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SEISMIC EFFECT ON MULTI-STOREY R.C.C, STEEL AND COMPOSITE BUILDING

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Abstract*— In India reinforced concrete structures are mostly used since this is the most convenient and 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. Composite construction combines the better properties of both steel and concrete along with lesser cost, speedy construction, fire protection etc. The major objective of this project work is to study the seismic behaviour of high rise building made by reinforced cement concrete, steel and composite material. In this work multi-storied commercial building (G+14) located in seismic zone IV is considered. The equivalent static method and push over analysis is adopted and analysis is carried out by using ETABS V15 software. The various seismic parameters such as storey shear, displacement, storey drift, base shear and time period are obtained from analysis and the results were compared. From the study it is observed that Storey displacement, Storey shear, Storey drift, time period, Bending moment and shear force are reduced in steel and composite building as compared to R.C.C building. These values are slightly more in case of composite building as compared to steel building. From the pushover analysis it is clear that composite building has higher values of displacement and base shear as compared to R.C.C and steel building. From overall study it is concluded that the composite building frame shows better performance due to seismic effect as compared to R.C.C building frame, and steel building frame.

***Keywords*— Composite construction, Seismic, Equivalent static analysis, pushover analysis, ETABS,**

I. INTRODUCTION

In the previous years, for the design of a building, the choice was usually between a concrete structure and a masonry structure. However, the disappointment of numerous multi-storied and low-rise reinforced cement concrete and masonry structure due to earthquake has enforced the structural engineers to look for the alternate technique of construction. The two materials generally and inevitably used as construction material are steel and concrete for structures ranging from buildings to bridges. Though these materials are having different properties and characteristics, they both seem to complement each other in many ways. Steel section has exceptional resistance to tensile loading but lesser weight ratio so thin sections are used which may be inclined to buckling phenomenon. On the other hand concrete members are good in resistance to compressive force. Steel may be utilized to impart ductility an essential criteria for tall structure, while corrosion protection and thermal insulation can be done by concrete. Likewise buckling of steel section can also be controlled by concrete. In order, to obtain the optimum benefits from both materials composite construction is generally preferred.

A. Composite Construction

A composite member is constructed by combining concrete member and steel member so that they act as a single unit. As we know that concrete is strong in compression and weak in tension on the other side steel is strong in tension and weak in compression. The concrete strength in compression is complemented by strength of steel in tension which results in an efficient section. The structural elements which are comprised in a composite construction are as follows

- *Composite Slab*

Conventional steel and concrete floors consist of built-up or rolled structural steel beams and cast in-situ concrete floors joined together using shear stud connectors in such a way that they would act monolithically. The principal advantage of steel-concrete composite construction lies in the utilization of the compressive strength of concrete slab in combination with steel beams, in order to improve the stiffness and strength of the steel girder. More recently, composite floors using profiled sheet decking have become very popular in the developed country for high rise office buildings.

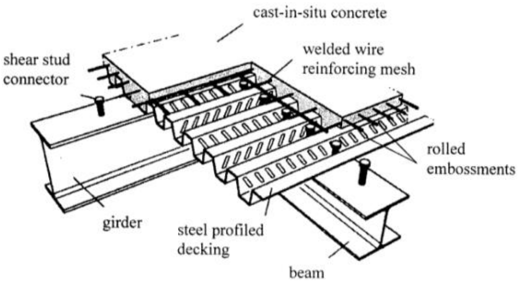

Fig. 1 Typical composite beam slab details with shear connectors

- *Composite Beams*

In conventional composite construction concrete slab is placed over steel beams and are supported by them. Under the effect of load these two components act independently and there is a possibility of relative slip at the intersection, if there is no connection between them. With the help of more effective and appropriate connection provided between them can be eliminated.

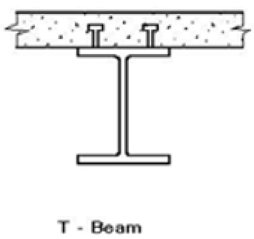

Fig. 2 Composite beam

- *Composite Columns*

A steel concrete composite column section is a compression member, comprising either of a concrete encased with hot rolled steel section or a concrete filled in hollow section of hot rolled steel. It is generally used as a load bearing member in a composite frame. Composite members are mostly subjected to compression and bending. At present there is no Indian standard code covering the design of composite column section.

