Comparison of Seismic Behavior of Reinforced Cement Concrete and Composite Frame Structure

[1]Deepak Kumar, [2]Amit Kumar, [3]Neelaz Singh,
[1]Assistant Professor, [2]Assistant Professor, [3]Assistant Professor,
[1, 2,3]Aravali College of Engineering and Management, Faridabad, India

***Abstract**:* Composite steel and concrete Constructions are very frequently used and have benefits over conventional Concrete and Steel constructions. Concrete structures are heavy and provide more seismic weight and less deflection whereas Steel structures instruct more deflections and ductility to the structure, which is helpful in resisting earthquake forces. Composite Construction contain the better properties of both steel and concrete along with less cost, speedy construction, fire protection etc. Hence the objective of the study is to compare seismic performance of a multistorey 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 RCC, Steel or Steel- concrete composite sections. Equivalent static method and Response Spectrum method are used for seismic analysis. SAP 2000 v25.0.0.software is used and results are compared. Costminimizations based on material cost for all types of structures is determined. The study concludes that the composite frames structures have better than steel and concrete constructions in the parameters of material cost and along with better seismic performance.

Keywords: *Composite structures, SAP2000 v25.0.0, Seismic performance, RCC, Steel structure*

Introduction

Common building structures in India come under the category of low rise buildings. Low rise structures RCC members are used mostly used due to convenient and economical construction in nature.

Due to growing population in different cities and the land is limited; there is a requirement of high rise building in these areas. So, for the arrangement of this, a large number of moderate to high rise buildings are coming up these days. In 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 in medium 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.

In construction industry in India use of steel is very less as compared to other developing nations like China, Brazil etc. Seeing the development in India, there is a dire need to exploremore in the field of construction and devise new improved techniques to use Steel as a construction material wherever it iseconomical to use it. Steel concrete composite frames use more

A steel-concrete composite column is a compression member comprising of a concrete filled tubular section of hot-rolled steel or a concrete encased hot-rolled steel section. In a composite column, both the concrete and the steel interact together by friction and bond. Therefore, they resist external loading. Generally, in the composite construction, the initial construction loads are bear and supported by bare steel columns. Concrete is filled on later inside the tubular steel sections or is later casted around the I section. The combination of both steel and concrete is in such a way that both of the materials use their attributes in the most effective way. Due to the lighter weight and higher strength of steel, smaller and lighter foundations can be used. The concrete which is casted around the steel sections at later stages inconstruction helps in limiting away the lateral deflections, sway and bucking of the column. It is very convenient and efficient to erect very high rise buildings if we use steel- concrete composite frames along with composite decks and beams. The time taken for erection is also less due to which speedy construction is achieved along better results.

Objective of the study:

1) All frames are designed for same gravity loadings. The RCC slab is used in all three cases.
2) The main aim of the present study is to compare performance of eight story Reinforced cement concrete, Steel and composite building frame situated in earthquake zone V.
3) Analysis of framed structure by using *SAP2000 v25.0.0*. Software and results are compared.
4) Cost minimization

Methodology

Step1: Design of beam and column sections the frame is analyzed with dead and live loads for RCC sections for beams and columns in SAP2000 v25.0.0. 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), 2016 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 are determined.

Design and Analysis

Design data

Eight storey building frame with three bays in horizontal and three bays in lateral direction is analyzed by Equivalent Static Method and Response Spectrum Method. Thegeometrical parameters of the building are as follows:

- Height of each storey = 3.6 m
- Center-to-center span between each column along X and Y direction = 5 m
- Fixed type support at the bottom. The loads on the building are as follows:
- **Dead Load:-**

1. **Self-weight of the frame**
2. **Dead load of floors**

a. Dead floor load of all the intermediate floors = 7.2 KN/m2

b. Dead load of the roof floor = 5.4 KN/m2

3. **Dead load of walls**

a. On outer beams = 11 KN/m2

b. On inner beams = 5KN/m2

- **Live load**

a. Live load on all the intermediate floors = 4.2KN/m2

- Live load on roof floor = 1.52 KN/m2
- Earthquake load in X-direction & Y-direction asspecified in IS 1893: 2016.
- The seismic parameters of the building site are asfollows:
- Seismic Zone: V
- Zone factor Z : 0.36
- Soil type= Type II (Medium Soil)
- Building Frame System: Moment resisting RC frame.
- Response Reduction Factor = 5
- Importance factor = 1
- Fundamental natural time period, T= 0.075 H0.75 (moment-resisting frame building without brick in thepanels).

