Comparative Seismic Analysis of RCC, Steel & Steel-Concrete Composite Frame

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Abstract
The aim of the present study is to compare performance of a 3D (G+7) story RCC, Steel and composite building frame situated in earthquake zone V. All frames are designed for same gravity loadings. The RCC slab is used in all three cases. Beam and column sections are made of either RCC, Steel or Steel-concrete composite sections. Equivalent static method and Response Spectrum method are used for seismic analysis. SAP 2000 software is used and results are compared. Cost effectiveness based on quantity of materials of all types are determined.

Keywords: 3D (G+7), RCC, SAP 2000

1. Introduction

In India most of the building structures fall under the category of low rise buildings. So, for these structures reinforced concrete members are used widely because the construction becomes quite convenient and economical in nature. But since the population in cities is growing exponentially and the land is limited, there is a need of vertical growth of buildings in these cities. So, for the fulfillment of this purpose a large number of medium to high rise buildings are coming up these days. For these high rise buildings it has been found out that use of composite members in construction is more effective and economic than using reinforced concrete members. The popularity of steel-concrete composite construction in cities can be owed to its advantage over the conventional reinforced concrete construction. Reinforced concretes frames are used in low rise buildings because loading is nominal. But inmedium and high rise buildings, the conventional reinforced concrete construction cannot be adopted as there is increased dead load along with span restrictions, less stiffness and framework which is quite vulnerable to hazards.

2. Literature Review

D.R. Panchal & **Dr. S.C. Patodi** evaluated the seismic performance of multistoried building forwhich they have considered Steel-Concrete Composite and R.C.C. For their analysis the methods that they used were Equivalent static method and Linear Dynamic Response Spectrum Analysis. The results thus obtained were analyzed and compared with each other.

Jingbo Liu, Yangbing Liu, Heng Liu proposed a performance based fragility analysis based method in which the uncertainty due to variability in ground motion and structures are considered. By the proposed method of fragility analysis they performed analysis of a 15 storeyed building having composite beam and concrete filled square steel tube column.

G.E. Thermou, A.S. Elnashai, A. Plumier, C. Doneux have discussed clauses and deficiencies of the Eurocode which earlier used to cause problem for the designers. For obtaining the response of the frames, methods of pushover analysis were also employed. Their main purpose was to study and investigate if the designed structure could behave in an elastically dissipative way.

Shashikala. Koppad, Dr. S.V.Itti considered steel-concrete composite with RCC options for analyzing a B+G+15 building which is situated in earthquake zone III and earthquake loading is as per the guidelines of IS1893(part-I): 2002. The parameters like bending moment and maximum shear force were coming more for RCC structure than the composite structure. Their work suggested that composite framed structures have many benefits over the traditional RC structures for high rise buildings.

D.R. Panchal and P.M. Marathe used a comparative method of study for RCC, Composite and steel options in a G+30 storey commercial building situated in earthquake Zone IV. For this they used Equivalent static method and used the software ETABS. The comparative study included size, deflections, material consumption of members in RCC and steel sections as compared to Composite sections was also studied closely and based on this study a cost comparison analysis was also performed.

A.S. Elnashai and A.Y. Elghazouli developed a model for analysis of structures subjected to cyclic and dynamic loads. These structures were primarily Steel-Concrete Composites and the model they developed was a non-linear model. The efficiency and accuracy of the developed model is shown through correlation between the experimental results and analytical simulations.The model was used for parametric studies resulting in providing important conclusion forductility based earthquake-resistant design

3. Methodology

Step1:

Design of beam and column sections

The frame is analyzed with dead and live loads for RCC sections for beams and columns inSAP 2000.

The maximum forces in columns and beams are determined from output file.

The sections are designed manually for these maximum forces as RCC, Steel and Composite sections for the three types of frame separately.

The codes IS 456-2000, IS 800-2007 and AISC LRFD 1999 are used for RCC, Steel and Composite column section design. The steel beam designed for steel frame is provided in composite frame too. The RCC beam section provided is 0.3m x 0.4 m.

Step 2:

Analysis

Each type of frame is analyzed separately by using Equivalent Static Load Method and Response Spectrum Method by using SAP 2000.

