Study on Seismic Analysis of RCC and Steel-Concrete Composite Structure and Cost Comparison with Different Support Conditions

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Abstract— For high rise constructions RCC structures are more bulky and having more seismic weight and are less ductile in nature as compare to composite structures In this paper comparison of seismic performance of G+5, G+10, G+15 buildings of continuous RCC frame and continuous composite frames and simply supported composite frames is presented situated in earthquake zone V with the help of different parameters like deflections, base shear, story drift, self-weight, cost. Equivalent static method is used for seismic analysis ETABS 2015 software is used. Comparative study concludes that the continuous composite frames are more ductile as compare to RCC structures and having deflections within acceptable limits and are more economical as compare to RCC structures.

Key words: Seismic Performance, Continuous Composite, Simply Supported Composite

I. Introduction

The tallness of a building is relative and cannot be defined in absolute terms either in relation to height or the number of stories. But, from a structural engineer's point of view the tall building or multi-storied building can be defined as one that, by virtue of its height, is affected by lateral forces due to wind or earthquake or both to an extent that they play an important role in the structural design. Tall structures have fascinated mankind from the beginning of civilization. The Egyptian Pyramids, one among the seven wonders of world, constructed in 2600 B.C. are among such ancient tall structures. Such structures were constructed for defense and to show pride of the population in their civilization. The growth in modern multi-storied building construction, which began in late nineteenth century, is intended largely for commercial and residential purposes. The development of the high-rise building has followed the growth of the city closely. The process of urbanization that started with the age of industrialization is still in progress in developing countries like India. Industrialization causes migration of people to urban centers where job opportunities are significant. The land available for buildings to accommodate this migration is becoming scarce, resulting in rapid increase in the cost of land. Thus developers have looked to the sky to make their profits. The result is multi-storied buildings, as they provide a large floor area in a relatively small area of land in urban centers. The construction of multi-storied building is dependent on available materials, the level of construction technology and the availability of services such as elevators necessary for the use in the building. In ancient Rome, people used to build multi-storied structures with wood. For those buildings built after the Great Fire of Rome, Nero used brick and a form of concrete material for construction. Wood lacked strength for buildings constructed with brick and masonry occupied a large space for their walls. Technology responded to these drawbacks of construction materials with the development of high strength and structurally more efficient materials like wrought iron and then subsequently steel. These new materials resulted in construction of skyscrapers of the order of 120 stories such as Petronas Tower, Sears Tower, World Trade Centre, and Empire State Building etc. all over the world. In contrast, the tallest building in India is 35 storey's in reinforced concrete, Hotel Oberoi Sheraton (116m). Even though in the last two decades a number of multi- storied buildings have been constructed in India, the tall building technology is at its infancy in India, particularly in structural steel.

II. Literature Review

Composite structures can be defined as the structures in which composite sections made up of two different types of materials such as steel and concrete are used for beams, and columns. Numbers of the studies are carried out on composite construction techniques by different researchers in different parts of the world and found it to be better earthquake resistant and more economical as compared to RCC construction. In composite construction different types of composite sections are used such as composite beams (RCC slab rest over steel beam), encased composite beams (steel sections encased in concrete), pure steel column sections, composite column sections (encased composite column sections and concrete filled in steel tubes column sections). Sometimes composite deck slabs (concrete slab on steel profiled sheets) are also used in the construction of high rise buildings.

The primary structural components use in composite construction consists of the following elements.

- Composite slab
- Composite beam
- Composite column
- shear connector

A. Composite Slab

Traditional steel-concrete floors consist of rolled or built-up structural steel beams and cast in-situ concrete floors connected together using shear connectors in such a manner that they would act monolithically. The principal merit of steel-concrete composite construction lies in the utilization of the compressive strength of concrete slabs in conjunction with steel beams, in order to enhance the strength and stiffness of the steel girder.