Since H= 27 m, hence T= 0.9369 sec along both directions.

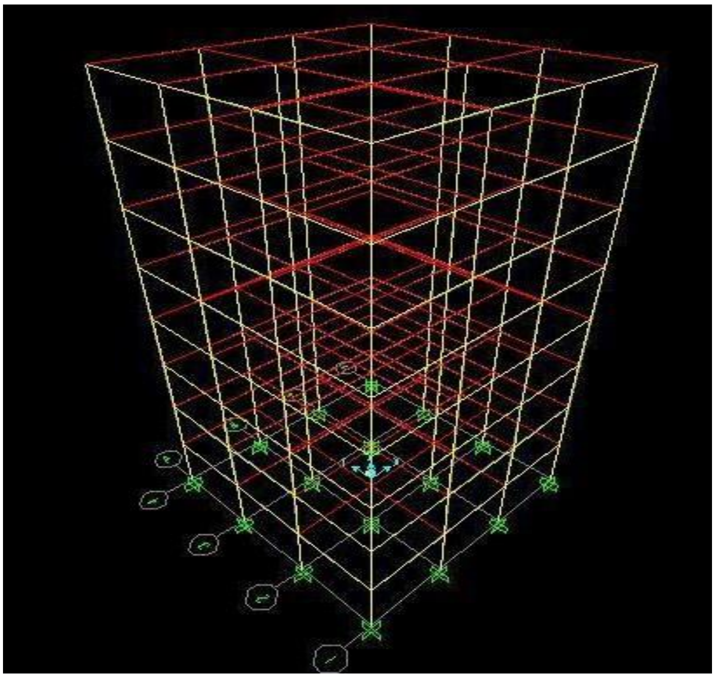


Figure 1: 3-D model of the Figure frame structure

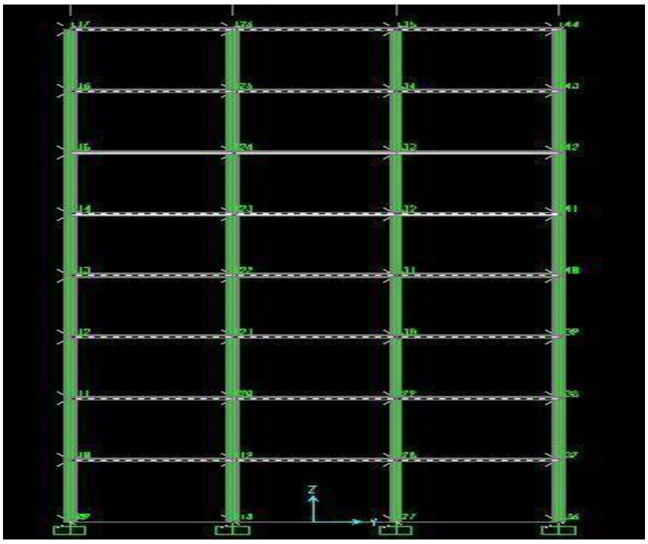


Fig 2: 2-D (y-z plane) model of the frame structure

Design and analysis

The sections are designed for maximum moment.

The sectionsadopted for analysis are

Table 1: Sections Used In the Structures

Section	RCC	Steel	Composite
Column	).460mx 0.730m Cross section	B 300H	0.34m x0.34 m with ISHB 250 steel section
Beam Main and secondary	).35m x 0.41m	ISMB 200 with 125 mm thick concrete slab on topwithout shear Connectors	ISMB 250 with 125 mm thick concrete slab on top without shear Connectors.