Fig. 3 Composite column

- *Shear Connectors*

The total shear force acting at the intersection between concrete composite slab and steel beam is approximately eight times the total load carried by the beam. Therefore, mechanical shear stud connectors are necessary at the intersection of concrete and steel. These shear stud connector are intended to (a.) transmit horizontal shear along the intersection, and (b.) to avoid the detachment of steel beam and concrete slab at the intersection. For the design of composite column American Institute of Steel Construction code book is used.

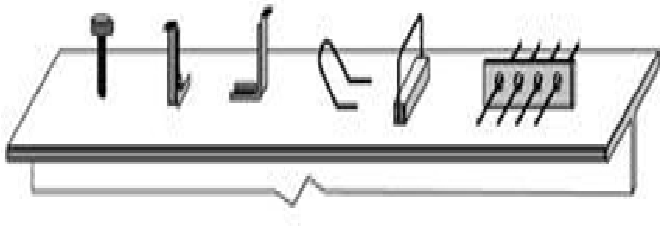

Fig. 4 Types of shear connectors

B. Objectives

The present work aims at the study of following objectives.

1. To study the seismic behaviour of R.C.C, steel and composite building using Linear Static Analysis (Equivalent static method).
2. To study the variation of different parameters such as storey displacement, storey shear, storey drift, bending moment and shear force in R.C.C, steel and composite building.
3. To study the performance of R.C.C, steel and steel-concrete composite building using Non-Linear pushover Analysis.

II. METHODOLOGY

A. Analysis Method

Two types of analysis is performed

- Linear Static Analysis
- Non-linear Static Analysis

1) Linear Static Analysis (Equivalent Static Analysis)

Equivalent static method is an analysis where a linear relation exists between applied forces and displacements. This is related to structural problems where stresses are in the linear elastic region of the material used. In a equivalent static method the model's stiffness matrix is constant, and the solving process is comparatively small compared to a non-linear analysis on the similar model. Therefore, for a initial estimate, the equivalent static method is usually used before performing non-linear analysis.

2) Non-Linear Static Analysis (Pushover Analysis)

A non-linear analysis is an analysis where a non-linear relation holds between displacements and applied forces. Non-linear effects can occur due to geometrical non-linearity's (i.e. large deformations), material non-linearity's (i.e. elasto-plastic material), and contact. These effects result in a stiffness matrix which is not constant during the load application. This is opposed to the linear static analysis, where the stiffness matrix remained constant. As a result, a different solving strategy is required for the non-linear analysis and therefore a different solver.

- -Geometric Non-linearity

In analyses involving geometric non-linearity, changes in geometry as the structure deforms are considered in formulating the constitutive and equilibrium equations. Numerous building applications, for example, metal framing, tire examination, and medicinal gadget analysis require the utilization of large deformation analysis in view of geometric non-linearity. Small deformation analysis in view of geometric non-linearity is required for a few applications, similar to analysis including cables, shells and arches.

- Material Non-linearity

Material non-linearity involves the non-linear behaviour of a material based on a rate of deformation, deformation history, temperature, rate of deformation, pressure, and so on. Examples of non-linear material models are large strain hyper-elasticity and elasto-plasticity (plastic materials and rubber).

B. Model Description

The seismic loads are considered to be carried by the beam column frame as a moment resisting frame. Fourteen storey (G+14) commercial building with eight bays in horizontal and four bays in vertical direction. Three model are created that are reinforced concrete building , steel building with steel as structural member and composite building with composite section and is analyzed by Equivalent Static Method and Pushover Method.

TABLE I

EARTHQUAKE PARAMETER

SL.No.	Particulars	parameter
1.	Earthquake Zone	IV
2.	Importance Factor, I	1.2
3.	Type of soil	Type II, Medium
4.	Response Reduction Factor, R	5
5.	Seismic Zone Factor, Z	0.24

TABLE II

STRUCTURE PARAMETER

SL.No.	Particulars	parameter
1.	No of storey	G+14
2.	Plan Dimension	44.6mX21.2m
3.	Height of each storey	3.0 m
4.	Dead load	
	a. On outer beams	10.557 kN/m
	b. On inner beams	6.885 kN/m
	c. Floor finish	1.5 kN/m^2
5.	Live load	
	a. Live load on roof floor	1.5 kN/m^2
	b. Live load at floor	4 kN/m^2
	c. Live load at toilets	2 kN/m^2
6.	Grade of concrete for slab	M30
7.	Grade of concrete for beam and columns	M30
8.	Grade of shear wall	M30
9.	Grade of reinforcing steel	F_y=415N/mm^2 F_u =485N/mm^2
10.	Grade of structural steel	F_y =345N/mm^2 F_u =450N/mm^2
11.	Density of concrete	24 kN/m^3