The analysis is conducted for IS 1893(Part 1), 2002 specified combinations of loadings.

Step 3:

Comparison of results

The results obtained are compared in terms of base shear, story deflections, story drifts ,modal participation factor etc. and cost effectiveness with respect to material quantities aredetermined.

3. Model and Analysis

The sections are designed for maximum moment. The sections adopted for analysis are

Table 2.2 SECTIONS USED IN THE STRUCTURES

Section	RCC	Steel	Composite
Column	0.45mx 0.75m Cross section	ISHB 300 H	0.35m x0.35 m with ISHB 250 steel section
Beam Main and secondary	0.3m x 0.4m	ISMB 200 with 125 mm thick concrete slab on top without shear connectors.	ISMB 250 with 125 mm thick concrete slab on top without shear connectors.

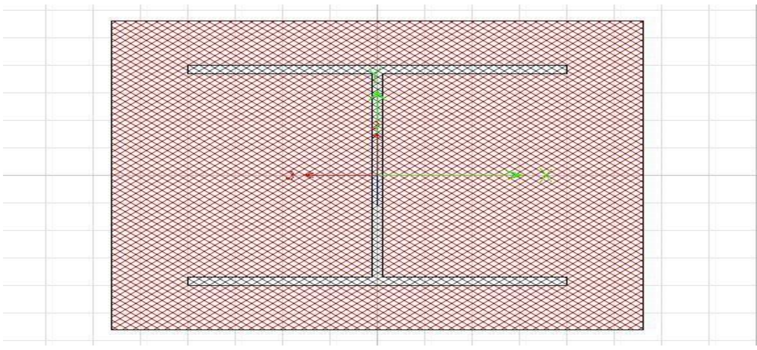

Figure 2.2.a Column Section for Composite frame

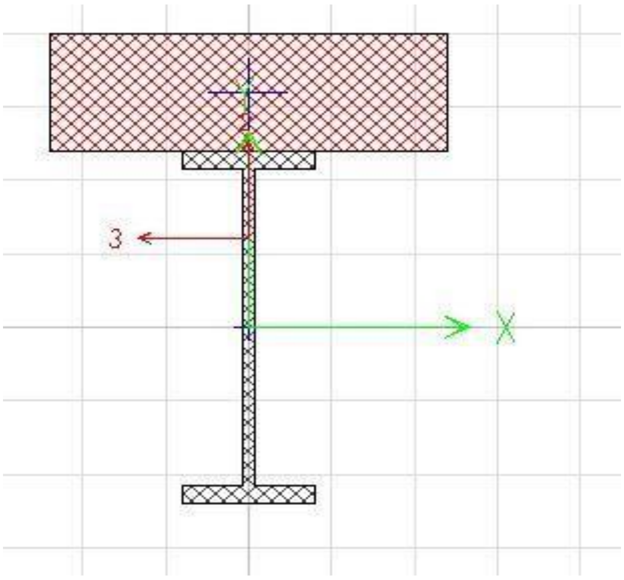

Figure 2.2.b Beam section for Composite frame and steel frame

Analysis

In the present work the two methods of analysis which have been performed are as follows.

- **Equivalent Static Analysis:**

This method is based on the assumption that whole of the seismic mass of the structure vibrates with a single time period. The structure is assumed to be in its fundamental mode of vibration. But this method provides satisfactory results only when the structure is low rise and there is no significant twisting on ground movement. As per the IS 1893: 2002, total design seismic base shear is found by the multiplication of seismic weight of the building and the design horizontal acceleration spectrum value. This force is distributed horizontally in the proportion of mass and it should act at the vertical center of mass of the structure.

- **Response Spectrum Analysis:**

Multiple modes of responses can be taken into account using this method of analysis. Except for very complex or simple structure, this approach is required in many building codes. The structure responds in a way that can be defined as a combination of many special modes. These modes are determined by dynamic analysis. For every mode, a response is perused from the design spectrum, in view of the modal frequency and the modal mass, and they are then combined to give an evaluation of the aggregate response of the structure. In this we need to ascertain the force magnitudes in all directions i.e. X, Y & Z and afterwards see the consequences for the building. Different methods of combination are as follows:

- Absolute-peak values are added together.
- Square root of the sum of squares(SRSS).
- Complete quadratic combination(CQC).