More recently, composite floors using profiled sheet decking have become very popular in the West for high rise office buildings. Composite deck slabs are particularly competitive where the concrete floor has to be completed quickly and where medium level of fire protection to steel work is sufficient. However, composite slabs with profiled decking are unsuitable when there is heavy concentrated loading or dynamic loading in structures such as bridges. The alternative composite floor in such cases consists of reinforced or pre-stressed slab over steel beams connected together to act monolithically.

A typical composite floor system using profiled sheets is shown in Fig There is presently no Indian standard covering the design of composite floor system using profiled sheeting.

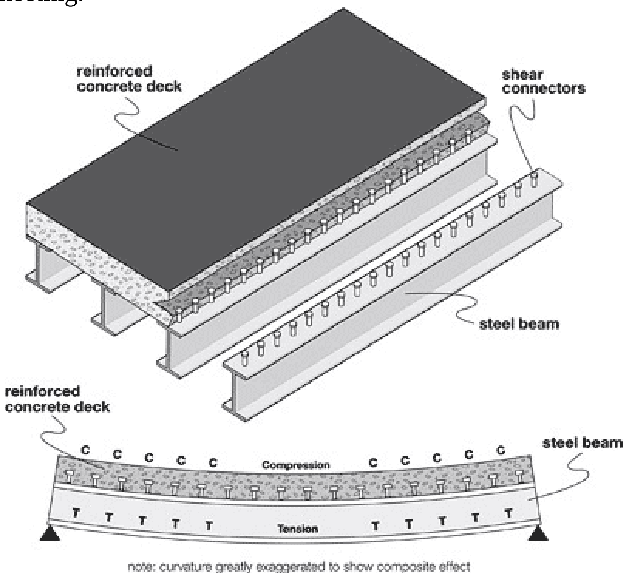

Fig. 1: Composite Slab

B. *Composite Beams*

In conventional composite construction, concrete slabs rest over steel beams and are supported by them. Under load these two components act independently and a relative slip occurs at the interface if there is no connection between them. With the help of a deliberate and appropriate connection provided between them can be eliminated. In this case the steel beam and the slab act as a "composite beam" and their action is similar to that of a monolithic Tee beam. Though steel and concrete are the most commonly used materials for composite beams, other materials such as pre-stressed concrete and timber can also be used. Concrete is stronger in compression than in tension, and steel is susceptible to bucking in compression. By the composite action between the two, we can utilize their respective advantage to the fullest extent. Generally in steel-concrete composite beams, steel beams are integrally connected to prefabricated or cast in situ reinforced concrete slabs.

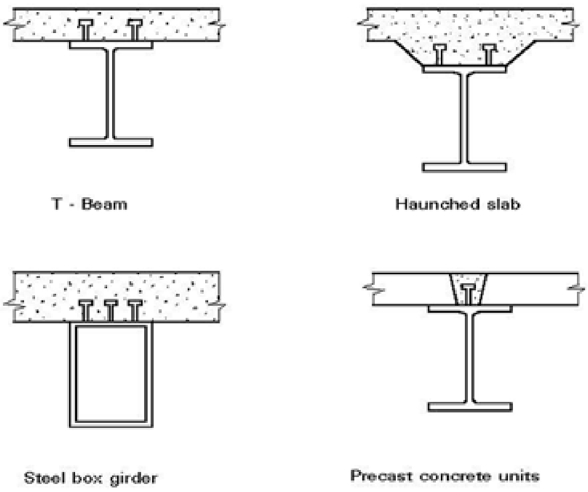

Fig. 2: Composite Beams

C. *Composite Columns*

A steel concrete composite column is a compression member, comprising either of a concrete encased hot rolled steel section or a concrete filled hollow section of hot rolled steel. It is generally used as a load bearing member in a composite framed structure. Composite members are mainly subjected to compression and bending. At present there is no Indian standard code covering the design of composite column. The method of design in this report largely follows EC4, which incorporates latest research on composite construction. Indian standard for composite construction IS 11384-1985 does not make any specific reference to composite columns. This method also adopts the European bucking curves for steel columns as a basic of column design.

