"STATIC &DYNAMIC ANALYSIS OF MULTISTORY BUILDING USING COMPOSITE STRUCTURE"

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Abstract

Steel concrete composite construction means the concrete slab is connected to the steel beam with the help of shear connectors so that they act as a single unit. In the present work steel concrete composite with RCC options are considered for comparative study of G+15 story commercial building which is situated in earthquake zone-III and for earthquake loading, the provisions of IS: 1893(Part1)-2002 is considered. A three dimensional modeling and analysis of the structure are carried out with the help of SAP 2000 software. Equivalent Static Method of Analysis and Response spectrum analysis method are used for the analysis of both Composite & R.C.C. structures. The results are compared and found that composite structure more economical)

Keywords: *Composite beam, Column, RCC column, RCC beam, Shear Connector, SAP 2000 Software.etc…*

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1. INTRODUCTION

The use of Steel in construction industry is very low in India compared to many developing countries. Experiences of other countries indicate that this is not due to the lack of economy of Steel as a construction material. There is a great potential for increasing the volume of Steel in construction, especially the current development needs in India. Composite construction essentially different materials are completely compatible and complementary to each other; they have almost the same thermal expansion; they have an ideal combination of strengths with the concrete efficient in compression and the steel in tension; concrete also gives corrosion protection and thermal insulation to the steel at elevated temperatures and additionally can restrain slender steel sections from local or lateral-tensional buckling. This paper includes comparative study of R.C.C with Composite Story building Comparative study includes Storey Stiffness , Displacement, Drifts, Axial Force in column , Shear force in column, Twisting Moment, Bending Moments in composite with respect to R.C.C. Sections. Steel-concrete composite frame system can provide an effective and economic solution to most of these problems in medium to high-rise buildings.

1.1 Objective

The composite sections using Steel encased with Concrete are economic, cost and time effective solution in major civil structures such as bridges and high rise buildings. This project has been envisaged which consists of analysis and design of a high rise building using Steel-Concrete composites. The project also involves analysis and design of an equivalent R.C.C structure so that a cost comparison can be made between a Steel-Concrete composite structure and an equivalent R.C.C. structure.

2. ELEMENTS OF COMPOSITE STRUCTURE

In the past, for the design of a building, the choice was normally between a concrete structure and a masonry structure. But the failure of many multi-storied and low-rise R.C.C. and masonry buildings due to earthquake has forced the structural engineers to look for the alternative method of construction. Use of composite or hybrid material is of particular interest, due to its significant potential in improving the overall performance through rather modest changes in manufacturing and constructional technologies. 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. Formally the multi-story buildings in India were constructed with R.C.C framed structure or Steel framed structure but recently the trend of going towards composite structure has started and growing. In composite construction the two different materials are tied together by the use of shear studs at their interface having lesser depth which saves the material cost considerably. Thermal expansion (coefficient of thermal expansion) of both, concrete and steel being nearly the same. Therefore, there is no induction of different thermal stresses in the section under variation of temperature.

Shear Connectors:-Shear connections are essential for steel concrete construction as they integrate the compression capacity of supported concrete slab with supporting steel beams to improve the load carrying capacity as well as overall rigidity.

Fig -1, Shear Connectors

Composite Slab:- The loads are applied in such a way that the load combination is most unfavorable. Load factors of 1.5 for both dead load and imposed load are employed in design calculations.

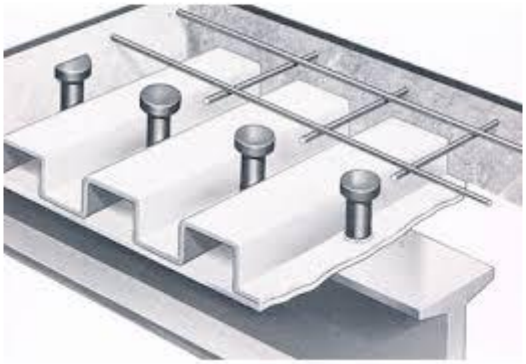

Fig 2, Composite Slab

Composite beam:-A steel concrete composite beam consists of a steel beam, over which a reinforced concrete slab is cast with shear connectors. The composite action reduces the beam depth.

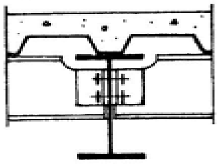

Fig 3, Composite beam

Composite Column:- 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, Battered Section.

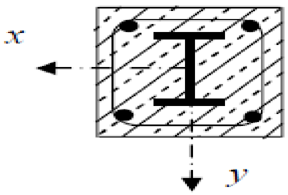

Fig -4 Composite Column

3. EARTHQUAKE ANALYSIS AND DESIGN PROCEDURE

The traditional codes gives us procedure attempts to satisfy implicitly objectives.

i) Negligible damage in once in a lifetime earthquake shaking demands having a return period of about 50 years. This can be achieved by elastic structural response and limiting the storey drifts to minimize damage to non-structural components such as cladding and internal walls.

ii) Collapse prevention under the largest earthquake demanded that may occur at the site. Such earthquake occurs with a return period of approximately 2500 years. The inelastic deformation demands are smaller than their deformation capacities taking approximate account of gravity loads, second order effects and deterioration of stiffness and strength due to cyclic loading. Also the story deformations are sufficiently small so as to prevent catastrophic damage to non structural elements. Deformations are the key parameter for performance based earthquake design rather than force or strength. Deformation can be classified in to three categories.

a) Overall building movements & Story drifts & other internal deformations.

b) Story drifts & other internal deformations.

c) Inelastic deformations for structural components and elements.