In our present study we have used the SRSS method to combine the modes. The consequence of a response spectrum analysis utilizing the response spectrum from a ground motion is commonly not quite the same as which might be computed from a linear dynamic analysis utilizing the actual earthquake data.

Load combinations as per IS1893- 2002 :

- 1.7(DL+LL)
- 1.7(DL+EQ)
- 1.7(DL-EQ)
- 1.3(DL+LL+EQ)
- 1.3(DL+LL-EQ)

4. Result and Discussion

Results obtained from the analysis are

1. Equivalent Static method

Table 3.1.1.a Storey Drift due to Equivalent Static Analysis in X-direction

rey number	ft of Steel in X-direction	ft of Compositein X-direction	ft of RCC in X-direction
0	0	0	0
1	0.228706	0.0634	0.0085
2	0.25166	0.16	0.0185

3	0.2623	0.21	0.026
4	0.2397	0.223	0.028
5	0.2016	0.219	0.032
6	0.19956	0.198	0.027
7	0.170416	0.167	0.02
8	0.132716	0.132	0.0105

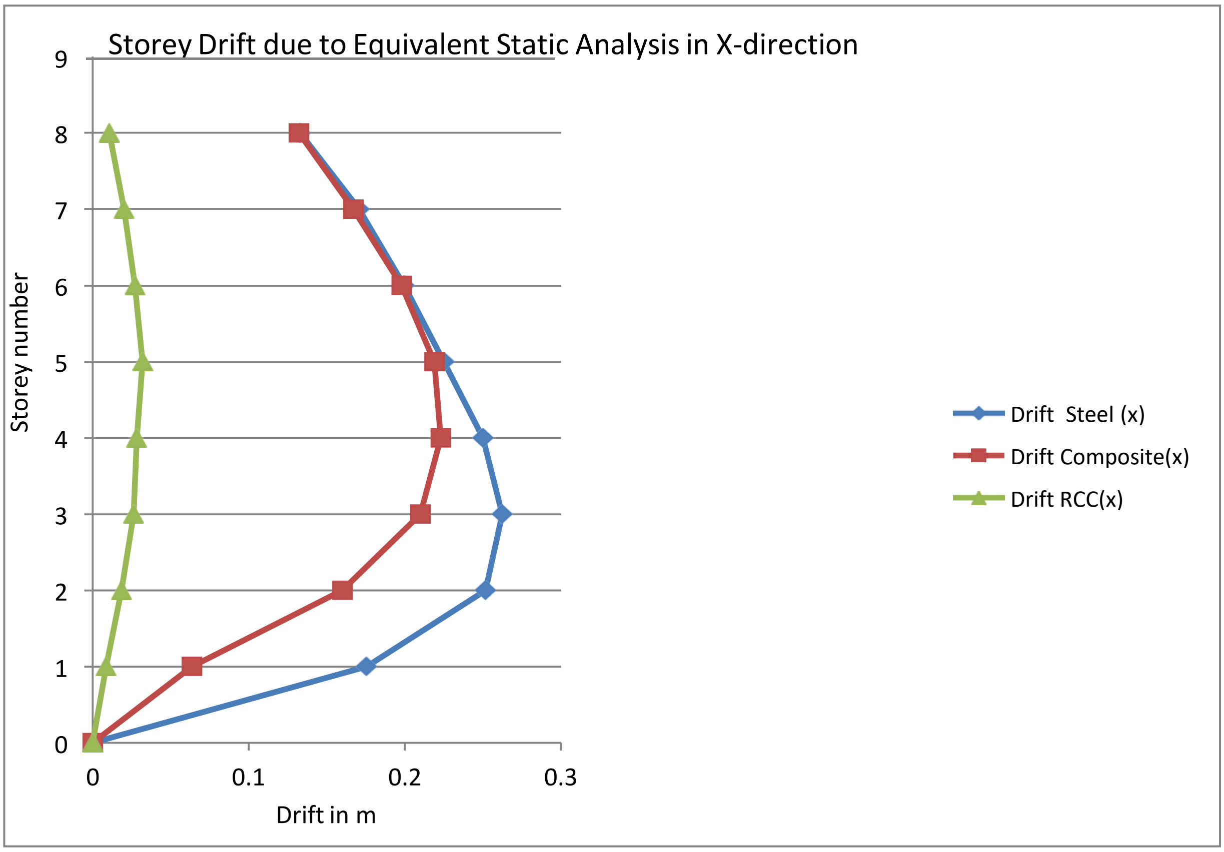