- Plan Details

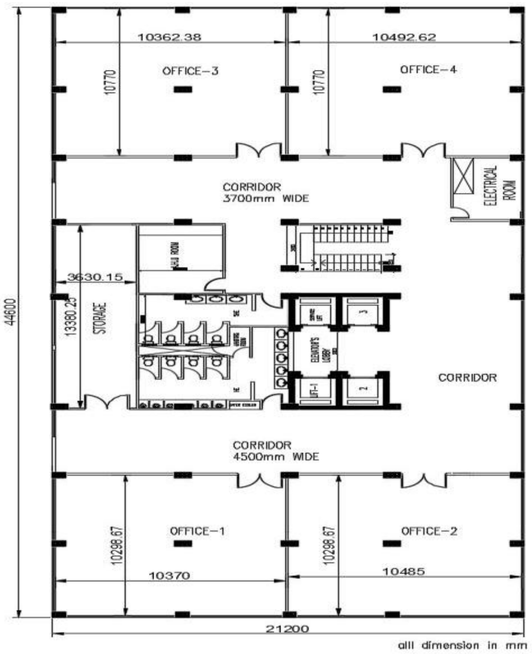

Fig. 5 Typical floor plan

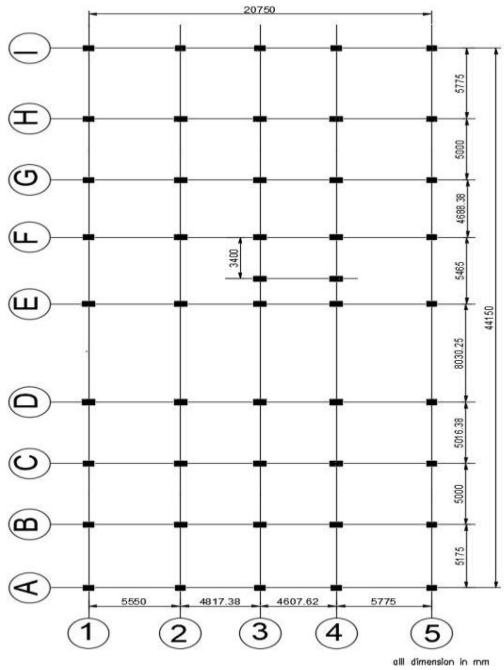

Fig. 6 Column centre line layout

TABLE III

FRAME SECTION PROPERTIES

Particular	R.C.C building	Steel building	Composite building
1. Column size	400mmX600mm(outer column) 400mmX750mm(inner column)	Double I section (ISHB400) with 20 mm plate	Composite column 600x400 with ISHB450 encased
2. Beam size	300mm X 450mm 300mm X 600mm	ISHB400(primary beam) ISMB250(secondary beam)	ISHB400 (primary beam) ISMB250(secondary beam)
3.Slab thickness	140mm	125mm	125mm
4. Shear wall	230mm	230mm	230mm

III. RESULT AND DISCUSSION

In this study G+14 storey building is modelled. Three types of building are analysed that are reinforced concrete building, steel building with steel as structural member and composite building with composite section and is analysed by Equivalent Static Method. Results obtained from the Equivalent Static method are as follows.