4. BUILDING DESCRIPTION

The building considered here is an office building having G+15 stories located in seismic zone III and for earthquake loading, the provisions of IS: 1893(Part1)-2002 is considered. The wind velocity 39m/s. The plan of building is shown in figure showing position Figure 4 of columns and plan dimensions. The building is planned to facilitate the basic requirements of an office building. The building plan is kept symmetric about both axes. Separate provisions are made for car parking, lift, staircase, security room, pump house and other utilities. The plan dimension of the building is 24.00m by 36.00m, which is on land area of about 1800m2. Height of each storey is kept same as 3.50m and the total height of building is kept as 59.55m. Columns are placed at 6m centre to centre and are taken to be square, as the square columns are more suitable for earthquake resistant structures. The study is carried on the same building plan for RCC and composite constructions with some basic assumptions made for deciding preliminary sections of both the structures. The basic loading on both type of structures are kept same. Other relevant data is tabulated in Table 1

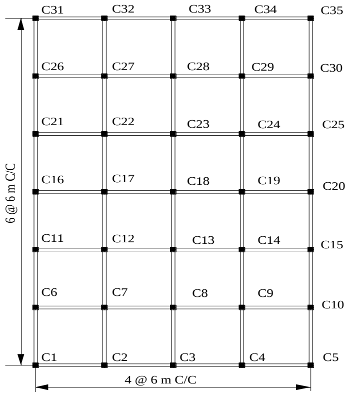

Fig 5 Position of columns and Building plan

Table - 1

Particulars	RCC Structure	Composite Structure
Plan dimensions	24m X 36m	24m X 36m
Total height of building	38.5m	38.5m
Height of each storey	3.5m	3.5m
Height of parapet	0.90m	0.90m
Depth of foundation	2.50m	2.50m
Plinth height	1.00m	1.00m
Size of beams	300mmX 600mm	ISMB400@61.6kg/m
Size of columns	700mmX 700mm	500X500mm (SC250@85.6kg/m + 125mm concrete cover)
Thickness of slab	125mm	125mm
Thickness of external walls	230mm	230mm
Thickness of internal walls	115mm	115mm
Seismic zone	III rd	III rd
Soil condition	Hard soil	Hard soil
Response reduction factor	5	5
Importance factor as per Is-1893-2002 Part -1 for different. zone as per clause 6.4.2.	1.5	1.5
Zone factor	0.16	0.16
Floor finishes	1.875 kN/m2	1.875 kN/m2
Live load at roof level	2.0 kN/m2	2.0 kN/m2
Live load at all floors	5.0 kN/m2	5.0 kN/m2
Grade of Concrete	M20	M20
Grade of concrete in composite column	----	M30
Grade of reinforcing Steel	Fe415	Fe415
Grade of Structural Steel	----	Fe250
Density of Concrete	25 kN/m3	25 kN/m3
Density of brick masonry	20 kN/m3	20 kN/m3
Damping ratio	5%	3%

4.1 Modeling of Building

The building is modeled using the finite element software SAP 2000. The analytical models of the building include all components that influence the mass, strength, stiffness and deformability of structure. The building structural system consists of beams, columns, slab, walls, and foundation. The non-structural elements that do not significantly influence the building behavior are not modeled. Beams and columns are modeled as two noded beam elements with six DOF at each node. The floor slabs are assumed to act as diaphragms, which insure integral action of all the vertical load-resisting elements and are modeled as four noded shell elements with six DOF at each node. Walls are modeled by equivalent strut approach and wall load is uniformly distributed over beams. The diagonal length of the strut is same as the brick wall diagonal length with the same thickness of strut as brick wall, only width of strut is derived. Walls are considered to be rigidly connected to the columns and beams. The 3D building model generated in SAP2000 are shown in Figure -06

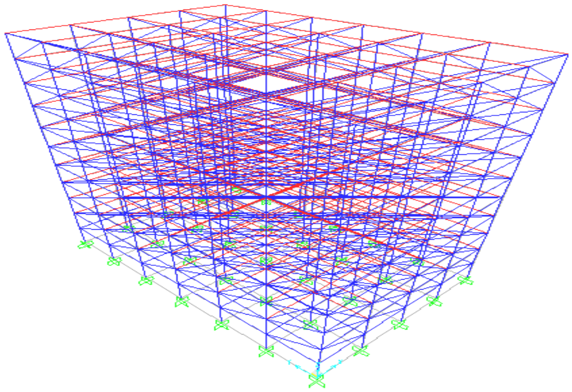

Fig 6, 3D model of commercial building

4.2 Analysis of Building

In India, Indian Standard Criteria for Earthquake Resistant Design of Structures IS 1893 (Part-I): 2002 is the main code that provides outline for calculating seismic design force.

4.2.1 Equivalent Static Analysis and Dynamic Analysis: -

a) The weight of all the floors and the roof is calculated and total seismic weight of the building is found out.

$$W = \sum_{i=1}^{n} W_i$$

b) The approximate fundamental natural period of vibration (Ta), in seconds, of all buildings, including moment-resisting frame buildings with brick infill panels, is estimated by the empirical expression

$$T_a = \frac{0.09h}{\sqrt{d}}$$

c) The design horizontal seismic coefficient A_h for a structure is determined by the following expression:

$$A_h = \frac{Z}{2} X \frac{I}{R} X \frac{Sa}{g}$$

d) The total design lateral force or design seismic base shear is determined by the following expression.

$$V_B = A_h X W$$

e) The design base shear computed as above is distributed along the height of building as per the following expression.