Table 2: Storey Drift due to Equivalent Static Analysis in X-direction

Storey number	Drift of Steel in X-direction	Drift of Compositein X- direction	Drift of RCC in X- direction
0	0	0	0
1	0.238706	0.0534	0.0075
2	0.24166	0.16	0.0185
3	0.2623	0.21	0.026
4	0.2497	0.223	0.028
5	0.2016	0.229	0.032
6	0.19956	0.198	0.027
7	0.170416	0.167	0.02
8	0.122716	0.132	0.0105

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.

Storey number	Drift of Steel in Y-direction	Drift of Composite in Y-direction	Drift of RCC in Y- direction
0	0	0	0
1	0.163725	0.0534	0.0075
2	0.335014	0.16	0.0185
3	0.34656	0.21	0.026
4	0.344811	0.233	0.027
5	0.308372	0.219	0.032
6	0.240333	0.198	0.027
7	0.173608	0.167	0.02
8	0.094878	0.132	0.0105

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:

- 1.5(DL+LL)
- 1.5(DL+EQ)
- 1.5(DL-EQ)
- 1.2(DL+LL+EQ)
- 1.2(DL+LL-EQ)

RESULTS AND DISCUSSION

Results obtained from the analysis are

Equivalent Static method

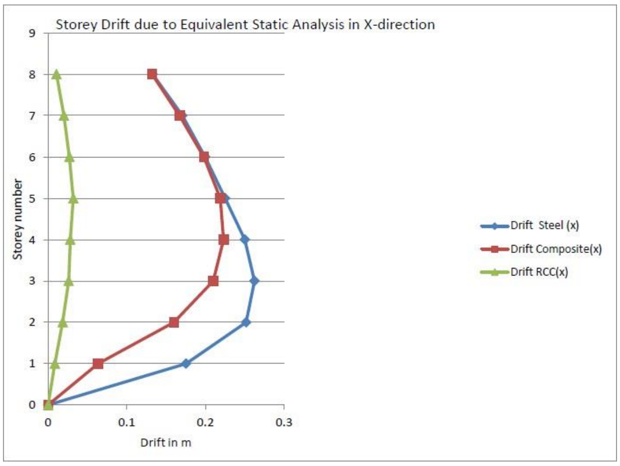
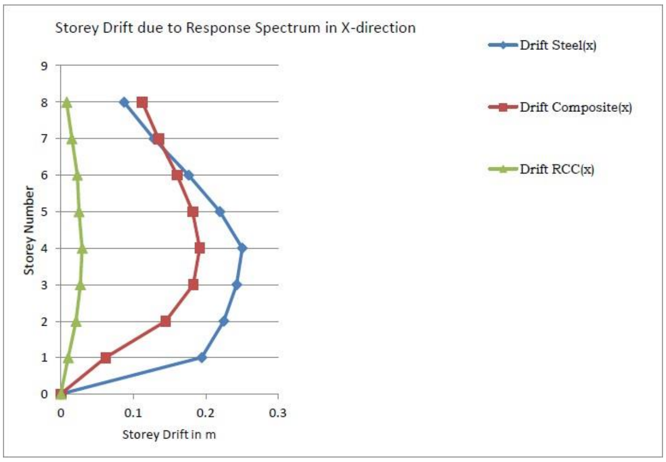
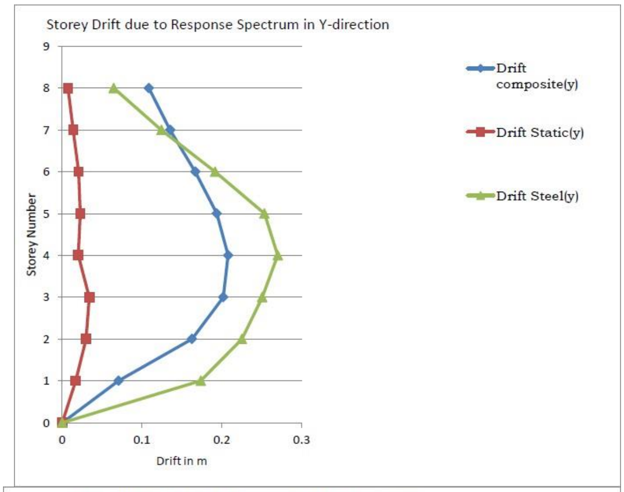


