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Comparative Analysis on the Performance of Column Supported Elevated Storage Reservoir (ESR) Having Different Material Properties

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Abstract - *Elevated Storage Reservoir (ESR) is a tall structure which stores the water in huge amount. Hence, proper designing and analysis must be carried out prior to the construction. Same way, columns are the main part of any structure. Basically, they transfer the load from super structure to foundation. That makes the selection of the column type very crucial. RCC Column, Steel Column are used in Construction of Residential Building, Malls, Theatres as well as in Industrial area. Generally, concrete filled steel tube (CFST) columns are used in the design og high-rise buildings, bridges, irregular shapes of building etc. CFST column is a composite section formed by filling concrete into a hollow steel tube. It resists the applied load through the composite action of concrete and steel. Whereas the special structure like water storage reservoir or ESR uses the RCC column.*

I would like to replace the traditional way of construction using RCC column with CFST column. Hence, I would like to carry out a comparative study on the design and the analysis of ESR construction using RCC column and CFST column. The Comparison can be between their behaviors, moments, loading conditions or construction point of view. To achieve this result, I will make 54 models using necessary software like ETABS with respect to different locations, different staging height and different earthquake zone, keeping in mind the Indian Standard Code (ISC).

***Key Words**:* **Elevated Storage Reservoir, RCC Column & CFST Column, ETABS, Response spectrum analysis, Seismic response parameters, Seismic Zone-II,III,IV**

1. INTRODUCTION

Now a day, in India to fulfill the need of high-rise building concrete filled steel tube (CFST) is best suited for infrastructural growth rather than RCC and STEEL. CFST structural system can be defined as the structures in which composite section made up of two different types of material such as steel and concrete are used for beams, and columns. Their usage as column in high-rise and multi-story buildings, as beams in low-rise industrial buildings has become widespread in countries like China and many other countries in last few decades but their usage in India is a new concept. Now a days, in India to fulfill the need of high-rise building concrete filled steel tube (CFST) is best suited for infrastructural growth rather than RCC and STEEL. CFST structural system can be defined as the structures in which composite section made up of two different types of material such as steel and concrete are used for beams, and columns. Their usage as column in high-rise and multi-story buildings, as beams in low-rise industrial buildings has become widespread in countries like China and many other countries in last few decades but their usage in India is a new concept.

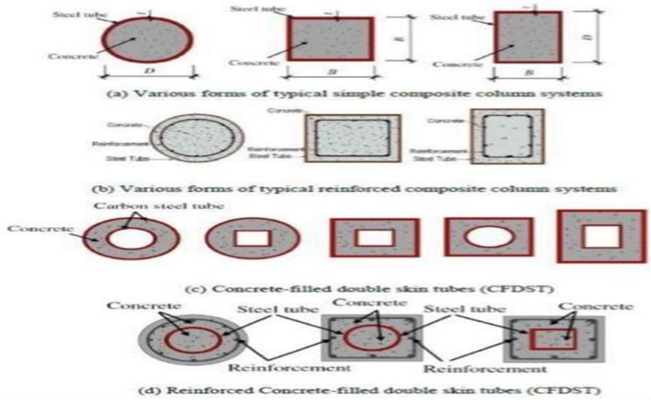


Fig -1: Types of CFST Column

2. LITERATURE REVIEW

Sangeetha P., Ashwin Muthuraman RM. , Dachina G. Dhivya M.,Janani S. and Sai Madumathi [2018] [1]: Concrete filled steel tubular columns are preferred due to their excellent static and dynamic resistant properties such as a high strength, high ductility and large energy absorption capacity. The ultimate strength of CFST, RCC and HST were compared and CFST having the advantages of both concrete and steel is found to behave better and average bond strength ranges between 0.7 to 1.1N/mm2. The failure mode of the column specimens was studied and it was found that HST were buckled inward, RCC columns were failed by crushing and CFST columns were by outward buckling. The Load carrying Capacity is 2.5 times Greater than Normal Reinforced Concrete Column.