$$Q_i = V_B X \frac{W_i {h_i}^2}{\sum_{j=1}^{n} W_j h_j^2}$$

4.2.1 Response spectrums Analysis

a) The modal mass (Mk) of mode k is given by

$$M_k = \frac{[\sum_{i=1}^{n} W_i \phi_{ik}]^2}{g \sum_{i=1}^{n} W_i (\phi_{ik})^2}$$

b) The modal participation factor (Pk) of mode k is given by

$$P_k = \frac{\sum_{i=1}^{n} W_i \phi_{ik}}{\sum_{i=1}^{n} W_i (\phi_{ik})^2}$$

c) The peak lateral force (Qik) at floor i in mode k is given by

$$Q_{ik} = A_k \phi_{ik} P_k W_i$$

d) The peak shear force (Vik) acting in the storey i in mode k is given by

$$V_{ik} = \sum_{j=i+1}^{n} Q_{ik}$$

e) The design lateral forces, Froof and Fi, at roof and at floor i is given by

$$F_{roof} = V_{roof} \text{ and } F_i = V_i - V_{i+1}$$

5. RESULTS AND DISCUSSION

5.1 Equivalent Static Analysis

Equivalent static analysis is performed on both types of structures. Loads are calculated and distributed as per the code IS1893: 2002 and the results obtained are compared with respect to the following parameters.

i) **Storey stiffness**: - It can be observed that transverse and longitudinal storey stiffness for composite structure is large as compared to RCC structure. The storey stiffness for composite structure is about 12% to 15% more in transverse direction and about 6% to 10% more in longitudinal direction than the RCC structure. Shown in Figure 07 and 08

Chart -1 Comparison of storey stiffness

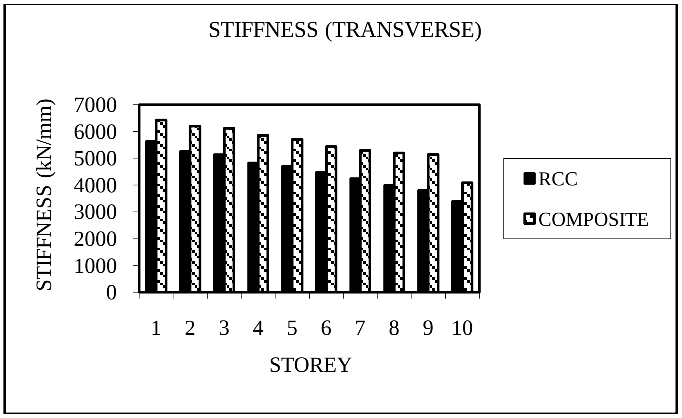

Chart -2 Comparison of storey stiffness

ii) **Lateral displacement:** - Displacement in composite structure is reduced by 41% to 58% in transverse direction and about 37% to 57% in longitudinal direction than that in RCC structure.

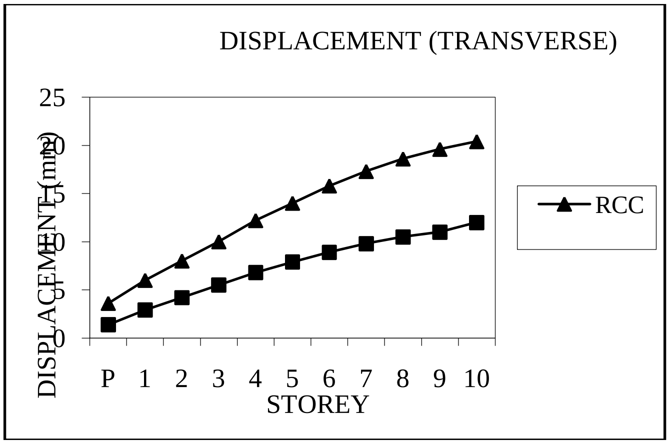

Chart-3 Comparison of displacements

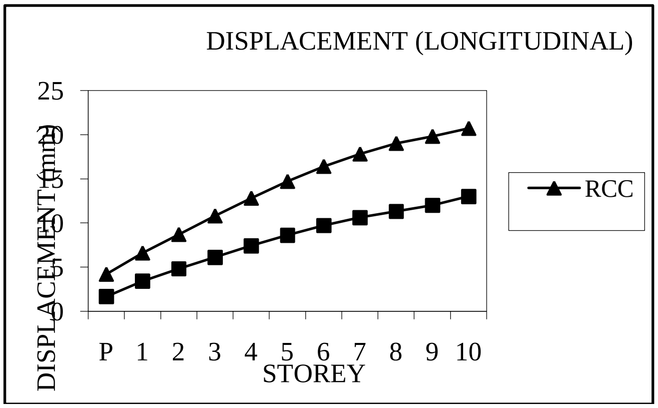

Chart-4 Comparison of displacements

iii) **Storey drift**: - The result shows that the inter storey drift for composite structure is comparatively less than RCC structure in both transverse and longitudinal direction. The storey drift is reduced by 35% to 50% and 27% to 38% in transverse and longitudinal directions respectively.