Figure 3: Storey Drift in X-direction

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: Storey Drift in Equivalent Static method in Y-direction





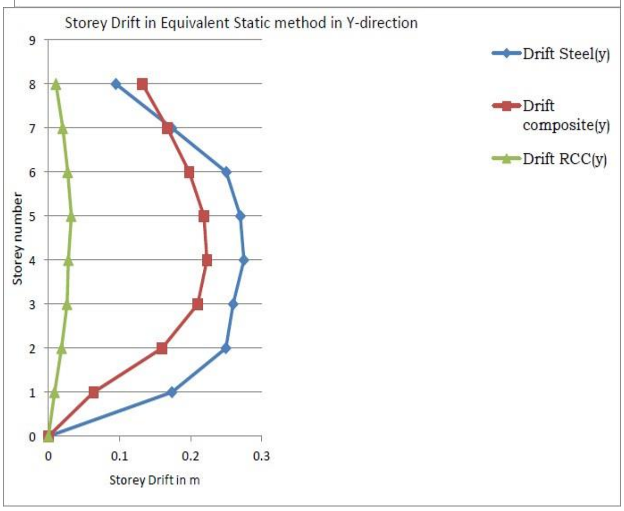


Figure 4: Storey Drift in Y-direction

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 is different in both directions.

Response Spectrum Analysis:

Table 5: Storey Drift due to Response spectrum(X-direction)

Storey number	**Drift of steelX-direction(m)**	**Drift of Composite inX-direction (m)**	**Drift ofRCC inX-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 6: Storey drift profile in X-direction

Table 4: Storey Drift due to Response Spectrum (Y-direction)

Storey number	**Drift of Steel in Y- direction**	**Drift of Composite in Y-direction**	**Drift of RCC inY-direction**
0	0	0	0
1	0.163695	0.070635	0.016823
2	0.2251	0.1625	0.030067
3	0.24015	0.20172	0.033999
4	0.260017	0.207945	0.020062
5	0.243265	0.19353	0.022671
6	0.181607	0.16681	0.020568
7	0.124383	0.1354	0.014956
8	0.064534	0.108515	0.00736

Figure 5: 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.

Base Shear Calculation

Table 6: Base Shear for Different Cases

	Composite	RCC	STEEL
EQx	1305.798KN	2172.7KN	1236.916KN
EQy	1305.798KN	2164.19KN	1236.92KN
RSx	1305.798KN	2179.42KN	1236.969KN
RSy	1305.798KN	2179.42KN	1236.94KN

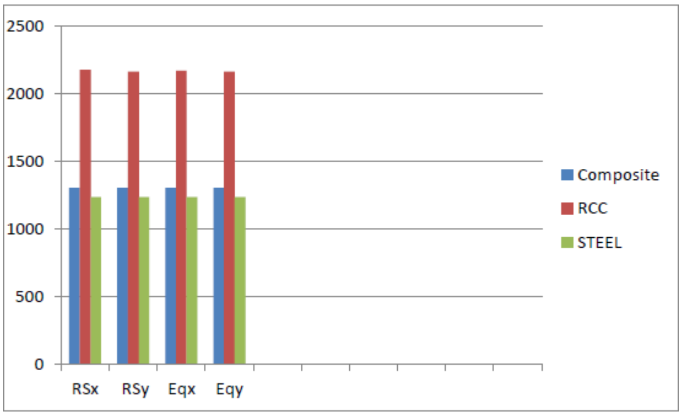


Figure 7: Base Shear for Different Cases

Base Shear for RCC frame is maximum because the weight ofthe RCC frame is more than the steel and the composite frame.