A. Displacement

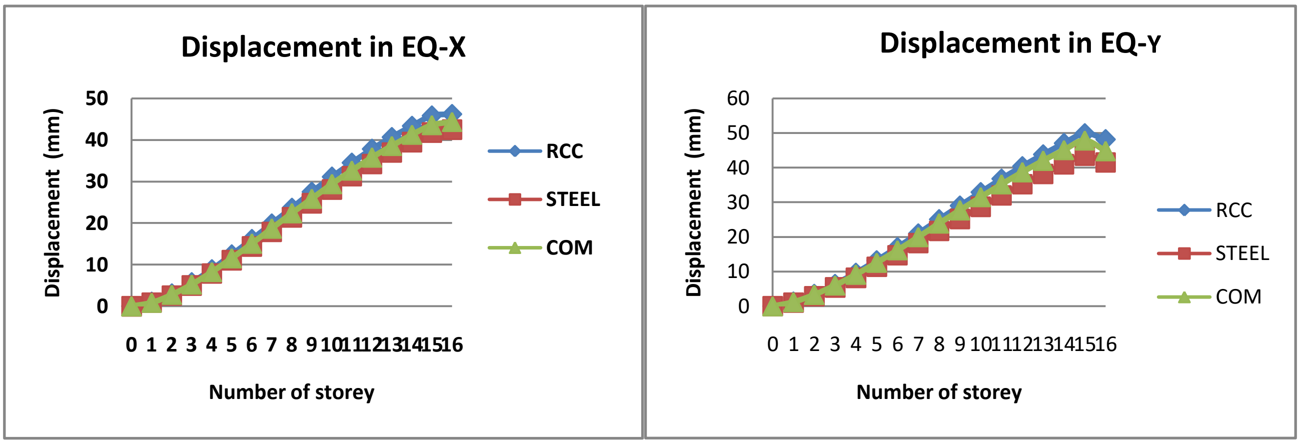

Fig. 7 Displacement in EQ-X and EQ-Y

From the *Fig. 7* it is observed that the story displacement is least for steel building as compared to R.C.C and Composite building because of the higher stiffness of the members in steel and composite building compared to R.C.C building.

The maximum Storey displacement is reduced by 8.0% and 12.8% in x and y direction respectively for Steel building as compared to RCC building. The maximum Storey displacement is reduced by 3.9% and 4.0% in x and y direction respectively for composite building as compared to R.C.C building. The maximum storey displacement for steel building is reduced by 4.2% and 9.1% in x and y direction respectively as compared to composite building.

B. Storey shear

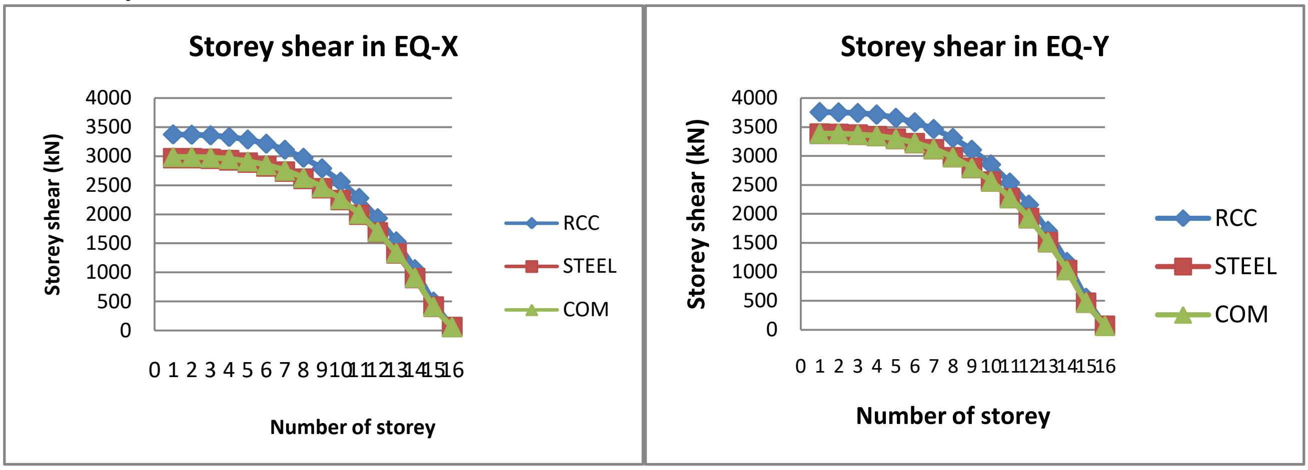

Fig. 8 Storey Shear in EQ-X and EQ-Y

From the *Fig. 8* it is observed that storey shear is nearly same for steel and composite building and is less as compared to R.C.C building because the weight of R.C.C building is more than the steel and the composite building.

The maximum Storey shear is reduced by 11.9% and 10.0% in x and y direction respectively for Steel building as compared to R.C.C building. Maximum Storey shear is reduced by 11.3% and 9.8% in x and y direction respectively for composite building as compared to R.C.C building. Maximum storey shear for steel building is reduced by 0.73% and 0.11% in x and y direction respectively as compared to composite building.

