International Journal of Research in Engineering, Science and Management
Volume-1, Issue-5, May 2018
www.ijresm.com

Use of Composite Structures in Multistory Building

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***Abstract*— R.C.C Structures and Steel structures are generally used for low rise and high rise buildings respectively. But, nowadays new construction techniques and innovations have been imparted to increase life span of building. Steel-concrete composite construction is a new innovation in the field of construction owing to their benefits over traditional R.C.C & steel construction. Concrete structures are bulky and imparts more seismic weight and less deflection whereas steel structures imparts more deflections and ductility to structure which resists earthquake forces. Composite structures combines both the properties of steel and concrete to provide strength and stability to structure. Comparative study proved that composite structure are best suited for earthquake prone areas.**

Index Terms—Composite structures

I. Introduction

The design of buildings is basically done with concrete and masonry structure. Reinforced Concrete Structures have been satisfying greater demands in civil and structural engineering sector for more than 3-4 decades. R.C.C structures are more popular due to ease in construction and fulfilling the demands of growing population. In India, the use of steel in construction industry is very low as compared to other developing countries. Experiences of other countries indicate that this is not due to lack of economy of steel as a construction material. Low rise buildings are generally selected in India, but due to rapid increase in population medium to high rise building is preferred. Reinforced Concrete Structures are generally preferred for low rise building but for medium to high rise building, RC Structures are not economical due to increased formwork, span restriction & dead load and due to earthquake many multistory buildings have been affected. Hence structural designers want to use some innovative construction technology to reduce the failure of multistory buildings. So, for such a high rise building it was found that composite structures are more beneficial over traditional R.C.C structures. The reason behind the reputation of composite structures is its benefits it possess when compared to R.C.C and steel construction. The purpose of this work is to use composite sections in multi-storeyed buildings, to study the structural members particularly used in building, their advantages over steel & R.C.C structures and applications in future.

Composite Structures:

Composite Structures are defined as structures which consist of composite sections which are made up of two different types of materials such as structural steel and concrete. Composite Structures combines the dynamic properties of structural steel (Tension) and concrete (Compression) which provides greater strength and stability to multistory buildings & also have same thermal expansion. Therefore there is no induction of different thermal stresses in a section under variation of temperature. Structural steel members are generally fabricated as component consisting of thin plate and shell elements, so on loading, they are subjected to lateral buckling .Concrete are thick enough & less prone to buckle but they are subjected to creep and shrinkage. Hence composite sections are used as it binds both the properties of steel & concrete.

Composite Sections are constructed such that the structural steel shape and concrete act together to resist axial compression and bending. A steel concrete composite frame consists of steel beam over which reinforced concrete slab is cast with the help of shear connectors.

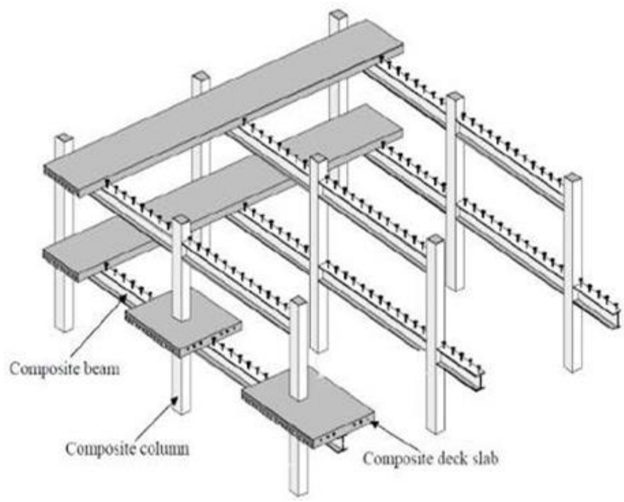

Fig. 1. Steel Concrete Composite Frame

II. Aim and Objectives

- To analyse and design of Structural steel, RCC and Composite Structure will be using Equivalent Static Method.
- To compare RCC (Reinforced Concrete Structure), Steel Structure and Composite Structures in various aspects such as Base Shear, Axial Force, Shear Force, Time and weight etc.