Figure 3.1.1.a Storey Drift in X-direction

It is observed that storey drift in Equivalent Static Analysis in X-direction is more for Steel frame as compared to Composite and RCC frames. RCC frame has the lowest values of storey drift because of its high stiffness.

Table 3.1.1.b Storey Drift in Equivalent Static method in Y-direction

Storey number	ft of Steel in Y-direction	ft of Composite inY-direction	ft of RCC in Y-direction
0	0	0	0

1	0.173725	0.0634	0.0085

	0.325014	0.16	0.0185
	0.35656	0.21	0.026
	0.344811	0.223	0.028
	0.308372	0.219	0.032
	0.250333	0.198	0.027
	0.173608	0.167	0.02
	0.094878	0.132	0.0105

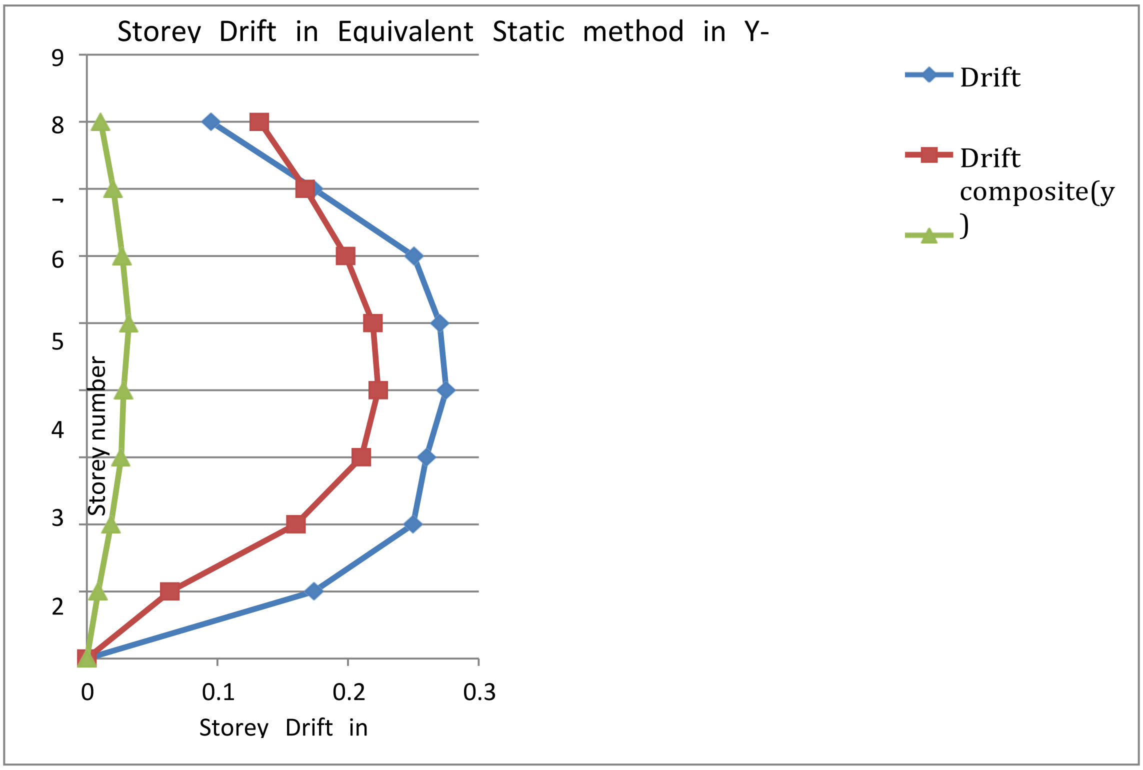

Figure 3.1.1.b Storey Drift in Y-direction

The differences in storey drift for different stories along X and Y direction are owing to orientation of column sections. Moment of inertia of column sections are different in bothdirections.