Composite columns with fully and partially concrete encased steel sections concrete filled tubular section are generally used in composite construction.

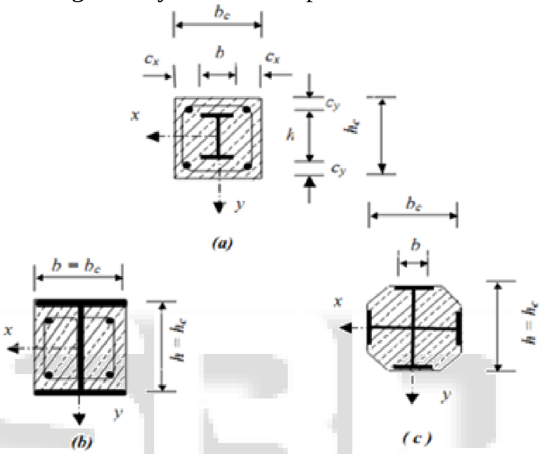

Fig. 3: Composite column encased

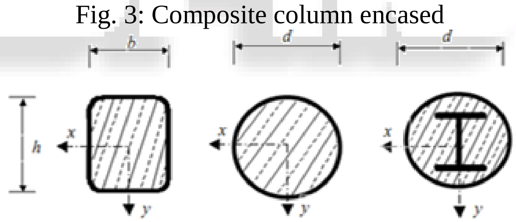

Fig. 4: Composite column in-filled

D. *Shear Connectors*

The total shear force at the interface between concrete slab and steel beam is approximately eight times the total load carried by the beam. Therefore, mechanical shear connectors are required at the steel-concrete interface. These connectors are designed to (a) transmit longitudinal shear along the interface, and (b) Prevent separation of steel beam and concrete slab at the interface.

Shear connectors are essential for steel concrete composite 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. The maximum shear force lies at the neutral axis. In case of composite beams the neutral axis of the section generally lies at the bottom of the concrete slab. This leads to separation of concrete slab from the steel beam. To avoid this there should be prefect bond between concrete and steel. This can be achieved by providing shear connectors at the interface of concrete and steel. Though steel to concrete bond may help shear transfer between the two to certain extent, yet it is neglected as per the codes because of its uncertainty. All codes therefore, specify positive connectors at the interface of steel and concrete. The shear connectors are designed to transmit longitudinal shear along the interface and horizontal shear between steel beam and concrete slab, ignoring the effect of any bond between the two. Shear connectors prevent separation of steel beam and concrete slab at the interface and also resist uplift force at the steel concrete interface.

III. System Development

The buildings considered here is a commercial building having G+5, G+10, G+15 stories located in seismic zone 4. The plan of building is shown in figure 3.1. The plan of building is kept symmetric about both the axes.

Wall Load	12KN/m
Floor Finish	1.5KN/m^2
Slab Load	3.125 KN/m^2
Live load	4 KN/m^2
Rcc design code	IS456
Earthquake design code	IS1893-2002
Composite Design	AISC 360-10