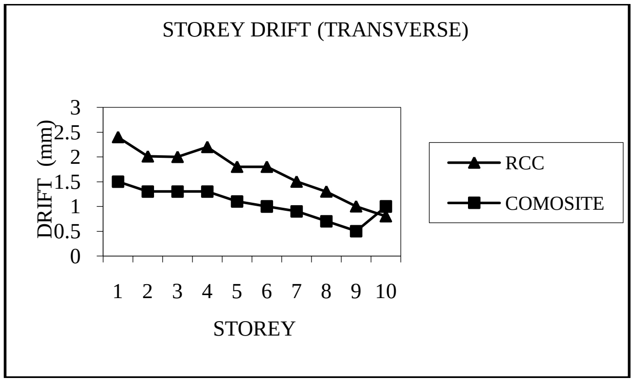

Chart-5 Comparison of storey drifts

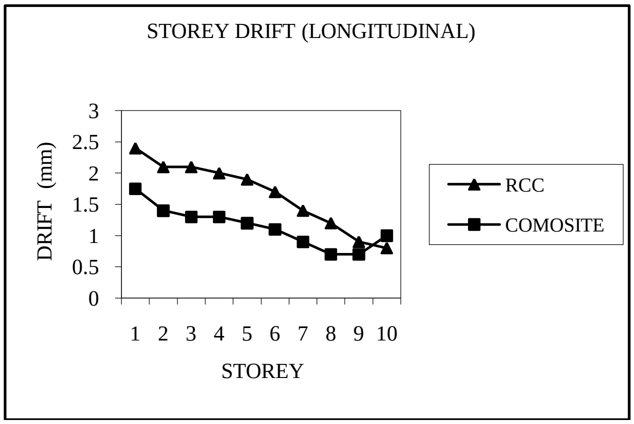

Chart-6 Comparison of storey drifts

iv) Axial force, shear force, twisting moment and bending moment in columns:- The result shows that axial force in composite columns is reduced by 20% to 30% than RCC columns shown in fig. 9 and From figure 10 and 11 Shear force in composite column is reduced by 28% to 44% and 24% to 40% in transverse and longitudinal directions respectively. The figure 12 and 13 shows that the twisting moments are found to be negligible and for composite structure these are reduced by 48% to 63% and 49% to 65% in transverse and longitudinal directions respectively as compared to RCC structure. The Chart 7 to13 that the bending moment in composite columns is reduced up to 22% to 45% in transverse direction and 23% to 47% in longitudinal direction as compared to RCC columns.