2. Response Spectrum Analysis:

Table 3.1.1.c Storey Drift due to Response spectrum(X-direction)

Storey number	ft of steel X-direction (m)	ft of Composite inX-direction (m)	ft of RCC in X-direction
0	0	0	0
1	0.194584	0.06183	0.00999
2	0.212933	0.14469	0.02082
3	0.24291	0.18271	0.026793
4	0.250454	0.19162	0.029301
5	0.219621	0.1818	0.024973
6	0.176447	0.16061	0.022574
7	0.128406	0.13484	0.015001
8	0.087103	0.112562	0.00792

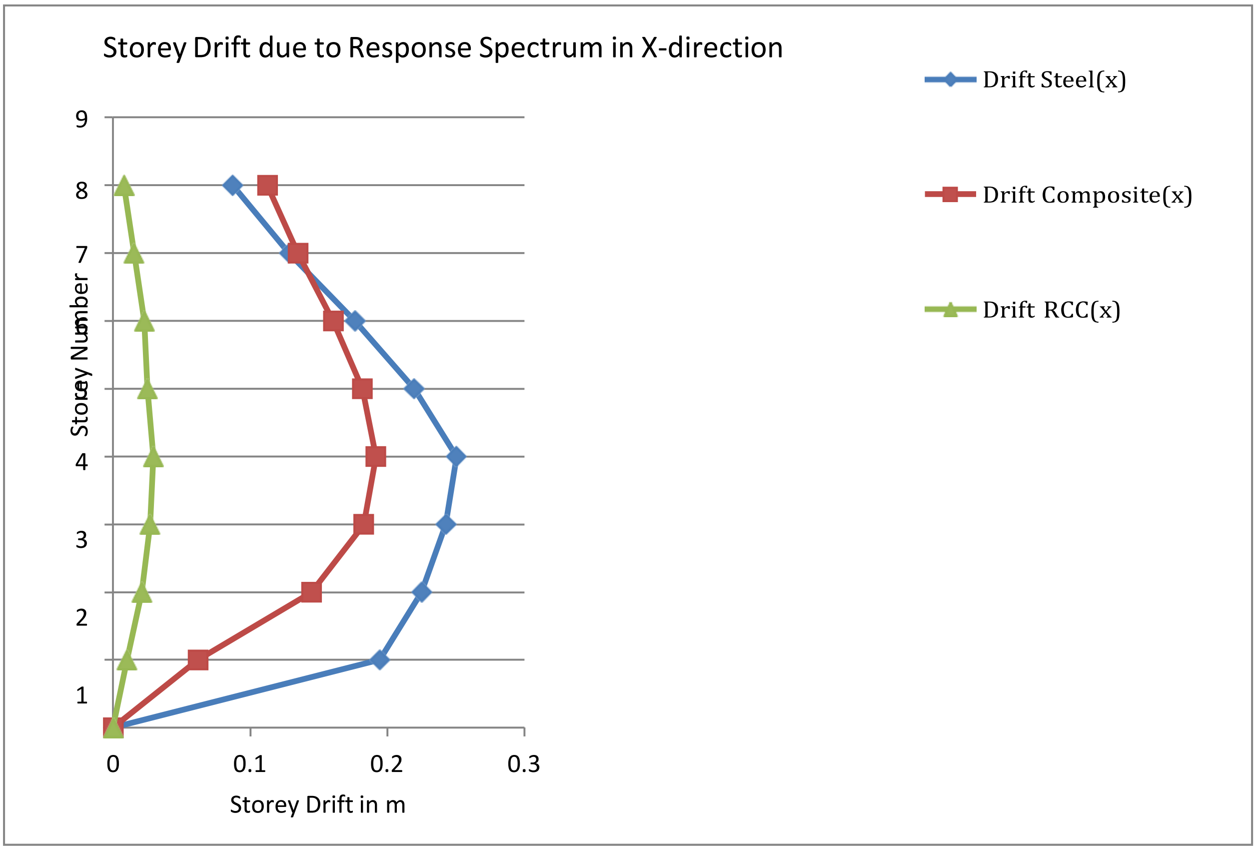

Figure 3.1.1.c Storey drift profile in X-direction

Table 3.1.1.d Storey Drift due to Response Spectrum (Y-direction)