III. Details of The Building

TABLE I
DETAILS OF THE BUILDING

Modal	G+7
Floor Height	3 m
Depth of Foundation	2.5 m
Building Height	21 m
Plan Size	11.20 m x 20.35 m
Plan Area	227.92 m2
Soil	Medium
Slab thickness	110 mm
Grade of Steel	Fe 415
Grade of Concrete	M-25
Density of Concrete	25 KN/m3
Density of Brick	20 KN/m3
Inner Wall Thickness	115 mm
Outer wall Thickness	230 mm
Density of Brick	20 KN/m3
Seismic Zone	Zone II
Importance Factor	I
Zone Factor	0.1

IV. Properties of Beams and Columns

Size of Beam & Column in Steel Building

a) Beam Size - ISMB 550
b) Column Size - ISMB 600 Double Profile

Size of Beam & Column in Composite Building

a) Beam Size - ISMB 500
b) Column Size - ISMB 600 Double Profile

Size of Beam & Column in RCC Building

a) Properties of Beam Plinth level to First Floor -0.3 m x 0.65 m
b) Properties of Beam Second Floor to Fourth Floor - 0.23 m x 0.30 m
c) Properties of Beam Fifth level to Seventh Floor -0.23 m x 0.23m
d) Properties of Outer Column Foundation level to Third Floor -0.75 m x 0.75 m
e) Properties of Outer Column Forth Floor to Seventh Floor - 0.45 m x 0.45 m
f) Properties of Outer Column Forth Floor to Seventh Floor -0.45 m x 0.45 m
g) Properties of Inner Column Foundation level to Third Floor - 0.35 m x 0.75 m
h) Properties of Inner Column Forth Floor to Seventh Floor- 0.35 m x 0.60 m

V. Analysis and Results of the Structure

The aim of the paper is to compare seismic performance of (G+7) storey R.C.C, steel and composite buildings situated at earthquake zone II. All the frames are analyzed for same loading. Equivalent static method is used for seismic analysis with using Staad.pro software. In India, standard criteria for earthquake resistant design of structures IS 1893:2002 is used for calculating seismic forces. Comparison of buildings is done between base shear, axial force, shear force, weight and time period.

A. Base Shear

Base shear depends on soil condition & sources of seismic activity due to geological faults. As the base shear is the horizontal reaction to the earthquake forces and horizontal forces results from storey weight. Storey weight includes self-weight of the structure and hence in R.C.C structure, the self-weight is more and hence maximizing the earthquake forces results in maximum base shear. As we have the static formula, base shear is directly proportional to seismic weight of building.

TABLE II
DETAILS OF THE BUILDING

MODEL	COMPOSITE	STEEL	RCC
BASE SHEAR (in KN)	695.909 KN	539.556 KN	733.361 KN

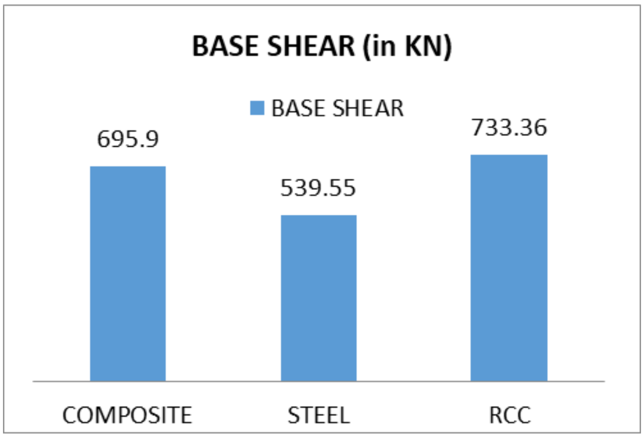

Fig. 2. Comparison of Base Shear

B. Axial Force

TABLE III
AXIAL FORCE

Storey No.	Column No.	RCC	STEEL	COMPOSITE
1	30	4712.31 KN	1196.12 KN	2670.31 KN
2	30	3613.38 KN	852.11 KN	1447.05 KN
3	30	2634 KN	570.73 KN	727.93 KN
4	30	1886.77 KN	340.97 KN	274.77 KN
5	30	1186.02 KN	403.12 KN	316.28 KN
6	36	848.59 KN	705.33 KN	801.20 KN
7	36	565.55 KN	472.19 KN	533.268 KN
8	36	282.86 KN	239.97 KN	270.18 KN

Axial force is the compression or tension acting on the member. If axial force is acts through the centroid of the member then it is called concentric loading and if it is acting through the centroid of member then it is called eccentric loading. Axial force in columns is in compression because column is a vertical member and are subjected to tensile forces when lateral forces.