K L Kulkarni, L.G. Kalukar [2016] [2]: This Paper present the comparative equivalent static and time history analysis of elevated encased composite column material water tank is during earthquake. The RCC column staging of elevated water tank can be replace by a encased composite column staging water tank, because the RCC water tank developed the cracks during earthquake, result in loss of their if strength and stiffness, so increase performance Of elevated water tank during earthquake to study the behavior of composite elevated water tank. Staging height of all water tank is 30m , 40m , 50m, And capacity of tank is 250cum.In Equivalent static analysis only time period Increase about 6% to 23%, Storey Stiffness decrease about 27% to 66%, Storey drift decrease about 25% to 66%, Base shear decrease about 41% to 54% and Storey displacement decreases about 10% to 30% for 30m, 40m, 50m.

Ms. Pranjali N. Dhange, Mr. Mandar M Joshi [2017] [3]: To study about the different methods of analysis and design of water tanks. To make a study about the guidelines for the dynamic analysis and design of liquid retaining structure according IS code. Check the computer software applicability and suitability for the dynamic analysis of RCC liquid storage tanks. Analysis the water tank of 50m3 capacity by using Response spectrum method, Displacement coefficient method and computational analysis. Consider two cases for same capacity of tank, change in geometry features of a container can show the considerable change in the response of elevated water tank. From above mentioned details study and analysis some of the conclusions can be made as follow for same capacity, same geometry, Same height, with same staging system, in the same Zone, With same importance factor & response reduction factor, response by equivalent static method to dynamic method differ considerably.

Aqsa S. Faras, V.G.Khurd [2018] [4]: Focuses mainly on the response of elevated circular tank under seismic loading. The analysis is carried out for four cases viz. 100%, 75%, 50%, 25% fill condition. Sloshing effect along with hydrostics effct is considered during analysis. A parametric study for max displacement and base shear is conducted. Finit element modeling of tank was carried out using software staad pro and seismic analysis was carried out Peak displacement, base shear obtained from analysis were compared. In this study 70m3 capacity tank is considered for analysis. Displacement decreases with decreases in water level. It is max for full fill condition and simultaneously goes on decreasing to quarterly fill condition. Base shear value increases for increasing water level in tank.

Jalaja MS, Nanjunda K N,Shylaja N, Avinash S Deshpande [2019] [5]: In this paper multi story RCC structure is selected as a study frame and then replaced it by concrete filled steel tube column. The modeling and analysis is carried out using time history method. Seismic parameters like Displacement, Storey Drift, Storey Shear, Storey Stiffness, Overturning moment and Base shear are compared for Zone-II and IV. Comparing Parameters like Storey Drift, Storey Displacement, Storey Shear, Stiffness. The result of composite Building is almost 5-6% less compare to RCC building in zone-II and 10-20% less in Zone-IV. This paper presents the seismic analysis for G+19 story structure for both RCC and CFST column using Etabs Software. Composite buildings have lesser displacement than RCC buildings even through they have lesser column areas. Composite buildings have lesser storey drift than RCC buildings despite having lesser column areas, but are well within the codel limits. Composite buildings have lesser storey shear values than RCC building even though they have lesser column areas.The reduction in column area composite buildings with concrete filled steel tube columns can be economical. Composite structure can be used in higher seismic zone and give better results than conventional RCC structure.

Spruha Wanjari, Sunil M. Rangari [2019] [6]: In this research paper evaluate the seismic response of elevated water tank with varying h/D ratio and seismic zone. To study the seismic performance of circular and intz elevated water tank with varying h/D ratio and seismic zone. Also study the sloshing effect and wind effect on water tank. In this research paper to analysis the displacement of the structure, study the base shear , axial force and moments of structure along different direction by seismic analysis and wind load analysis. The analysis is carried out by using FEM software and also use IS code 1893:2016 for seismic analysis and IS code 875:2015-part-3 for Wind analysis. Consider capacity of SMRF Elevated water tank is 5,00,000 liter and staging height is 20 m considering 4 m height of each panel are considered for study. Analysis carried out in all four seismic zone and consider the shape of the column is circular and H/D ration is 0.4, 0.5, 0.6. For tank full and empty conditions, as h/D ratios increases; Base shear with Base moment increases and Roof Displacement increases. For tank full and tank empty condition, joint displacement is higher as H/D ratio increases for intz tank than circular tank. For tank full and tank empty conditions, Base moment is higher as H/D ration increases for intz tank than circular tank.