Modal Participation factor

20 modes were considered for analysis. The cumulative modalmass both in X and Y direction are approximately equal to 90%, satisfying IS 1893 specifications

Table 7: Response Spectrum (Composite)

Mode Number	**Period in Seconds**	**Cumulative Modal participating mass in X-direction in translation**	**Cumulative Modal participating mass in Y-direction in translation**	**Cumulative Modal participating mass in X-direction in rotation**	**Cumulative Modal participating mass in X-direction in rotation**
1	7.399237	1.25E-20	0.68549	0.84247	0
2	7.140737	0.67209	0.68549	0.84247	0.83514
3	6.304384	0.67209	0.68549	0.84247	0.83514
4	6.083174	0.67209	0.68549	0.84247	0.83514
5	5.346745	0.67209	0.74163	0.90884	0.83514
6	5.204235	0.73306	0.74163	0.90884	0.90811
7	5.06926	0.73306	0.74163	0.90884	0.90811
8	4.930562	0.73306	0.74163	0.90884	0.90811
9	2.117262	0.73306	0.82692	0.90925	0.90811
10	2.062406	0.73306	0.82692	0.90925	0.90811
11	1.99172	0.8213	0.82692	0.90925	0.909
12	1.945541	0.8213	0.82692	0.90925	0.909
13	1.683302	0.8213	0.87092	0.90946	0.909
14	1.683135	0.8213	0.87092	0.90946	0.909
15	1.58303	0.86803	0.87092	0.90946	0.90946
16	1.582915	0.86803	0.87092	0.90946	0.90946
17	0.976256	0.86803	0.90594	0.91162	0.90946
18	0.970443	0.86803	0.90594	0.91162	0.90946
19	0.894884	0.90402	0.90594	0.91162	0.91158
20	0.890398	0.90402	0.90594	0.91162	0.91158

Table 8: Response Spectrum (RCC)

Mode Number	Period in Seconds	Cumulative Modal participating mass in X-direction in translation	Cumulative Modal participating mass in Y-direction in translation	Cumulative Modal participating mass in X-direction in rotation	Cumulative Modal participating mass in X-direction in rotation
1	2.547691	2.07E-18	0.77423	0.90591	1.06E-19
2	2.17747	0.71832	0.77423	0.90591	0.90268
3	2.052827	0.71832	0.77423	0.90591	0.90268
4	1.26328	0.71832	0.77423	0.90591	0.90268
5	0.96284	0.71832	0.77478	0.90685	0.90268
6	0.927038	0.71961	0.77478	0.90685	0.90434
7	0.842213	0.71961	0.88157	0.90773	0.90434
8	0.731998	0.71961	0.88157	0.90773	0.90434

8 modes were considered for analysis. The cumulative modal participating mass (in Y) reaches to a value of 90% of the total seismic mass. So, there is a need to increase the number of nodes so that the Cumulative modal participating mass can reach up to a sum of 90%

Table 9: Response Spectrum (Steel)

Mode Number	Period in Seconds	Cumulative Modal participating mass in X-directionin translation	Cumulative Modal participating mass in Y-direction in translation	Cumulative Modal participating mass in X-direction in rotation	Cumulative Modal participating mass in X- direction in rotation
1	9.280204	2.19E-18	0.74617	0.85068	1.63E-19
2	8.123352	0.69529	0.74617	0.85068	0.82725
3	7.934987	0.69529	0.74617	0.85068	0.82725
4	6.905939	0.69529	0.74617	0.85068	0.82725
5	6.552386	0.69529	0.79914	0.90858	0.82725
6	5.933679	0.76805	0.79914	0.90858	0.9106
7	5.88356	0.76805	0.79914	0.90858	0.9106
8	5.341508	0.76805	0.79914	0.90858	0.9106
9	3.060217	0.76805	0.86877	0.9102	0.9106
10	2.916718	0.76805	0.86877	0.9102	0.9106
11	2.489321	0.84353	0.86877	0.9102	0.91069
12	2.417077	0.84353	0.90181	0.91094	0.91069
13	2.413027	0.84353	0.90181	0.91094	0.91069
14	2.404411	0.84353	0.90181	0.91094	0.91069
15	1.960617	0.88305	0.90181	0.91094	0.91073
16	1.957717	0.88305	0.90181	0.91094	0.91073
17	1.67432	0.88305	0.92888	0.91317	0.91073
18	1.647212	0.88305	0.92888	0.91317	0.91073
19	1.3203	0.88305	0.94464	0.91444	0.91073
20	1.319799	0.88305	0.94464	0.91444	0.91073

20 modes were considered for analysis. The cumulative modal participating mass (both in X and Y) reaches to a value of 90% of the total seismic mass.