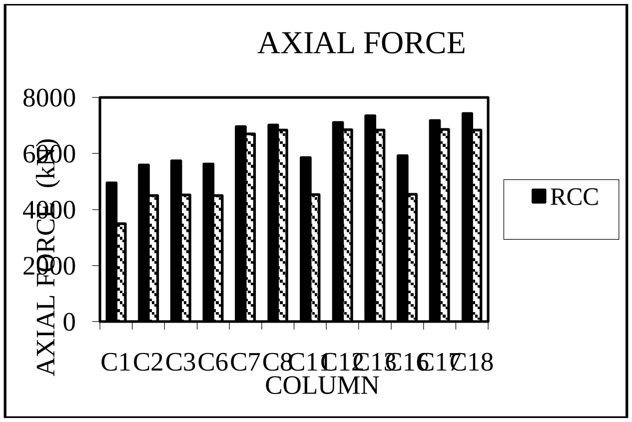

Chart-7 Comparison of axial force in columns

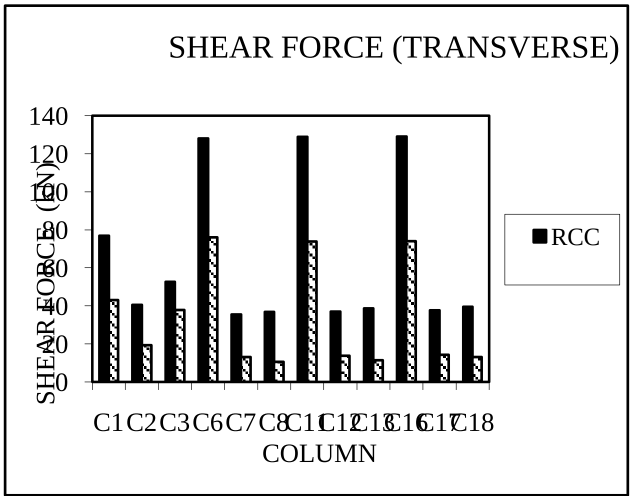

Chart-8 Comparison of shear force in columns

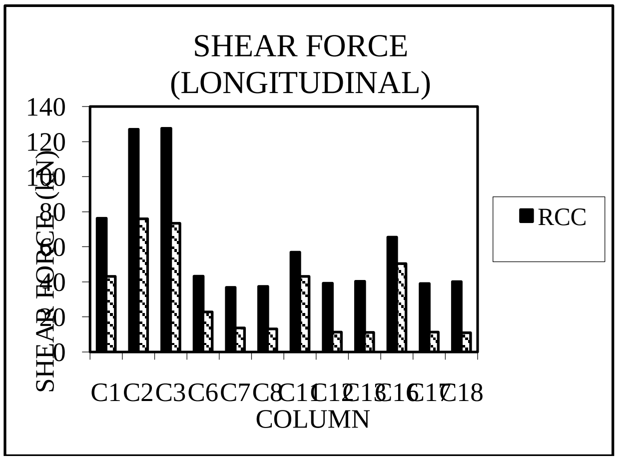

Chart-9 Comparison of shear force in columns

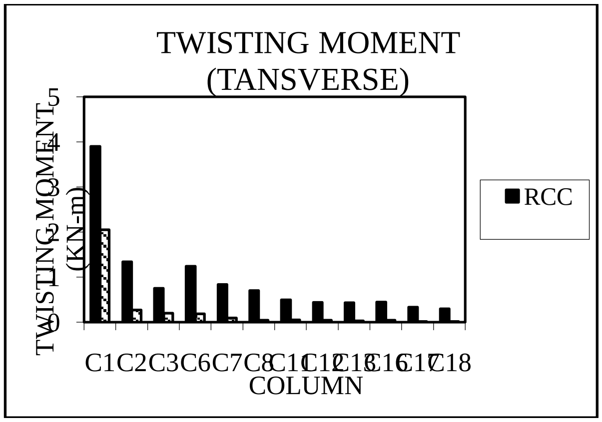

Chart-10 Comparison of twisting moment in columns

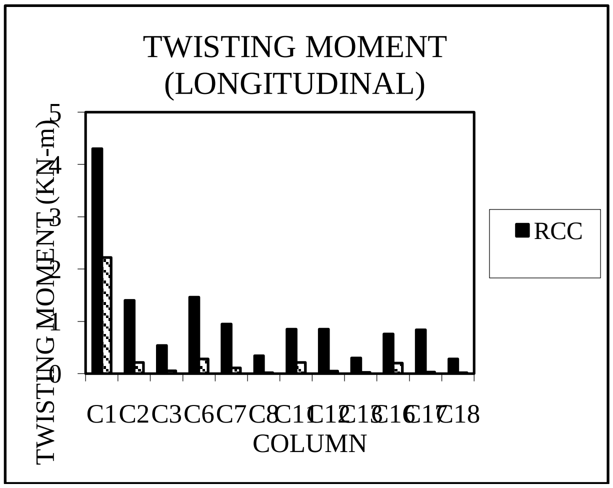

Chart-11. Comparison of twisting moment in columns

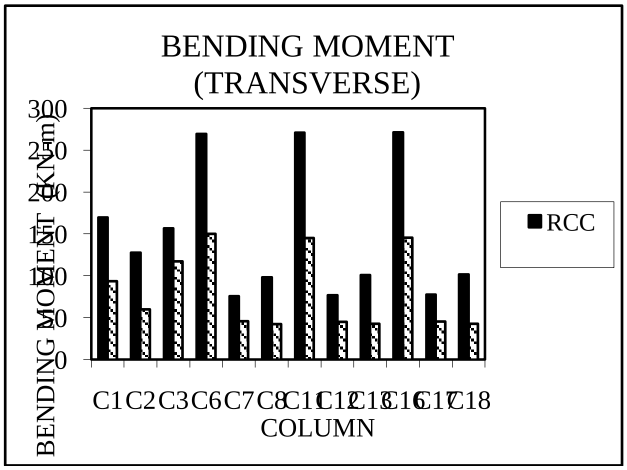

Chart-12,Comparison of bending moment in columns

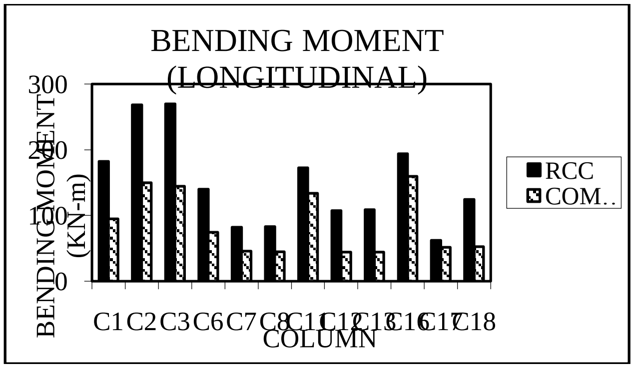

Chart-13 Comparison of bending moment in columns

5.2 Response spectrums Analysis

Response Spectrum analysis allow the users to analyze the structure for seismic loading

i) Time period and frequency:- The increased stiffness of the composite structure results in increased frequency and reduction in time period than the RCC structure. The frequency of composite structure is increased by 10% to 17% whereas time period is reduced by 14% to 29% from chart 14 to 15

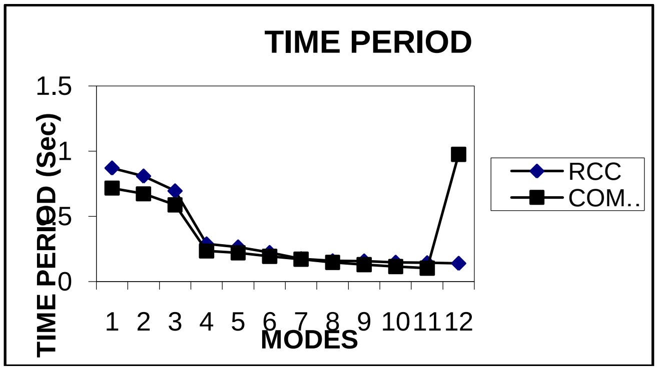

Chart-14 Time Period

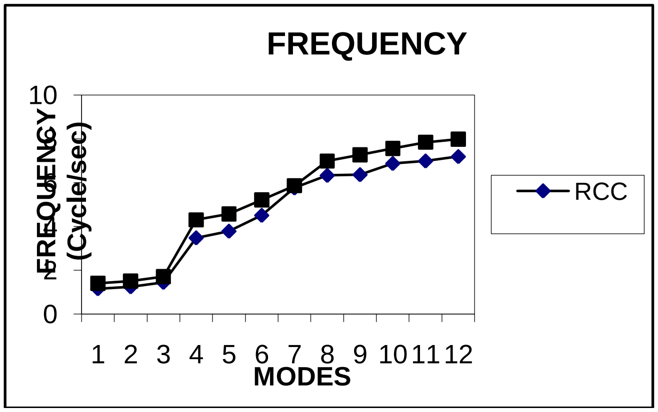

Chart-15, Comparison of Frequency

ii) Lateral displacement:- The lateral displacement in composite structure is reduced up to 46% to 58% and 45% to 56% in transverse and longitudinal directions respectively. This reduction is observed due to higher stiffness and reduction in seismic forces from chart 16 to 17