3. RESEARCH GAP

From the literature review, lot of research has been done for different type of structure systems in terms of size and shapes. Also, for the irregular shape of buildings. It is common to see the usage of RCC column and CFST column for the construction of High-Rise buildings, Bridges, Irregular shape of building etc. But the usages of same technique like CFST columns for elevated storage reservoir or water storage reservoir are yet not quite visible. Neither enough clarification nor research is available which provide the limitation of not using CFST column instead of RCC column for such constructions. Neither Comparison the values between different seismic parameters like Displacement, Joint Reaction, Stiffness, Story Drift by using

RCC column and CFST column for Elevated Storage Reservoir.

4. OBJECTIVE

The objective of this work is as follows:

1. To do comparative study of CFST column and RCC column for Elevated Storage Reservoir. To study its effectiveness in different seismic zone and for different height.
2. To understand the Comparison of Story drift in RCC and CFST column system. Also considered the Displacement, Joint reaction and Stiffness and story drift of the structural system.
3. Understand Behavior of Reinforced concrete column and Concrete filled tube structural system by using necessary software like ETABS.
4. To carry out Linear Dynamic Analysis method such as Response Spectrum Analysis method for both RCC and CFST Column Elevated Storage Reservoir models using software ETABS.
5. To study the behavior of RCC and CFST column Supported Elevated Storage Reservoir height of 30m, 35m, 40m in Seismic zone II, III, IV.
6. To perform a comparative study of the various seismic parameters such as Maximum Story Displacement, Story Drift, Story Stiffness of RCC and CFST Column Supported System of 30m, 35m, 40m height.

5. METHODOLOGY

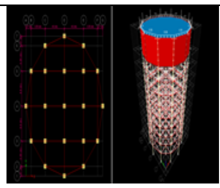
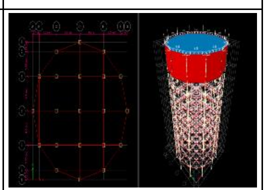
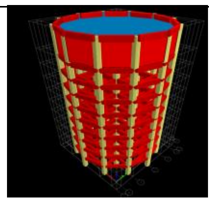
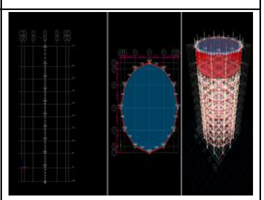
Two type of column supported system is taken in this project such as RCC column and CFST column. Also consider the different size of columns in different zone and analysis the seismic parameter results with respect to different height and size of column. Total 54 model are considered in this project such 18 models are prepared in zone-II with different column size and height, 18 models are prepared in zone-III with different Column Size and height and 18 models are prepared in Zone-IV with different column size and height . Linear Static Dynamic Analysis such as Response Spectrum Analysis has been carried out for seismic zone II, III, IV specified in IS 1893 (Part I): 2016 to understand the performance characteristics of the Elevated storage reservoir in comparison with regular RCC column and CFST column using software ETABS .

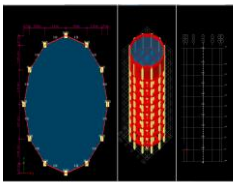
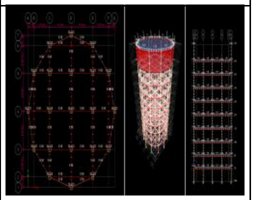
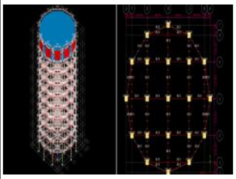
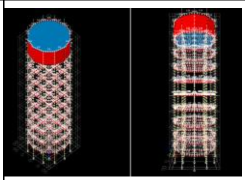
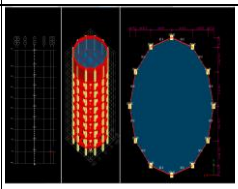
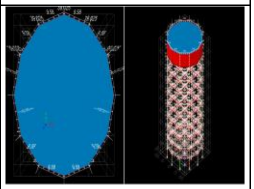
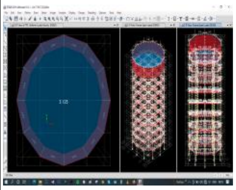
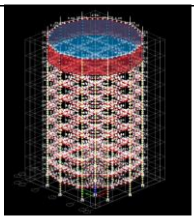
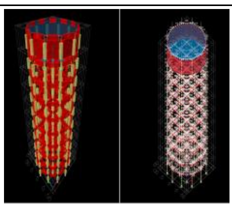
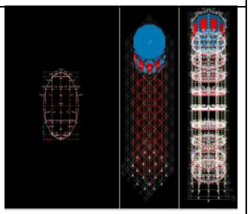
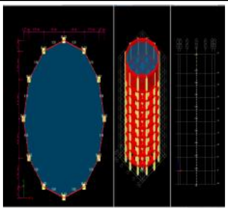
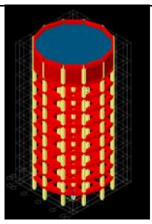
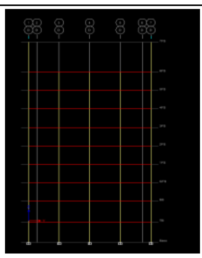
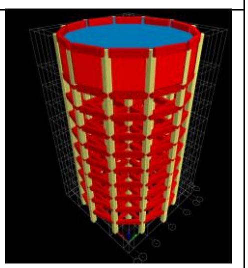
6. MODEL DATA