Modal Periods and Frequencies

Table 10: Response Spectrum (Composite)

Mode Number	Period in Seconds	Frequencyin Cyc/sec	Circular Frequencyin rad/sec	Eigen Value rad2/sec2
1	9.280204	0.10776	0.67705	0.4584
2	8.123352	0.1231	0.77347	0.59826
3	7.934987	0.12602	0.79183	0.627
4	6.905939	0.1448	0.90982	0.82778
5	6.552386	0.15262	0.95892	0.91952
6	5.933679	0.16853	1.0589	1.1213
7	5.88356	0.16997	1.0679	1.1405
8	5.341508	0.18721	1.1763	1.3837
9	3.060217	0.32677	2.0532	4.2156
10	2.916718	0.34285	2.1542	4.6406
11	2.489321	0.40172	2.5241	6.3709
12	2.417077	0.41372	2.5995	6.7574
13	2.413027	0.41442	2.6039	6.7801
14	2.404411	0.4159	2.6132	6.8288
15	1.960617	0.51004	3.2047	10.27
16	1.957717	0.5108	3.2094	10.301
17	1.67432	0.59726	3.7527	14.083
18	1.647212	0.60709	3.8144	14.55
19	1.3203	0.7574	4.7589	22.647
20	1.319799	0.75769	4.7607	22.664

Table 11: Response Spectrum (RCC):

Mode Number	Period in Seconds	Frequencyin Cyc/sec	Circular Frequencyin rad/sec	Eigen Value rad2/sec2
1	2.547691	0.39251	2.4662	6.0823
2	2.17747	0.45925	2.8855	8.3264
3	2.052827	0.48713	3.0607	9.3682
4	1.26328	0.79159	4.9737	24.738
5	0.96284	1.0386	6.5257	42.585
6	0.927038	1.0787	6.7777	45.937
7	0.842213	1.1873	7.4603	55.657
8	0.731998	1.3661	8.5836	73.678

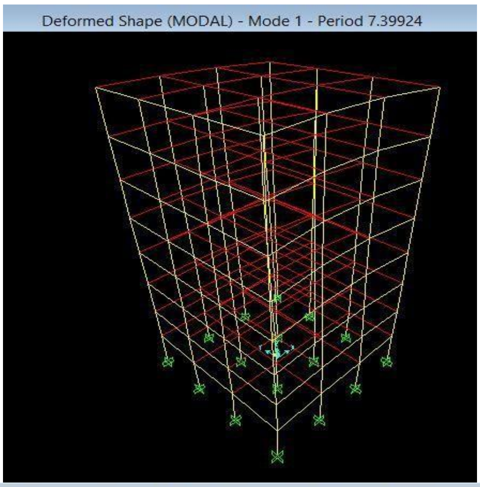
Cost Comparison Analysis

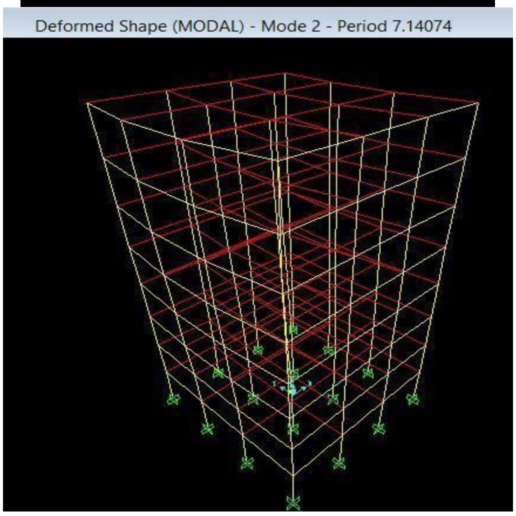
Table 12: Composite Frame Structure

Material	Quantity Used	Rate of material	Amount
Structural Steel (kg)	320	Rs 42000/MT	Rs 13,440
Concrete used (m^3)	120	Rs 3000/m^3	Rs 3,60,000
Total Sum			**Rs 3,73,440**