C. Story drift

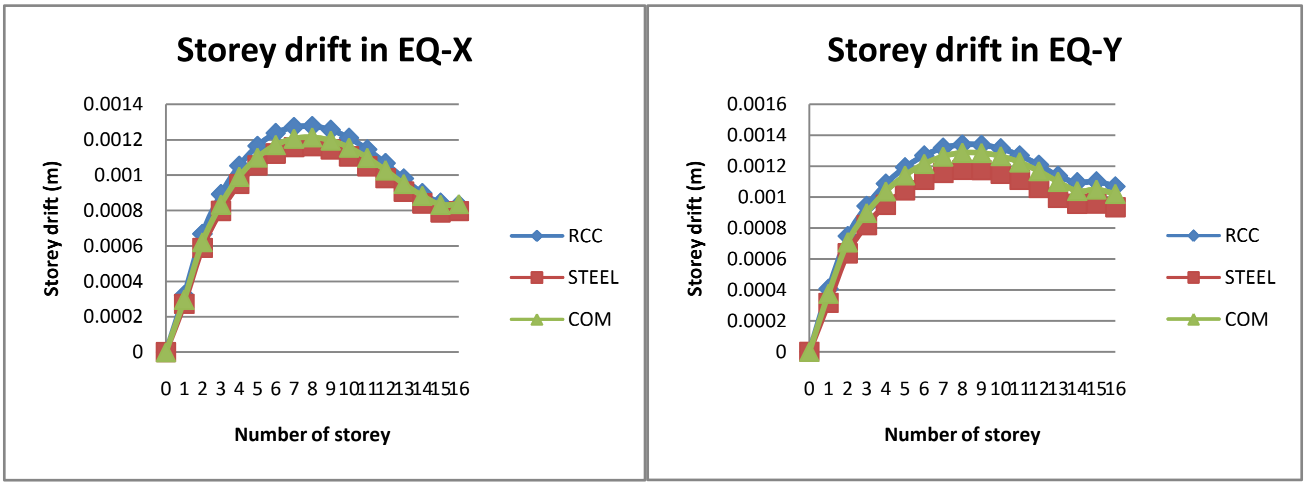

Fig. 9 Storey Drift in EQ-X and EQ-Y

From the *Fig. 9* it is observed that for steel structure has least value of storey drift as compared to R.C.C and composite building because the stiffness of steel is more as compared to R.C.C and composite building.

Maximum Storey drift is reduced by 8.8% and 12.3% in x and y direction respectively for Steel building as compared to R.C.C building. Maximum Storey drift is reduced by 4.9% and 3.9% in x and y direction respectively for composite building as compared to R.C.C building. Maximum Storey drift for steel building is reduced by 4.1% and 8.6% in x and y direction respectively as compared to composite building.

D. Bending Moment

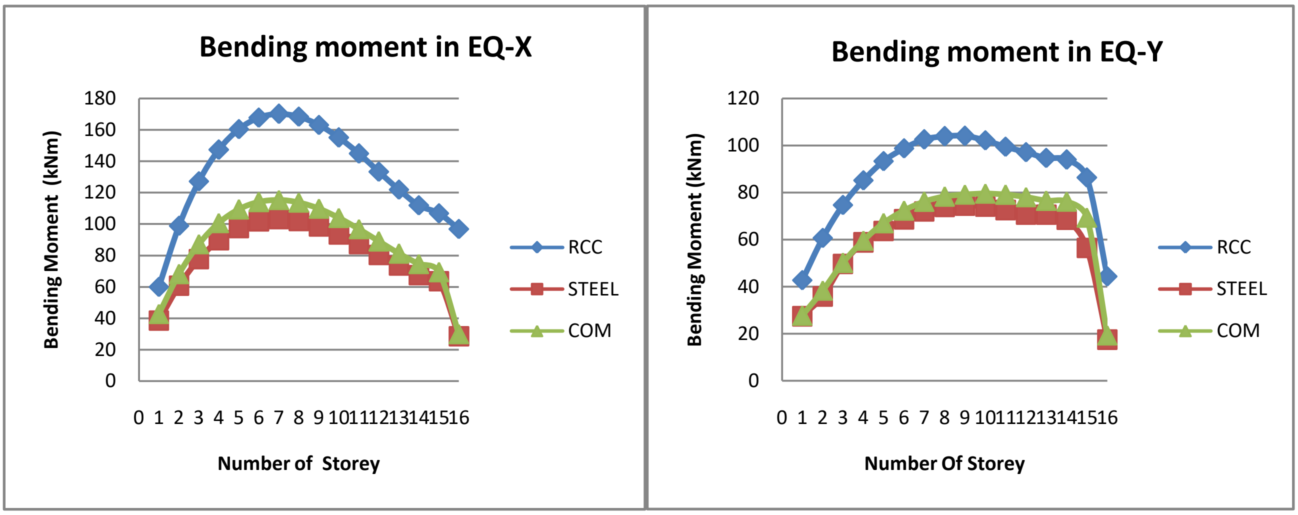

Fig.10 Bending Moment in EQ-X and EQ-Y

From the *Fig. 10* it is observed that bending moment for steel and composite building is nearly same and is less as compared to R.C.C structure because the storey drift and dead load of steel and composite structure is less as compared to R.C.C structure.