Storey number	ft of Steel in Y-direc-tion (m)	ft of Compositein Y-direction (m)	ft of RCC in Y-direc-tion(m)
0	0	0	0
1	0.173695	70635	0.016823
2	0.2251	0.1625	0.030067
3	0.25015	0172	0.033999
4	0.270017	07945	0.020062
	0.253265	9353	0.022671
	0.191607	6681	0.020568
	0.124383	0.1354	0.013956
	0.064534	08515	0.00736

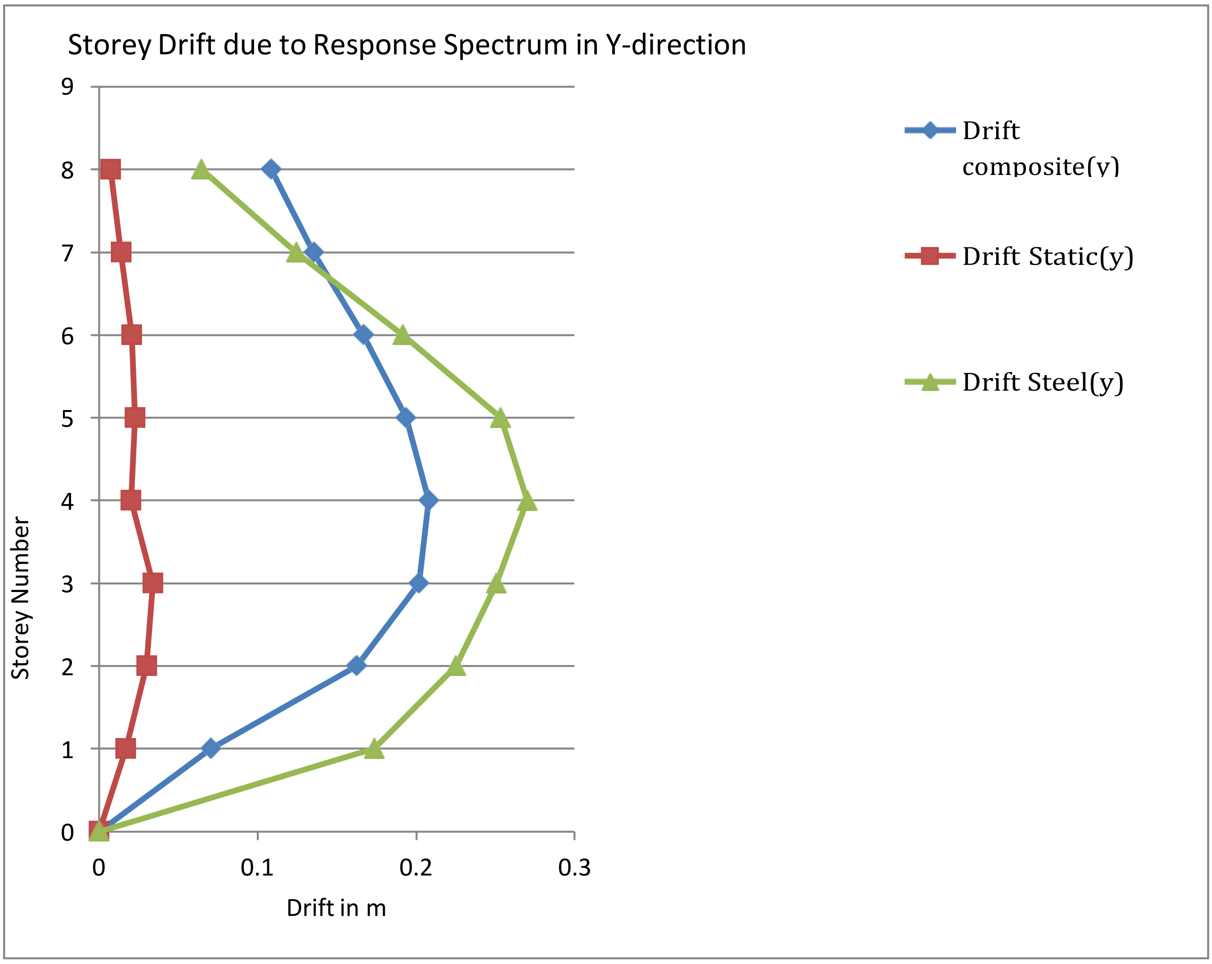

Figure 3.1.1.d Storey drift profile in Y-direction

Same storey drift patterns are obtained by using Response Spectrum method analysis validating the results obtained by the Equivalent Static method.

3.1.2. Base Shear Calculation

Table 3.1.2. Base Shear for Different Cases

	mposite	C	EEL
x	5.798KN	2.7KN	6.916KN
y	5.798KN	4.19KN	6.92KN
x	5.798KN	9.42KN	6.969KN
y	5.798KN	9.42KN	6.94KN

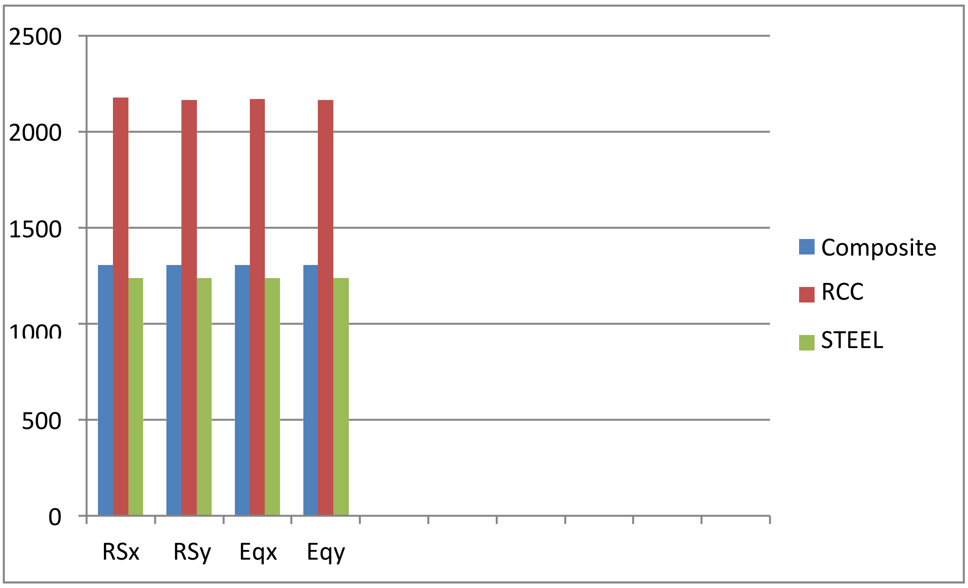

Figure 3.1.2. Base Shear for Different Cases

Base Shear for RCC frame is maximum because the weight of the RCC frame is more thanthe steel and the composite frame.

5. **Conclusion**

- Storey drift in Equivalent Static Analysis in X-direction is more for Steel frame as compared to Composite and RCC frames.
- RCC frame has the lowest values of storey drift because of its high stiffness.
- The differences in storey drift for different stories along X and Y direction are owingto orientation of column sections. Moment of inertia of column sections are differentin both directions.
- Same storey drift patterns are obtained by using Response Spectrum methodvalidating the results obtained by the Equivalent Static method.
- Base Shear for RCC frame is maximum because the weight of the RCC frame is morethan the steel and the composite frame. Base shear gets reduced by 40% for Composite frame and 45% for Steel frame in comparison to the RCC frame.
- Reduction in cost of Composite frame is 33% and Steel frame is 27% compared withcost of RCC frame. This involves material cost only and doesn't include fabrication cost, transportation cost, labour cost etc.

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