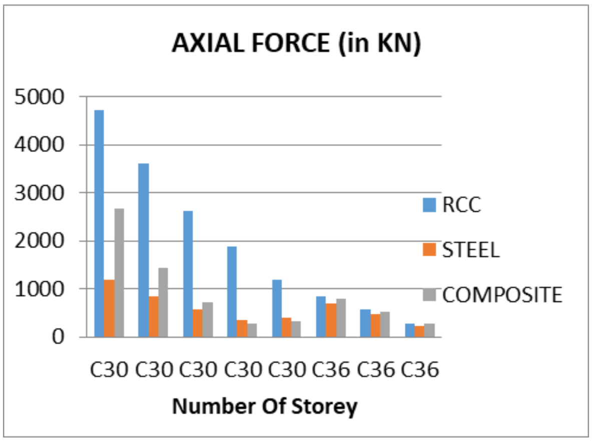

Fig. 3. Comparison of axial force

Where, C30 to C36 implies number of columns having maximum axial force in each storey.

C. *Shear Force*

Shear force at a section in a beam is the force that is obtained as the algebraic sum of all the forces including the reactions acting normal to the axis of the beam either to the left or to the right of the section. Shear force is the force in the beam acting perpendicular to its longitudinal (X) axis. Shear force is more important in beam to resist axial forces.

- Fy : It is the shear force in building's local Y direction.
- Fz : It is the shear force in building's local Z direction.

TABLE IV
SHEAR FORCE (FY)

NO OF STOREY	COLUMN NO	COMPOSITE	STEEL	RCC
1	21	583.88 KN	175.87 KN	293.01 KN
2	19	624.31 KN	204.10 KN	314.55 KN
3	19	601.83 KN	199.46 KN	244.50 KN
4	19	540.44 KN	186.28 KN	174.64 KN
5	19	461.40 KN	166.28 KN	171.64 KN
6	19	374.23 KN	140.81 KN	136.12 KN
7	31	283.12 KN	82.51 KN	70.18 KN
8	31	219.06 KN	57.4 KN	40.53 KN

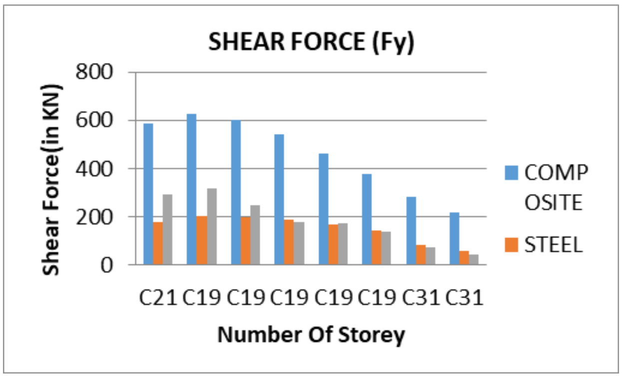

Fig. 4. Comparison of Shear Force

Where, C21 to C31 implies number of columns having maximum axial force in each storey.

TABLE V
SHEAR FORCE (FZ)

NO OF STOREY	COLUMN NO	COMPOSITE	STEEL	RCC
1	38	639.27 KN	231.10 KN	407.89 KN
2	42	619.72 KN	206.08 KN	502.45 KN
3	42	564.51 KN	188.41 KN	361.25 KN
4	42	494.52 KN	163.49 KN	252.52 KN
5	42	413.56 KN	135.29 KN	187.73 KN
6	42	325.41 KN	104.67 KN	142.16 KN
7	42	231.62 KN	71.83 KN	90.95 KN
8	19	160.91 KN	50.20 KN	33.17 KN

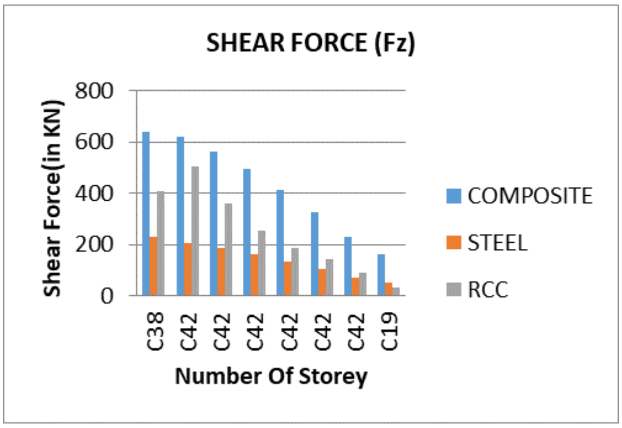

Fig. 5. Comparison of shear force

Where, C38 to C19 Implies number of columns having maximum axial force in each storey.