Table 1: Specifications of loading

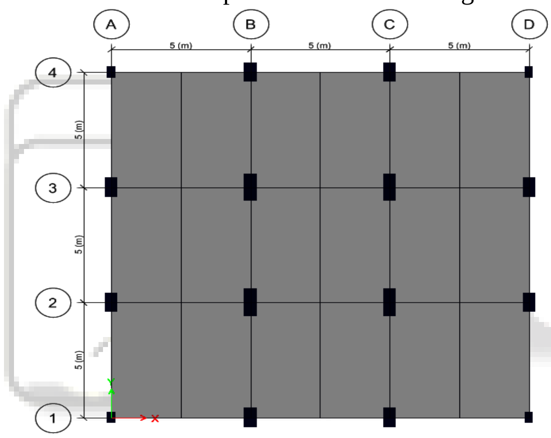

Fig. 5: plan view

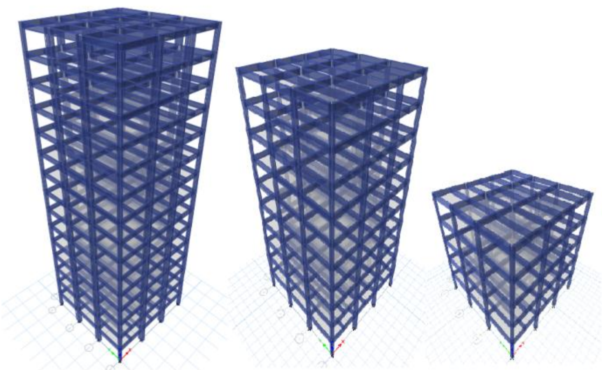

Fig. 6: 3D views of G+15, G+10, G+5 MODELS

Plan dimension	15mx15m
5 storey	15 m
10 storey	30 m
15 storey	45 m
Height of each storey	3 m
Thickness of slab	125 mm(same for all)
Thickness of wall	0.23 m
Seismic zone	IV
Importance factor	1
Zone factor	0.36
Floor finish	1.5
Grade of concrete for slabs	M20
Grade of reinforcing steel	415 mpa
Density of concrete	25 KN/m^3
Damping ratio	5%

Table 2: Specifications of Building

	G+5	G+10	G+15
RCC	Section	section	Section
Beam	230x600	230x600	230x600
column1	230x450	300x450	300x500
column2	300x500	300x600	450x1200
column3	300x700	400x900	450x850

Table 3: Specifications of RCC Buildings

G+5		
Continuous Composite	Section	Encased Section
beam1	ISMB300	
beam2	ISMB225	
beam3	ISMB200	
column1	300x550	ISWB400
column2	300x450	ISWB300
column3	300x400	ISWB250

Table 4: Specifications of continuous composite Building

G+10		
Continuous composite	Section	Encased section
beam1	ISMB300	
beam2	ISMB225	
beam3	ISMB200	
column1	350x700	ISWB500
column2	350x550	ISWB350
column3	300x450	ISWB250

Table 5: Specifications of continuous composite Building

G+15		
continuous composite	section	encased section
beam1	ISMB300	
beam2	ISMB225	
beam3	ISMB200	
column1	450x800	ISWB600-1
column2	300x600	ISWB400
column3	300x700	ISWB500
column4	350x800	ISWB600-1

Table 6: Specifications of continuous composite Building

G+5		
simply supported composite	section	encased section
beam1	ISMB350	
beam2	ISMB300	
beam3	ISMB250	
column1	300x600	ISWB350
column2	300x400	ISWB200
column3	300x350	ISWB175

Table 7: Specifications of simply supported composite Building

G+10		
simply supported composite	section	encased section
beam1	ISMB350	
beam2	ISMB300	
beam3	ISMB250	
column1	500x800	ISWB600-1
column2	400x600	ISWB400

column3	350x500	ISWB300

Table 8: Specifications of simply supported composite Building

G+15		
continuous composite	section	encased section
beam1	ISMB350	
beam2	ISMB300	
beam3	ISMB250	
column1	500x800	ISWB600-1
column2	600x1000	ISWB600-2
column3	450x600	ISWB400

Table 9: Specifications of simply supported composite Building

IV. PERFORMANCE ANALYSIS

The above building models are analyzed using Equivalent Static Method. This method is briefly described in this section. The building models are then analyzed by the software ETABS 2015 Different parameters such as stiffness, drift are studied for all the models. Displacements are found out and inter story drift is calculated for each story. In India, Indian standard criteria for earthquake resistant design of structures IS 1893 (PART-1): 2002 is the main code that provides outline for calculating seismic design force. This force depends on the mass and seismic coefficient of the structure and the later in turn depends upon properties like seismic zone in which structure lies, importance of the structure, it's stiffness, the soil on which it rests and it's ductility. The code recommends following method of analysis.