The bending moment is reduced by 35% to 70% and 25.4% to 60% in x and y direction respectively for Steel structure as compared to R.C.C structure. The Bending moment is reduced by 28% to 69% and 18.8% to 56% in x and y direction respectively for composite structure as compared to R.C.C building. The bending moment for steel is reduced by 4.6% to 10% and 1.0% to 18% in x and y direction respectively as compared to composite structure.

E. Shear force

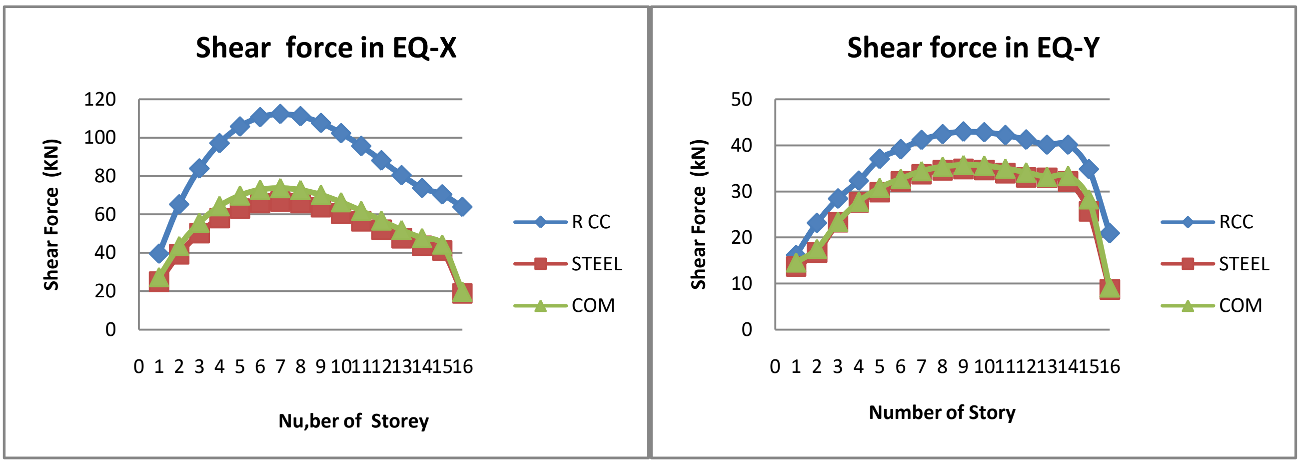

Fig.11 Shear Force in EQ-X and EQ-Y

From the above *Fig 11* it is observed that shear force for steel and composite building is nearly same and is less as compared to R.C.C building because the storey drift and dead load of steel and composite structure is less as compared to R.C.C structure.

The shear force is reduced by 37% to 70% and 15% to 58% in x and y direction respectively for Steel structure as compared to R.C.C structure. The Shear force is reduced by 30% to 69% and 14% to 56% in x and y direction respectively for composite structure as compared to R.C.C The shear force for steel building is reduced by 4.6% to 9.7% and 0.5% to 9.3% in x and y direction respectively as compared to composite building.