D. *Self-Weight*

Self-Weight is the load on the structure imposed by its own weight. Self-weight is directly proportional to density of the structure.

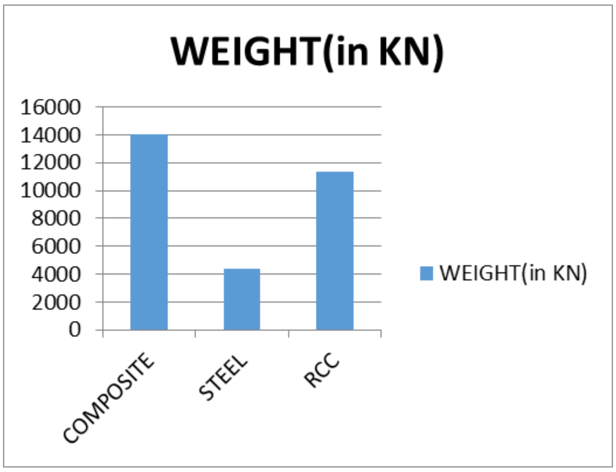

Fig. 6. Comparison of weight (in KN) in buildings

E. *Time Period*

The fundamental period of vibration of building for lateral motion in direction is considered as time period (T). According to code IS 1893:2016, for building heights up to 40m, the value of T are as follows:

- RC building
  $T = 0.075\ H^{0.75}$
  $= 0.735$ sec.
- Steel building
  $T = 0.085\ H^{0.75}$
  $= 0.833$ sec.
- Composite buildings
  $T = 0.080 H^{0.75}$
  $= 0.784$ sec.

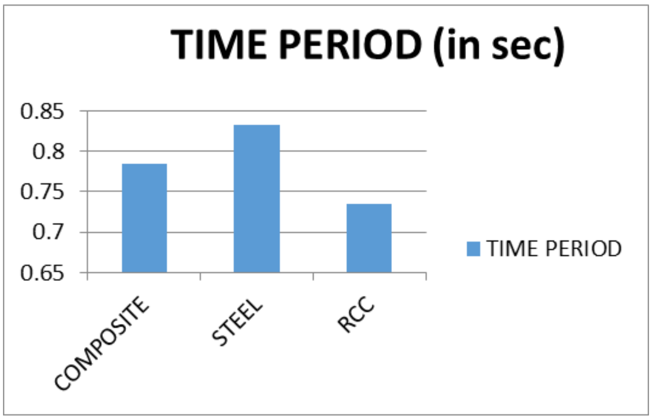

Fig. 7. Comparison of time period (in sec) in buildings

VI. CONCLUSION

- The value of base shear is maximum in RCC structure, because the base shear (V_b) is directly proportional to the weight of structure (W). Hence greater the weight of structure, higher will be the base shear.
- The base shear in composite structure is reduced by 6% and reduced by 27% in steel structure as compared to R.C.C structure.
- Axial force in R.C.C structures is on higher side for same loading as compared to composite structure and least in Steel structure.
- The overall axial force in composite structure is reduced by 37.65% and reduced by 53.23% in steel structure as compared to R.C.C structure.
- Shear force in Composite structure is more as compared to R.C.C and Steel structure due to increase in self-weight and member size.
- The overall shear force in local Y direction is reduced by 67.57% in steel structure and 63.70% in R.C.C structure as compared to composite structure. Similarly, in local Z direction shear force in steel and R.C.C is reduced by 67.13% and 48.89% respectively.
- From the results, the self-weight of composite structure is more as compared to steel and RCC structure which implies that the foundation cost of composite structure is more.
- The weight of R.C.C structure and steel structure is reduced by 19.61% and 68.61 % respectively in comparison with composite structure.
- Due to the increased stiffness of RCC structure, time period reduces in steel and composite structure.
- The time period in R.C.C structure is reduced by 12% and reduced by 6% in composite structure as compared to steel structure

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