Table -1: Model data

Geometric Parameters	
Height of ESR	30m,35m,40m
Staging Height	3.1m, 3.8m,4.5m
Number of Floors	7
Height of Basement	3.5m
Total dimension of plan in X-direction	18.4m
Total dimension of plan in Y-direction	18.4m
Cylindrical tank Height	5 m
Dimension of Members	
RCC Column Size RCC Column Size RCC column Size	600mm x 600mm 650mm x 650mm 700mm x 700mm
CFST column size CFST column size CFST column size	450mm x 450mm 500mm x 500mm 550mm x 550mm
Beam Size	300mm x 900mm
Slab Thickness	125mm
Thickness of Wall	115mm
Material Properties	
Grade of Concrete for RCC column	M30
Grade of Steel for RCC column	Fe 500
Grade of Concrete for CFST column	M20
Grade of Steel for CFST column	FE 345
Tank Capacity	14 LL
Loads Taken	
Unit weight of RCC	25 kn/m3
Floor Finish Load	5 kn/m2
Live Load	39.025 kn/m2
Wall Load	2.875 kn/m2
Seismic Parameters	
Seismic Zone Factor	0.10 (II) 0.16(III) 0.24(IV)
Response Reduction Factor	5
Importance Factor	1.5
Type of Soil	Medium (II)
Support Condition	Fixed
Frame Type	SMRF
Wind Speed	33 m/s (II) 39 m/s (III) 44 m/s(IV)

Table -2: 3D view of structure models

Zone	**Height**	**RCC Column**	**CFST Column**
II	30M		
	35M		

Zone	Height	RCC Column	CFST Column
II	40M		
III	30M		
	35M		
	40M		
IV	30M		
	35M		
	40M		

7. RESULT

Maximum value of storey displacement, storey stiffness, storey drift and joint reaction are taken from the software. The comparison of RCC column and CFST column parameters mentioned above presented in table below.

Table-3: Seismic parameter comparison results of Zone-II for 30meter height of Elevated Storage Reservoir

	STORY DISPLACEMENT		STORY DRIFT		STORY STIFFNESS		JOINT R EACTION	
	EQX	EQY	EQX	EQY	EQX	EQY	EQX	EQY
RCC (600X600)	1.7118	1.7118	0.00016	0.00016	11483254	1451619	9.875	8.3062
CFST (450X450)	1.3236	1.3236	0.00012	0.00012	4689033	2297453	9.9305	8.3273
RCC (650X650)	0.5679	0.7151	0.000052	0.000065	4952671	984297	5.2229	5.5555
CFST (500X500)	0.5513	0.6942	0.000051	0.000062	895544	895549	4.7786	5.0347
RCC (700X700)	0.5395	0.6793	0.000049	0.000061	1916246	1607181	5.4984	5.9032
CFST (550X550)	0.4897	0.6167	0.000044	0.000056	1261382	1261392	5.262	5.6333

Table-4: Seismic parameter comparison results of Zone-II for 35meter height of Elevated Storage Reservoir