Table 11: Response Spectrum (Steel)

10	2.916718	0.34285	2.1542	4.6406
11	2.489321	0.40172	2.5241	6.3709
12	2.417077	0.41372	2.5995	6.7574
13	2.413027	0.41442	2.6039	6.7801
14	2.404411	0.4159	2.6132	6.8288
15	1.960617	0.51004	3.2047	10.27
16	1.957717	0.5108	3.2094	10.301
17	1.67432	0.59726	3.7527	14.083
18	1.647212	0.60709	3.8144	14.55
19	1.3203	0.7574	4.7589	22.647
20	1.319799	0.75769	4.7607	22.664





Reduction Factor for Composite= Cost of Composite/Cost of RCC
= 373440/560750

= 0.67

Reduction Factor for Steel= Cost of Steel/Cost of RCC
= 3, 97,000/560,750
= 0.72

Hence, reduction in cost of composite frame is 33% and steel frame is 27% compared with cost of RCC frame. This involves

Mode Shapes:-Response Spectrum (Composite)
Figure 8: The mode shapes for the first 6 modes for the composite building are: material cost only and doesn‟t include fabrication cost, transportation cost, labour cost etc.

CONCLUSION

Storey drift in Equivalent Static Analysis in X-direction is more for Steel frame as compared to Composite and RCC frames.

(i) RCC frame has the lowest values of storey drift because of its high stiffness.
(ii) The differences in storey drift for different stories along X and Y direction are owing to orientation of column sections. Moments of inertia of column sections are different in both directions.
(iii) Same storey drift patterns are obtained by using Response Spectrum method validating the results obtained by the Equivalent Static method.
(iv) Base Shear for RCC frame is maximum because the weight of the RCC frame is more than 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.
(v) Reduction in cost of Composite frame is 33% and Steel frame is 27% compared with cost of RCC frame. This involves material cost only and doesn't include fabrication cost, transportation cost, labour cost etc.

References

1. LIU Jingbo, LIU Yangbing (2008), " Seismic behaviour analysis of steel-concrete Composite frame structure systems", Tsinghua University, Beijing, China,.
2. IS 1893: 2016, "Code for earthquake resistant design of structures- general provisions for buildings, Part I, Bureau of Indian Standards", New Delhi.
3. IS 800: 2007, "Indian Standard Code of practice for General Construction of Steel in India, Bureau of Indian Standards", New Delhi
4. IS 11384:1985, "Code of Practice for Design of Composite Structure, Bureau of Indian Standards", New Delhi.
5. Shashikala. Koppad, Dr. S.V.Itti Comparative Study of RCC and Composite Multistoreyed Buildings International Journal of Engineering and Innovative Technology (IJEIT) Volume 3, Issue 5, November 2013 ISSN: 2277-3754 ISO 9001:2008 Certified
6. Mohd. Amir Khan Comparative Study of R.C.C & Structural Steel -Concrete Composite Frame for Linear and Non-Linear Analysis International Research Journal of Engineering and Technology (IRJET) e- ISSN: 2395-0056 Volume: 04 Issue: 07 | July -2017 www.irjet.net p-ISSN: 2395-0072
7. S.R.Sutar1, P.M.Kulkarni2 Comparative inelastic analysis of

RCC and steel-concrete composite frame IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 13, Issue 4 Ver. IV (Jul. - Aug. 2016),

8. A.S. Boke, 2k. R. Suryawanshi comparative study of r.c.c and steel-concrete composite (g+10) residential building journal of information, knowledge and research in civil engineering Issn: 0975 – 6744| nov 16 to oct 17 | volume 4, issue 2 presented at nc-rdd-ems- 2017 on 18/03/2017
PP 22-32