A. *Equivalent Static Analysis*

This method of seismic analysis involves distribution of total base shear throughout the height of the structure. The base shear is found on the seismic coefficient which is based on the seismic hazard exposure of a particular location and total weight of the structure. Although, this method is a static procedure there is an incorporation of dynamic properties of the structure in terms of fundamental period and response reduction factor. However, this method is limited to a regular type structure whose maximum response is governed by the first mode of vibration. If the infill wall are considered while modeling and analysis, most of the structure lower than ten store's in height would give maximum response at first mode. This is due to an additional stiffness contributed by the infill which eventually makes the structure stiffer and rigid.

Result comparison of Composite and R.C.C. Buildings.

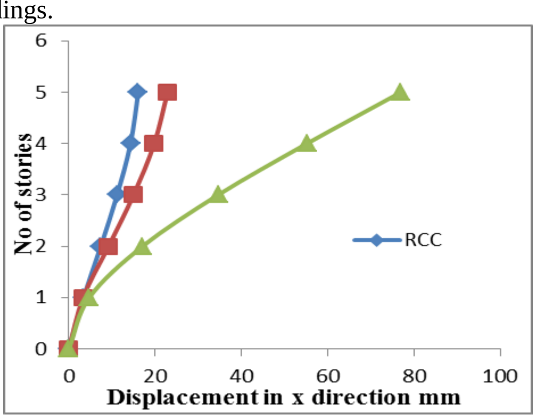

Fig. 7: Story displacement in x direction (For G+5)

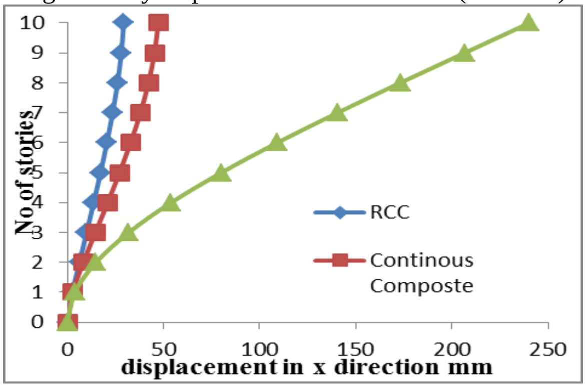

Fig. 8: Story displacement in x direction (For G+10)

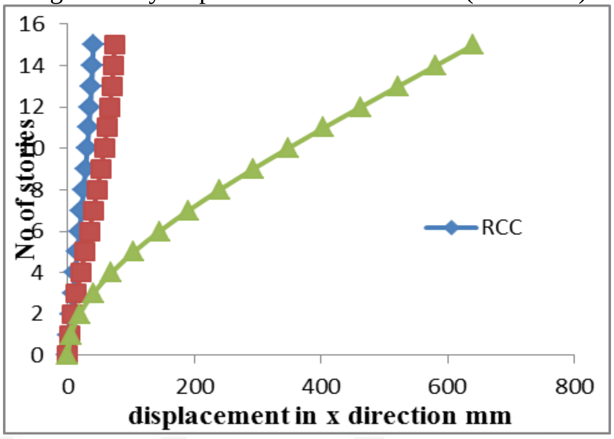

Fig. 9: Story displacement in x direction (For G+15)

The above result showes the displacement of different stories hieght, from this we can see the displacement for simply supported composit struvcture is relativly mor than other two types.