	STORY DISPLACEMENT		STORY DRIFT		STORY STIFFNESS		JOINT REACTION	
	EQX	EQY	EQX	EQY	EQX	EQY	EQX	EQY
RCC (600X600)	0.8389	1.0564	0.000063	0.00008	650000	630000	5.2091	5.4916
CFST (450X450)	0.8276	1.0422	0.000063	0.000079	670197	670193	4.7498	5.0128
RCC (650X650)	0.7826	0.9855	0.000059	0.000074	787880	777879	5.4952	5.8088
CFST (500X500)	0.7499	0.9443	0.000057	0.000072	829240	829231	4.9845	5.2646
RCC (700X700)	0.7479	0.9418	0.000056	0.000071	909095	911523	5.8122	6.1774
CFST (550X550)	0.703	0.8853	0.000053	0.000067	992646	992635	5.2503	5.5707

Table-5: Seismic parameter comparison results of Zone-II for 40meter height of Elevated Storage Reservoir

	STORY DISPLACEMENT		STORY DRIFT		STORY STIFFNESS		JOINT REACTION	
	EQX	EQY	EQX	EQY	EQX	EQY	EQX	EQY
RCC (600X600)	1.1523	1.451	0.00081	0.000102	660243	660237	5.4541	5.7275
CFST (450X450)	1.1258	1.4177	0.00008	0.000101	744591	744583	4.9224	5.1772
RCC (650X650)	1.0766	1.3557	0.000075	0.000095	813403	813392	5.7816	6.0823
CFST (500X500)	1.0211	1.2858	0.000072	0.000091	890112	890102	5.1923	5.4605
RCC (700X700)	1.0315	1.299	0.000071	0.00009	660243	660237	6.1434	6.4917
CFST (550X550)	1.1258	1.4177	0.00008	0.000101	1038984	1038971	4.9224	5.1772

Table-6: Seismic parameter comparison results of Zone-III for 30meter height of Elevated Storage Reservoir

	STORY DISPLACEMENT		STORY DRIFT		STORY STIFFNESS		JOINT REACTION	
	EQX	EQY	EQX	EQY	EQX	EQY	EQX	EQY
RCC (600X600)	78.19051	98.46333	0.006581	0.008287	631000.3	631813.2	7.1338	8.9839
CFST (450X450)	13.98571	17.61163	0.00057	0.000717	757927	757926	18.4034	19.8052
RCC (650X650)	90.51722	113.9843	0.00783	0.00986	609512	587512.1	7.6867	7.6827
CFST (500X500)	13.30259	16.75143	0.000556	0.0007	854263	854262	19.1473	20.9353
RCC (700X700)	109.8495	138.3621	0.009879	0.01244	568825.7	498886.7	3.3935	16.0483
CFST (550X550)	12.82844	16.15434	0.000548	0.00069	946596	946595	19.9831	22.1794

Table-7: Seismic parameter comparison results of Zone-III for 35meter height of Elevated Storage Reservoir

	STORY DISPLACEMENT		STORY DRIFT		STORY STIFFNESS		JOINT REACTION	
	EQX	EQY	EQX	EQY	EQX	EQY	EQX	EQY
RCC (600X600)	21.1191	26.59444	0.000101	0.000128	561880	561879	8.3345	8.7866
CFST (450X450)	1.342293	1.690291	0.000747	0.000941	757871	757865	19.143	20.6534
RCC (650X650)	20.16669	25.39533	0.000094	0.000119	635443	635442	8.7929	9.2941
CFST (500X500)	1.252138	1.576763	0.000729	0.000918	909918	909909	20.0368	21.9214
RCC (700X700)	19.56399	24.63614	0.00009	0.00032	706539	706538	9.2995	9.8838
CFST (550X550)	1.196632	1.506866	0.000722	0.00091	1067192	1067181	21.0634	23.326

Table-8: Seismic parameter comparison results of Zone-III for 40meter height of Elevated Storage Reservoir

	STORY DISPLACEMENT		STORY DRIFT		STORY STIFFNESS		JOINT REACTION	
	EQX	EQY	EQX	EQY	EQX	EQY	EQX	EQY
RCC (600X600)	88.66071	111.649	0.00634	0.007983	7054.433	7054.404	7.9553	10.0184
CFST (450X450)	2.882973	3.630402	0.000201	0.000254	384192	384183	5.9986	6.4099
RCC (650X650)	96.55595	121.5909	0.006975	0.008784	6958.231	6958.212	8.6364	10.8771
CFST (500X500)	2.819939	3.551028	0.000193	0.000243	456688	456675	6.476	7.0076
RCC (700X700)	106.5842	134.2183	0.007806	0.009883	6752.033	6752.075	9.397	11.8406
CFST (550X550)	2.802634	3.529236	0.000187	0.000235	534586	534570	7.0083	7.6825