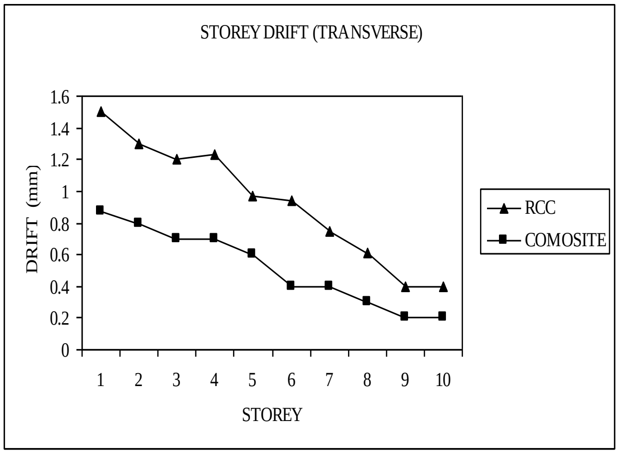

Chart-16 ,Comparison of story drifts

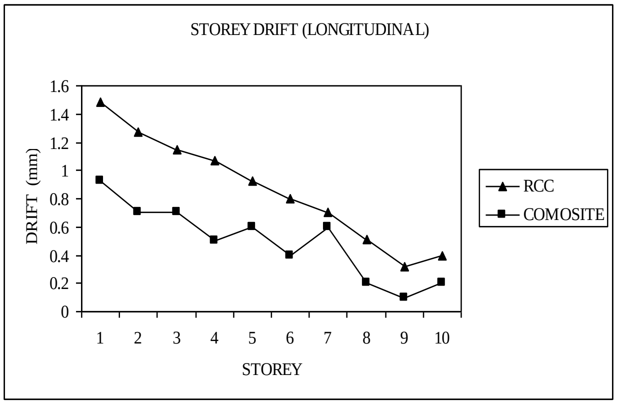

Chart-17 ,Comparison of story drifts

iii) Axial force, shear force, twisting moment and bending moment in columns:- The maximum axial force, shear force, twisting moment and bending moment in columns in transverse and longitudinal direction are as shown in Figure 22 to 28. The axial force in all composite columns is reduced by 18% to 30% than RCC columns. The shear force in exterior columns is observed to be more than interior columns in transverse direction and for composite columns it is reduced by 31% to 47%. Shear force in longitudinal direction is also more for exterior columns than interior columns and for composite columns it is reduced by 30% to 45%. Twisting moment in columns of composite structure is reduced from 40% to 66% and about 39% to 65% in transverse and longitudinal directions respectively as compared to RCC structure. It can be seen that the bending moment in composite columns in transverse direction is reduced by 24% to 41%

whereas in longitudinal direction it is reduced only by 25% to 42% from chart 18 to 23.