F. Axial force

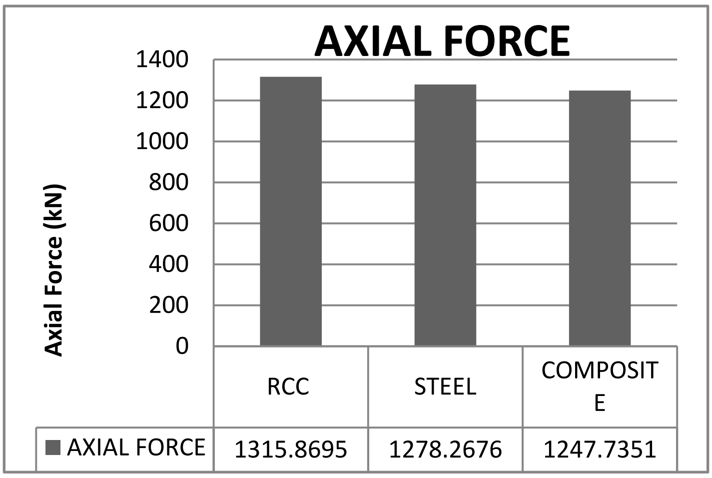

Fig.12 Axial Force in Column

From the above *Fig. 12* it is observed that the maximum Axial force is for R.C.C structure because steel and composite section are slender and has high strength to weight ratio as compared to R.C.C section therefore higher axial force in R.C.C structure. Maximum axial force in R.C.C building is 2.8% more as compared to Steel. Maximum axial force is 5.2% and 2.39% more in R.C.C and steel as compared to composite structure.

G. Time period

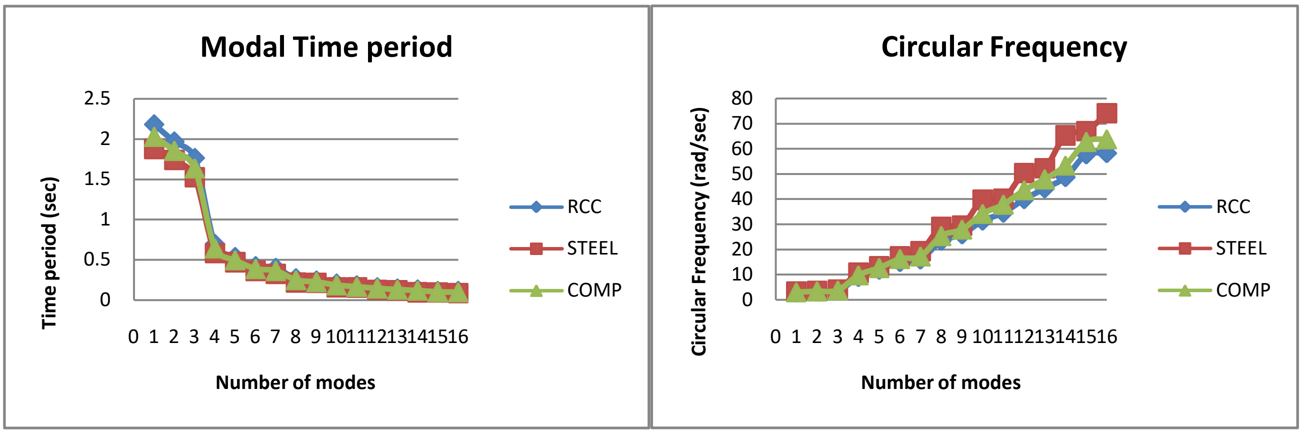

Fig.13 Time period and frequency

From the above *Fig. 13* it is observed that time period for steel is reduced by 13.94% and 7.4% as compared to R.C.C and composite structure respectively because of increase in stiffness and frequency.

Time period for composite structure is reduced by 7.0% as compared to R.C.C structure as the frequency of composite structure is more. It can be observed from the above chart that circular frequency is more for steel structure as compared to R.C.C structure. For composite structure circular frequency is more as compared to R.C.C structure.