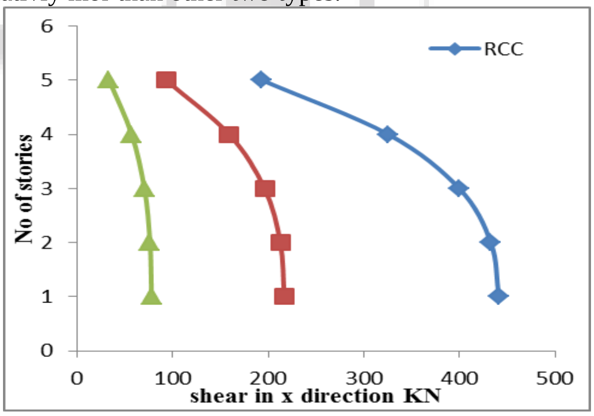

Fig. 10: Story shear in X direction (For G+5)

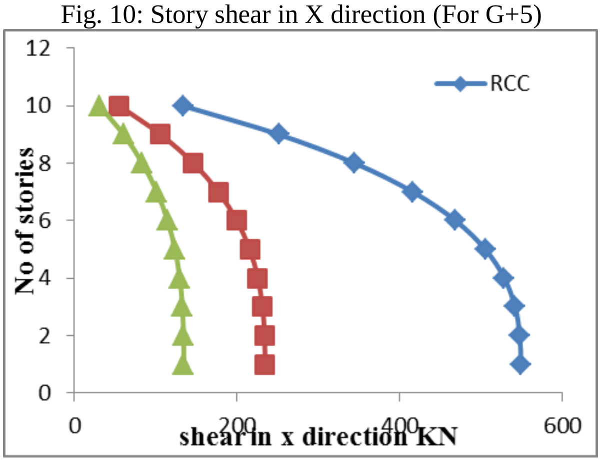

Fig. 11: Story shear in X direction (For G+10)

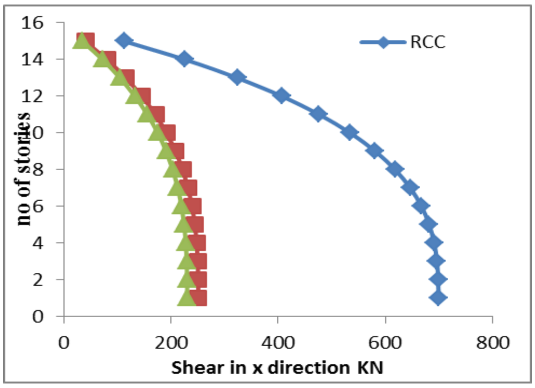

Fig. 12: Story shear in X direction (For G+15)

From above graphs we can see the base shear for RCC frame more/large as compare to composite structures. The difference is near about three times as compare to composite structures.

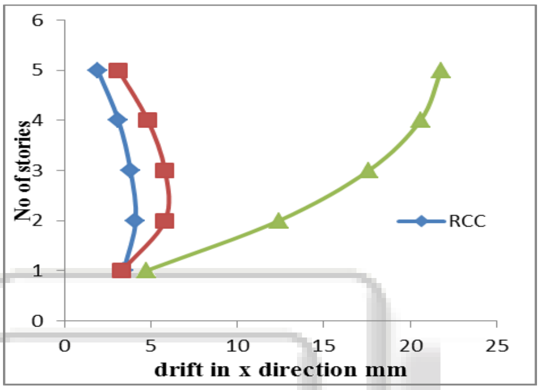

Fig. 13: Story drift in direction (For G+5)

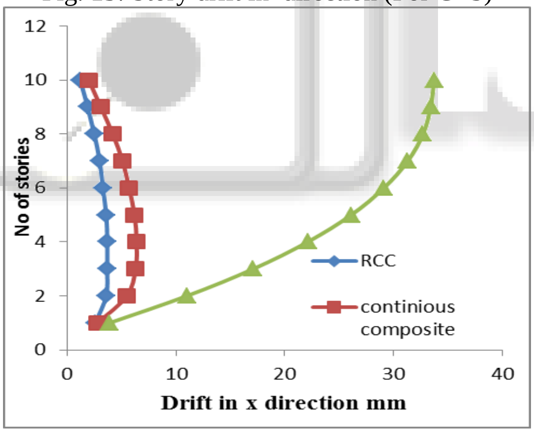

Fig. 14: Story drift in direction (For G+10)