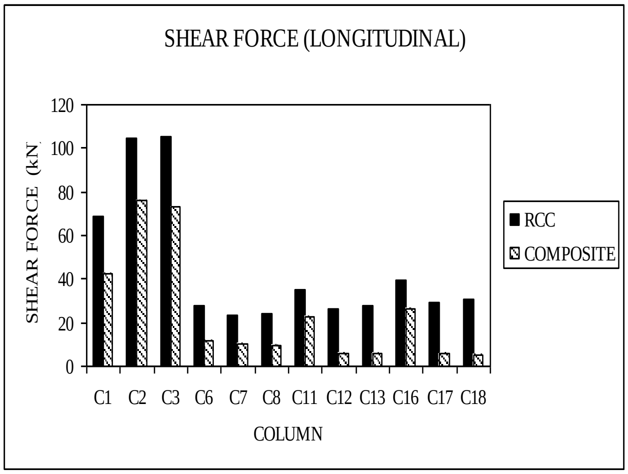

Chart-18 ,Comparison of shear force in columns

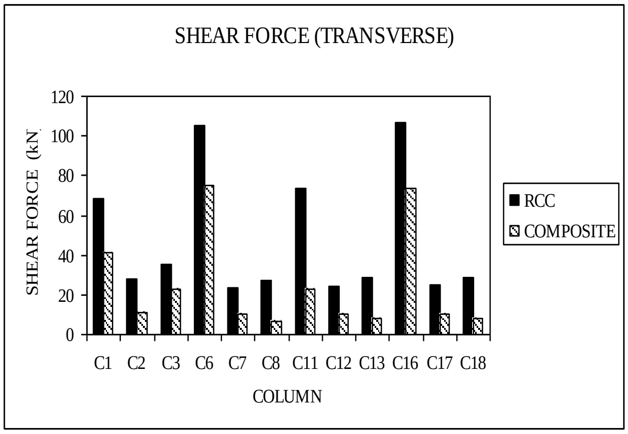

Chart-19 ,Comparison of shear force in columns

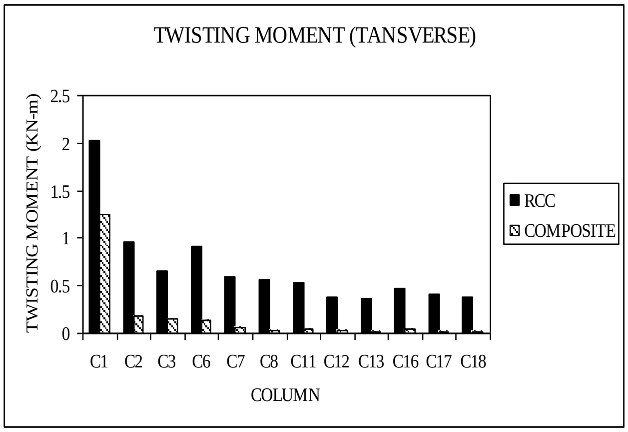

Chart-20 ,Comparison of twisting moment in columns

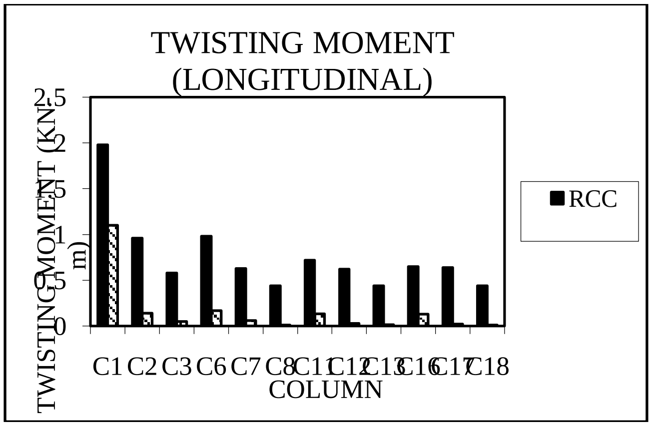

Chart-21 ,Comparison of twisting moment in columns

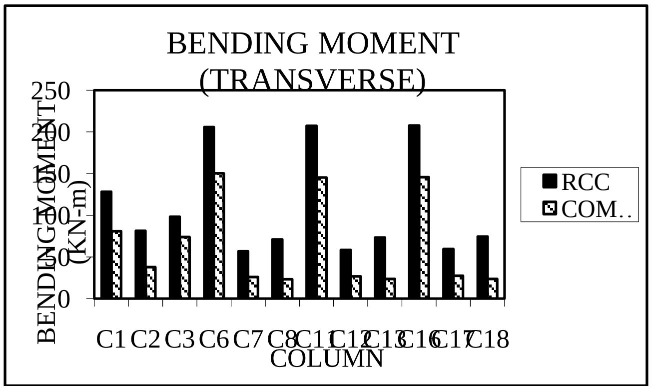

Chart-22 ,Comparison of bending moment in columns

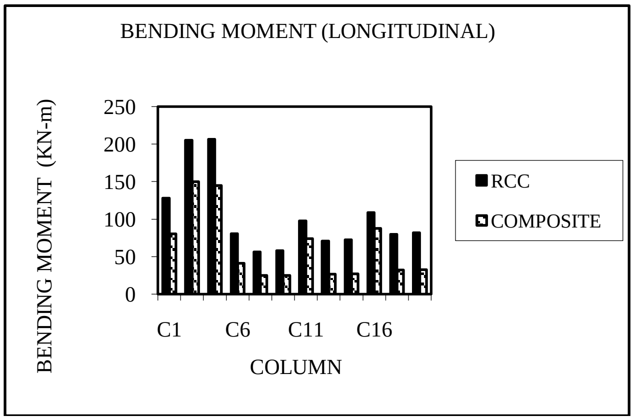

Chart-23,Comparison of bending moment in columns

CONCLUSIONS

Based on the analysis results following conclusions are drawn

1) The dead weight of composite structure is found to be 15% to 20% less than RCC structure and hence the seismic forces are reduced by 15% to 20%
2) It is observed that stiffness in composite structure is increased by 12% to 15% in transverse direction and

about 6% to 10% in longitudinal direction as compared to reinforced concrete structure.

3) It is also observed that for composite structure the lateral displacements are reduced from 41% to 58% in transverse direction and about 37% to 57% in longitudinal direction than the RCC structure in linear static analysis and for linear dynamic analysis it is reduced by 46% to 58% and 45% to 56% in transverse and longitudinal directions respectively.
4) It is found that the lateral drift for composite structure is reduced by 35% to 50% and 27% to 38% in transverse and longitudinal directions respectively in linear static analysis. In linear dynamic analysis the lateral drift is reduced by 42% to 50% and by 37% to 48% in transverse and longitudinal directions respectively than that of RCC structure.
5) The axial force in composite columns is found to be 20% to 30% less than RCC columns in linear static analysis and in linear dynamic analysis it is found to be 18% to 30% less than RCC columns.
6) The shear force in composite column is reduced by 28% to 44% and 24% to 40% in transverse and longitudinal directions respectively than the RCC structure in linear static analysis.
7) The shear force in response spectrum analysis is also found to be less by 31% to 47% in transverse direction and about 30% to 45% in longitudinal direction in composite column than the RCC column.
8) The twisting moment in composite columns is found to be 48% to 63% less and 49% to 65% less in transverse and longitudinal directions respectively than reinforced concrete columns in linear static analysis and in case of linear dynamic analysis the twisting moment is reduced by 40% to 66 % and about 39% to 65% in transverse and longitudinal directions respectively than the RCC structure.
9) The frequency of composite structure is increased by 10% to 17% and time period decreased by 14% to 29% than the RCC structure.
10) The maximum negative bending moment in composite beam is found to be reduced by 16% to 32% in equivalent static analysis and is also reduced by 11% to 18% in composite beams in response spectrum analysis than pure RCC beams.
11) In composite structure due to high ductile nature of steel it leads to increased seismic resistance of the composite section. Steel component can be deformed in a ductile manner without premature failure and can withstand numerous loading cycles before fracture.

ACKNOWLEDGEMENTS

This paper too could not be completed without the help and support of many special persons.

