from top to bottom.
	Middle	-161.12	199.73	-149.49	194.08	
	basement	-22.18	42.94	-19.39	35.14	
BM	Top	-211.19	-244.75	-135.68	-255.87	BM is higher in middle level beams . In top level beam , BM is less.
	Middle	-239.34	-309	-192.37	-285.85	
	basement	1.89	-39.98	0.49	-31.01	
TM	Top	-7.60	2.89	-0.045	0.0301	TM is negligible for Bottom beams and max. for top level beam
	Middle	-23.15	8.27	-0.17	0.0969	
	basement	-5.23	-5.23	-0.049	-0.049	
All action are less for Composite structure						

Table 8: Max. values of different action of AF,SF, BM and TM for column at different story for RCC and Composite

Action	Level	Max value for RCC		Max value for Composite		Remark
		End 1	End 2	End 1	End 2	
AF	Top	-634.32	-634.32	-526.26	-526.26	Axial force increase For RCC structure From top to bottom
	Middle	-4119.35	-4119.35	-3578.95	-3578.95	
	basement	-8408.75	-8408.75	-7708.61	-7708.61	
SF	Top	-32.60	-32.60	145.43	145.43	Shear force increase For RCC structure From top to bottom
	Middle	316.35	316.35	336.22	336.22	
	basement	682.26	682.26	511.13	511.13	
BM	Top	-410.5	-332.25	91.76	-235.46	BM increase For RCC structure From top to bottom
	Middle	226.77	-532.47	454.68	-301.82	
	basement	3255.90	2641.86	1355.96	972.61	
TM	Top	-1.89	-1.89	-2.63	-2.63	Negligible TM
	Middle	0.651	0.651	-2.24	-2.24	
	basement	-0.25	-0.25	-0.78	-0.78	
All action are less for Composite structure						

VI. CONCLUSION:

- The reduction in the self-weight of the Steel-Concrete Composite structure is reduced by is 9.48 % as compared to R.C.C. frame Structure.
- 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.
- Bending moments in main beams in composite structure are increased **52.57%** as compared to R.C.C. framed structure while in secondary beams in composite structure are reduced by average **28.93 %** as compared to RCC framed structure.
- Axial forces in column in Composite framed structure have been reduced by average reduced by average **9.08 %** as compared to RCC framed structure.
- Overall response of composite structure is better than RCC structure i.e. composite structure produces less displacement , resist more structure forces/ action. Earthquake response is more than wind load.
- In both the options the values of story displacements are within the permissible limits as per code limits. Still roof displacement and drift with earthquake in X and Y direction are less in Composite framed structure as to R.C.C. framed structure. This may be due to more ductility in case of Composite structure as compared to the R.C.C. which is best suited under the effect of lateral forces.

From the observations and concluding remark, it can be said that Steel-Concrete-Composite option is better than RCC for high rise building.

VII. REFERENCES:

1. [1] Institute for steel development & Growth, "B+G+40 Storied Residential Building with Steel-Concrete Composite Option" *India, Dec 2007*.
2. [2] M. Nageh, "How To Model and Design High Rise Building Using ETABs Program" *Cairo 2007*.
3. [3] M. Willford, A. Whittaker and R. Klemencic, "Recommendations for Seismic Design of High-Rise Buildings" *Council of Tall building and urban habitat Feb 2008*.
4. [4] IS: 456, Code of practice for plain and reinforced concrete code of practice, Bureau of Indian Standards, New Delhi, 2000.
5. [5] IS: 1893, Criteria for earthquake resistant design of structures –general provisions for buildings, Part 1, Bureau of Indian Standards, New Delhi, 2002.
6. [6] IS: 875, "code of practice for design load (other than earthquake) for buildings and structures" Bureau of Indian Standards, New Delhi, 2002.
7. [7] IS: 800, Code of practice for general construction in steel, Bureau of Indian Standards, New Delhi, 2007.
8. [8] AISC 360-10, Specification of structural steel building, An American national standard, American Institute Of Steel Construction, Inc., 2005.
9. [9] IS: 11384, Code of practice for composite construction in structural steel and concrete, Bureau of Indian Standards, New Delhi, 1985.

Authors

First Author – Mr. Nitish A. Mohite , M.E. Civil Structural Engg. Student, Department of Civil Engineering, PVPIT, Budhgaon, Sangli, MS, India , nitish.mohite5381@google.com

Second Author- Mr. P.K.Joshi, Associate Professor, Department of Civil Engineering, PVPIT, Budhgaon, Sangli, MS, India pkjvpit@gmail.com

Third Author- Dr. W. N. Deulkar, Associate Professor, Department of Civil Engineering, DYPCOET, Kolhapur, MS, India wasudeon@gmail.com