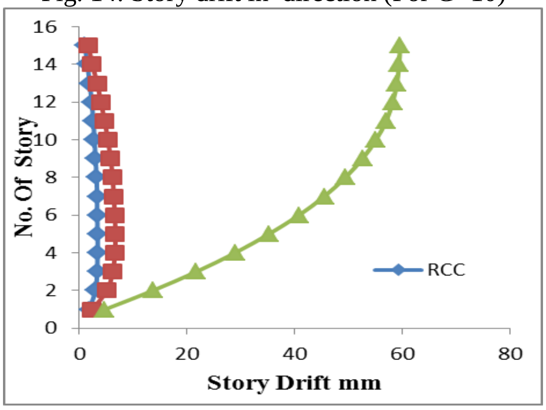

Fig. 15: Story drift in direction (For G+15)

Above three graphs (figure 5.7, 5.8, 5.9) shows relative more story drift in simply supported compoite as compare to RCC and continous composite structure.

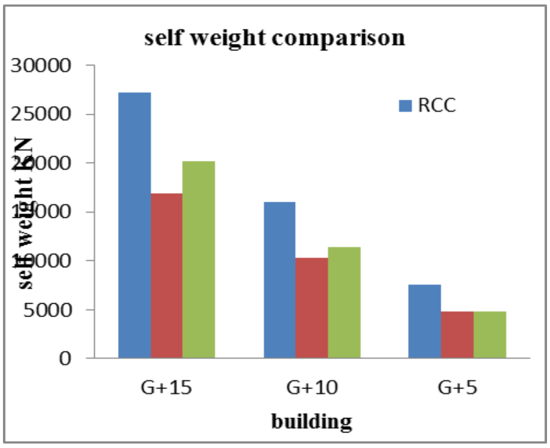

Fig. 16: Self weight

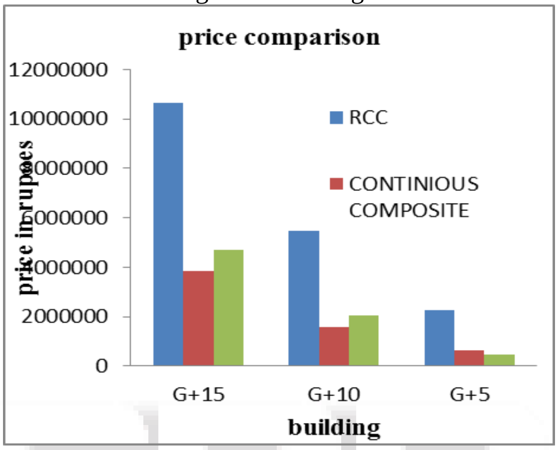

Fig. 17: Price Comparison

V. CONCLUSIONS

Analysis and design results of G+15, G+10, G+5 storied continuous RCC frames and continuous composite frames and simply supported composite frames shows that

1) On the application of seismic force the deflection in continuous composite frame is more than RCC frame but within limits but deflection in simply supported composite frame is much more than both frames and exceeds the desirable limits of deflection.
2) In high rise constructions Continuous Composite frames are more economical than R.C.C. frames and are safer than simply supported composite frames.
3) Self-weight of RCC frames are much more than continuous composite frames, and simply supported composite frames.
4) Story drift in RCC frames is very less as compare to continuous composite frames and simply supported composite frames because of the high stiffness of RCC frame.
5) Base Shear for simply supported composite frame is lowest as compare to continuous composite and RCC frames because the self-weight is low as compare to both type of frames.
6) Same pattern of deflections, base reactions, and story drifts are obtained for differential height of buildings.
7) For low rise structures the cost comparison of composite constructions and RCC construction is not noticeable therefore composite constructions are best suited for high rise constructions.

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