REFERENCES

[1] Institute for steel development & Growth, "B+G+40 Storied Residential Building With Steel-Concrete Composite Option” India Dec 2007.

[2] M. Willford, A. Whittaker and R. Kinematics, “Recommendations for Seismic Design of High-Rise Buildings” Council of Tall building and Urban habitat Feb 2008.

[3] J. Zils and J. Viis, “An Introduction To High Rise Design” StructureMagazine Nov 2003.

[4] IS: 456, Code of practice for plain and reinforced concrete code of practice, Bureau of Indian Standards, New Delhi, 2000

[5] IS: 1893, Criteria for earthquake resistant design of structures – general provisions for buildings, Part 1, Bureau of Indian Standards, New Delhi, 2002.

[6] IS: 875, “code of practice for design load (other than earthquake) forbuildings and structures” Bureau of Indian Standards, New Delhi, 2002.

[7] IS: 800, Code of practice for general construction in steel, Bureau of Indian Standards, New Delhi, 2007.

[8] SP 34:1987, “Handbook on Concrete Reinforcement and Detailing" Bureau of Indian Standards, New Delhi, India.

[9] AISC 360-05, Specification of structural steel building, An American national stanadard, American Institute Of Steel Construction, Inc., 2005.

[10] IS: 11384, Code of practice for composite construction in structural steel and concrete, Bureau of Indian Standards, New Delhi, 1985.

[11] Euro code 3, “Design of Steel Structures", European committee for Standardization committee European de normalization European sches committee fur forming.

[12] M.C. Gatti, F. Mola and A. Rizzo. “Behavior of Slender Composite Steel-Concrete Columns Subjected to Sustained loads.” Department of Structural Engineering Politecnico di Milano Piazza Leonardo da Vinci, 32 20133 Milano, Italy, pp 37-43.

[13] S.V. Hoa, B.H. Joureneaux and L. Di. Lalla. “Computer Aided Design for Composite Structures.” Composite Structure, Volume 13 No.1 1989, pp 67-79.

[14] Sherif tawil and Gregory G. Deierlein. “Nonlinear analysis of mixed steel concrete frames I: Element formulation.” Journal of Structural engineering, Vol. 127 No.6, June 2001, pp 647-655.

[15] Sherif tawil and Gregory G. Deierlein. “Nonlinear analysis of mixed steel concrete frames II: Implementation and verification.” Journal of Structural engineering, Vol. 127 No.6, June 2001, pp 656-665

[16] Gregory G. Deierlein and Hiroshi Noguchi. “Overview of U.S. Japan research on the seismic design of composite reinforced concrete and steel moment frame structures.” Jornal of structural engineering, Vol 130, No. 2, Feb 2000, pp 361-367.

[17] Johan Silfwerbrand. “Stresses and Strains in Composite Concrete Beams Subjected To Differential Shrinkage.” ACI Structural Journal, Vol. 94, No.4, July-Aug1997, pp 347-353.

[18] Sameh S. F. Mehanny and Gregory G. Deierlein. “Seismic damage and collapse assessment of composite moment frames.” Journal of Structural engineering, Vol. 127 No.9, Sep 2001, pp 1045-1053.

[19] C.C. Weng. “Shear strength of concrete encased composite structural members.” Jornal of structural engineering, Vol 127, No. 10, Oct 2001, pp 1190-1197.

[20] Mark Andrew Bradford and R. Ian Gilbert. “Composite Beams with Partial Interaction under Sustained Loads.” Journal of Structural Engineering, Vol. 118, No. 7, July 1992, pp 1871-1883.

[21] L. Calado, L. Simoes da Silva and R. Simoes. “Cyclic Behavior of Steel and Composite Beam-To-Column Joints.” Department Of Civil Engineering, Instituto Superior, Tecnico, Lisbon, Portugal And Universidade de Coimbra, Coimbra, Portugal, pp159-169.

[22] Sherif tawil and Gregory G. Deierlein. “Strength and ductility of concrete encased composite columns.” Journal of Structural engineering, Vol. 125 No.9, Sep 1999, pp 1009-1019.

[23] Thierry Chicoine, Robert tremblay, Bruno Massicotte and James M. Ricles. “Behavior and strength of partially encased composite columns with built up shapes.” Journal of Structural engineering, Vol. 128, No.3, Mach 2002, pp 279-288.

[24] Tai-Kuang Lee and Austin D. E. Pan. “Analysis of composite beam-columns under lateral cyclic loading.” Journal of Structural engineering, Vol. 127 No.2, Feb 2001, pp 186-193.

[25] A.Haufe, H.Menrath, E.Ramm. “Nonlinear Analysis of Composite Steel Concrete Stucture.” PP.219, Inst. of Struc. Mech. University of Stuttgart, Germany, Struc. Engg. in 21st Century

[26] Christopher J. Earls. “Geometric factors influencing structural ductility in compact I shaped beams.” Journal of structural engineering, Vol 126, No. 7, July 2000, pp 780-789.

[27] Mark A. Bradford and R. Ian Gilbert. “Time-Dependent Analyses and Design of Composite Columns.” Journal of Structural Engineering, vol. 116, No. 12, Dec 1990, pp 3338-3355

[28] JONSON R.P., composite structures of Steel and Concrete; Volume 1: Beams, Columns, Frames and Applications in Building. Granada. 1975.

[29] JONSON, R.P.Composite Construction 1 and 2.

[30] Design Aids (for Reinforced Concrete) to IS 456 :1978 ,Special Publication SP : 16,Bureau of Indian Standards, New Delhi,1980.

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