Table-9: Seismic parameter comparison results of Zone-IV for 30meter height of Elevated Storage Reservoir

	STORY DISPLACEMENT		STORY DRIFT		STORY STIFFNESS		JOINT REACTION	
	EQX	EQY	EQX	EQY	EQX	EQY	EQX	EQY
RCC (600X600)	1.585181	1.849374	0.000148	0.000172	818469	818474	12.8673	12.5238
CFST (450X450)	1.58339	1.847283	0.000149	0.000174	833050	833055	11.8622	11.5483
RCC (650X650)	1.47126	1.716467	0.000136	0.000158	984304	984311	13.5022	13.2025
CFST (500X500)	1.428123	1.666144	0.000133	0.000155	1055544	1055549	12.3789	12.0833
RCC (700X700)	1.395559	1.630483	0.000127	0.000148	1074665	1074673	14.209	13.9991
CFST (550X550)	1.330674	1.552556	0.000122	0.000143	1557783	1557792	12.9684	12.7446

Table-10: Seismic parameter comparison results of Zone-IV for 35meter height of Elevated Storage Reservoir

	STORY DISPLACEMENT		STORY DRIFT		STORY STIFFNESS		JOINT REACTION	
	EQX	EQY	EQX	EQY	EQX	EQY	EQX	EQY
RCC (600X600)	2.01344	2.535437	0.000152	0.000192	670197	670193	12.5018	13.1798
CFST (450X450)	1.986294	2.501252	0.000151	0.00019	757871	757865	11.3996	12.0308
RCC (650X650)	1.878207	2.365144	0.000142	0.000178	829240	829231	13.1885	13.9412
CFST (500X500)	1.799813	2.266429	0.000137	0.000172	909918	909909	11.9628	12.635
RCC (700X700)	1.794948	2.260301	0.000134	0.000169	992646	992635	13.9493	14.8257
CFST (550X550)	1.687206	2.124626	0.000127	0.00016	1067192	1067181	12.6006	13.3697

Table-11: Seismic parameter comparison results of Zone-IV for 40meter height of Elevated Storage Reservoir

	STORY DISPLACEMENT		STORY DRIFT		STORY STIFFNESS		JOINT REACTION	
	EQX	EQY	EQX	EQY	EQX	EQY	EQX	EQY
RCC (600X600)	2.765402	3.482349	0.000195	0.000245	660243	660237	13.0899	13.746
CFST (450X450)	2.70202	3.402535	0.000192	0.000242	744591	744583	11.8137	12.4252
RCC (650X650)	2.583725	3.253573	0.000181	0.000227	813403	813392	13.8758	14.5975
CFST (500X500)	2.450662	3.086015	0.000173	0.000217	890112	890102	12.4616	13.1052
RCC (700X700)	2.475656	3.117487	0.000172	0.000216	968988	968975	14.7443	15.5801
CFST (550X550)	2.302846	2.899875	0.000161	0.000202	1038984	1038971	13.1923	13.923

8. CONCLUSIONS

1. In zone-II the values of the Story Displacement, Story Drift and Joint Reaction are less in CFST column structural system compare to the RCC column structural system when the value of the stiffness is more in CFST column structural system compare to RCC column structural system.
2. CFST structural system is stables and effective compare to the RCC structural system in Seismic zone-II.
3. With increases the size of RCC column and CFST column the values of all parameters are increases. Increase of the size of CFST column it gives the more strength and Stiffness to the structure.
4. In zone-III, the values of Story displacement, story drift are very less for CFST column Structural system as compare to the RCC column structural system.
5. In zone-III, the values of the Story Stiffness and Joint Reaction are more for CFST column Structural system as compare to the RCC column structural system.
6. From the results of the different parameters we can say that the CFST column is more suitable in zone III as compare to the other zone.
7. In zone-IV, the values of the story displacement, story drift and Joint reaction is high as compare to the Zone-II and Zone-III.
8. In zone-IV, the values of the story displacement, story drift and joint reaction is almost same for the RCC column structural system and CFST column structural system.
9. From all the results we can say that the CFST column structural support system is safer and more stable and reliable as compare to the RCC structural support system in Zone-III and less safe and stable in Zone-IV.

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