H. Pushover result in X- direction

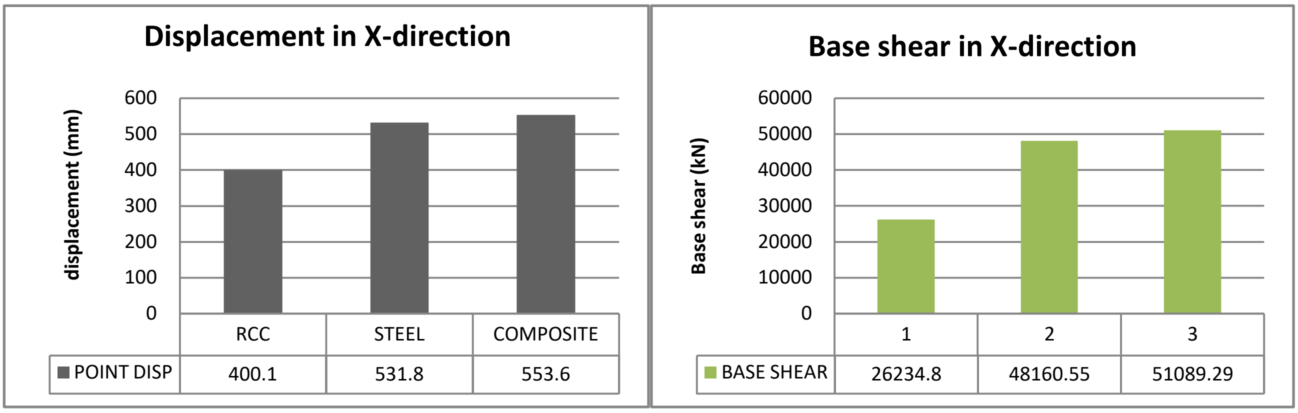

Fig. 14 Displacement and base shear in X-direction

I. Pushover result in Y-direction

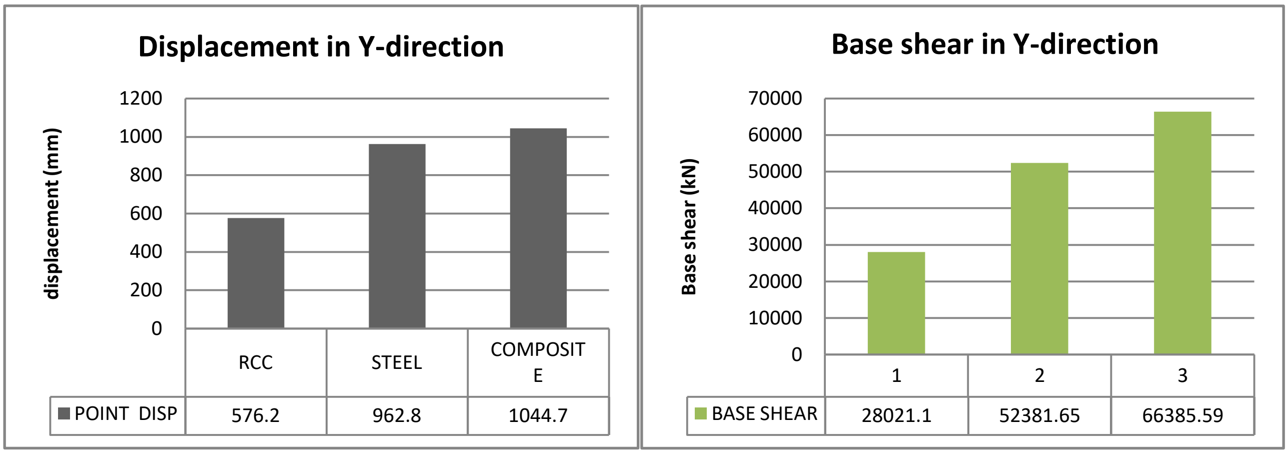

Fig. 15 Displacement and base shear in Y-direction

- Based on pushover analysis it is observed that the composite structure shows better performance as compared to steel and R.C.C structure.
- Displacement for composite structure is more as compared to R.C.C and steel structure in both the direction.
- Base shear of composite structure is more as compared to R.C.C and steel structure in both the direction.

IV. CONCLUSIONS

1. It is clear that Storey displacement in a steel building is less as compared to RCC and composite building in both directions because of the higher stiffness of the members in steel building.
2. Storey shear for composite and steel building is nearly same and is less as compared to R.C.C building because the self-weight of the R.C.C building is more as compared to composite and steel building.
3. Storey drift for R.C.C building is more as compared to steel and composite building as the stiffness of the R.C.C building is less as compared to steel and composite building.
4. Bending Moment and Shear force in beams for R.C.C building is more as compared to steel and composite building because of increase in storey drift and weight for the R.C.C building.
5. Axial force in column for R.C.C building is more as compared to steel and composite building because steel and composite sections are slender and has high strength to weight ratio as compared to R.C.C section therefore higher axial force in R.C.C building.

6. Time period for R.C.C building is more as compared to steel and composite building because of increased stiffness and frequency of steel and composite building.
7. From overall study it is concluded that the composite building frame shows better performance due to seismic effect as compared to R.C.C building frame, and steel building frame.

FURTHER SCOPE

1. Different shapes of high-rise building can be compared for R.C.C., Steel and Composite options for better guidelines of selection of system.
2. The research needs in regard to composite structures for different soil conditions, different zones and effect of fire.
3. Effect of wind load on tall building constructed using R.C.C, Steel and Composite material.

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