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Effects of Various Bracing in Building with Rectangular and Circular Columns

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ABSTRACT: In general the most suitable choices in improvement of reinforcement concrete frame against lateral loading is used R.C. bracing system. This paper is the next step of previously published two papers i.e. "Effects of various bracing in building with rectangular columns" and "Effects of various bracing in building with circular columns". In this paper, the seismic analysis of reinforced concrete (RC) buildings with different types of bracing (V type, inverted-V type, X type) in rectangular and circular columns are compared. For this analysis of work an eight-storey (G+8) building is considered which is situated in seismic zone III. The building models are analyzed by equivalent static analysis as per recommendation given by IS 1893:2002 using Staad Pro V8i software. This paper includes the comparison of seismic analysis of building with rectangular and circular columns by using different types of bracing system mentioned above and also the comparison between rectangular and circular column is carried out.

Keywords: Multistorey building, Rectangular column, Circular column, Seismic zone, Bracing system.

I. INTRODUCTION

Structural engineering is concerned with the structural design and structural analysis of building, bridges, towers, flyovers, tunnels, off shore structures like oil and gas fields in the sea, aero structure and other structure. This involves identifying the loads which act upon a structure and the forces and stresses which arise within that structure due to those loads, and then designing the structure to successfully support and resist those loads. The loads can be self-weight of the structure, the other dead load, live load, moving (wheel) load, wind load, earthquake load, load from temperature change etc. The structural engineer must design structures to be safe for their users and to successfully fulfill the function they are designed for (to be serviceable). Due to the nature of some loading conditions, sub-disciplines within structural engineering have emerged, including wind engineering and earthquake engineering.

The construction of RC building is a very common practice in urban India for last 25 years. Most of the RC buildings were designed for gravity loads only. These buildings performed very poorly during Bhuj earthquake of January 2001 and Killari earthquake of September 1993. Since then the earthquake design is made mandatory for design of high rise buildings. For resisting earthquake forces large sections for members need to be provided, these leads to increase in material cost. Another alternative to resist EQ forces is providing bracings in the structure which reduces the section size and also increase lateral stiffness, lateral strength as well as lateral stability of frames.[6] India at present is fast developing country which requires demands in increase of infrastructure facilities along with the growth of population. Due to increased population, the demand for land for housing is increasing day by day. To fulfill the need of the land for housing and other commercial offices, vertical development that is multistory buildings are the only option. This type of development requires safety because these multistory buildings are highly susceptible to additional lateral loads due to an earthquake and a wind. In broad, as the elevation of building increases, its reaction to lateral loads increases. Multistory reinforced concrete buildings are vulnerable to excessive deformation, which necessitate the introduction of special measures to decrease this deformation. RC bracing is one of the lateral loads opposing frameworks in multistory structures. RC bracing system enhances the resistance of the structure against horizontal forces by expanding its stiffness and stability. Bracings hold the structure stable by exchanging the horizontal loads, for example, quake or wind burdens down to the ground and oppose sidelong loads, in that way keep the influence of the structure. RC bracing members in RC multistory building is conservative, simple to set up etc. There are various types of bracing systems like X bracing, V bracing, inverted V bracing, K bracing, diagonal bracing and so on.[2]

II. RELATED WORK

2.1 Building Description

In this analysis, A G+8 storey reinforced concrete building of 3 bays have been considered for investigating the effect of Unbraced, X type, V type and inverted V type bracings and there arrangements in the middle bay of the building. The building having 3 bays in X direction and 3 bays in Z direction with the plan dimension is (15 m × 15 m) and in Y direction dimension is 3 m. All the data related with models are provided in previously published two papers i.e. "Effects of various bracing in building with rectangular columns" and "Effects of various bracing in building with circular columns".

- Comparisons between Seismic Analysis of RC multistoried building of rectangular columns model with provided different types of bracing systems i.e. (unbraced, X type, V type & inverted V type braced) and of circular columns model with provided different types of bracing systems i.e. (unbraced, X type, V type & inverted V type braced).
- Finally, the analysis results collected from STAAD.Pro V8i will be compared with the shear forces, bending moment, axial force, storey displacements and story drifts.

III. METHODOLOGY

3.1 General

Behaviour of the structures with rectangular columns and with circular columns subjected to earthquake loading is a complicated phenomenon. There are several numbers of factors affecting the behavior of building out of which the axial loading, moment, shear force, etc. are considered. The 3D analysis is carried out in all the building models. The equivalent static analysis method is carried out on all the 3D models using the software STAAD.Pro V8i. The results obtained from the analysis are discussed in this paper.

3.2 Method of Analysis

Equivalent static analysis is carried out on all the eight models. The results are presented in the form of tables and graphs. The loads are calculated and the results obtained are compared with respect to the following parameters like bending moment, shear force, storey drift, storey displacement and axial force.

Table 3.1 Shear Force (kN)

Height	Nodes	Rectangular Column				Circular Column			
		Unbraced	X-Braced	V-Braced	Inv. V-Braced	Unbraced	X-Braced	V-Braced	Inv. V-Braced
0	133	14.78	17.21	14.13	15.34	13.96	15.83	13.19	14.19
2	137	15.03	15.38	14.75	15.58	13.95	14.2	13.52	14.65
5	141	16.75	16.49	16.5	18.33	15.61	15.38	15.27	17.4
8	145	18.27	18.35	18.23	19.14	17.05	17.06	16.94	18.18
11	149	19.55	19.62	19.68	20.3	18.27	18.28	18.34	19.24
14	153	20.61	20.72	20.91	21.12	19.28	19.32	19.55	20
17	157	21.46	21.59	21.93	21.76	20.08	20.15	20.54	20.6
20	161	22.14	22.28	22.75	22.26	20.74	20.82	21.36	21.06
23	165	22.12	22.28	23.08	21.94	20.78	20.87	21.76	20.82

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26	169	26.74	27	27.43	26.49	24.38	24.53	25	24.31
29	173	26.74	27	27.43	26.49	24.38	24.53	25	24.31

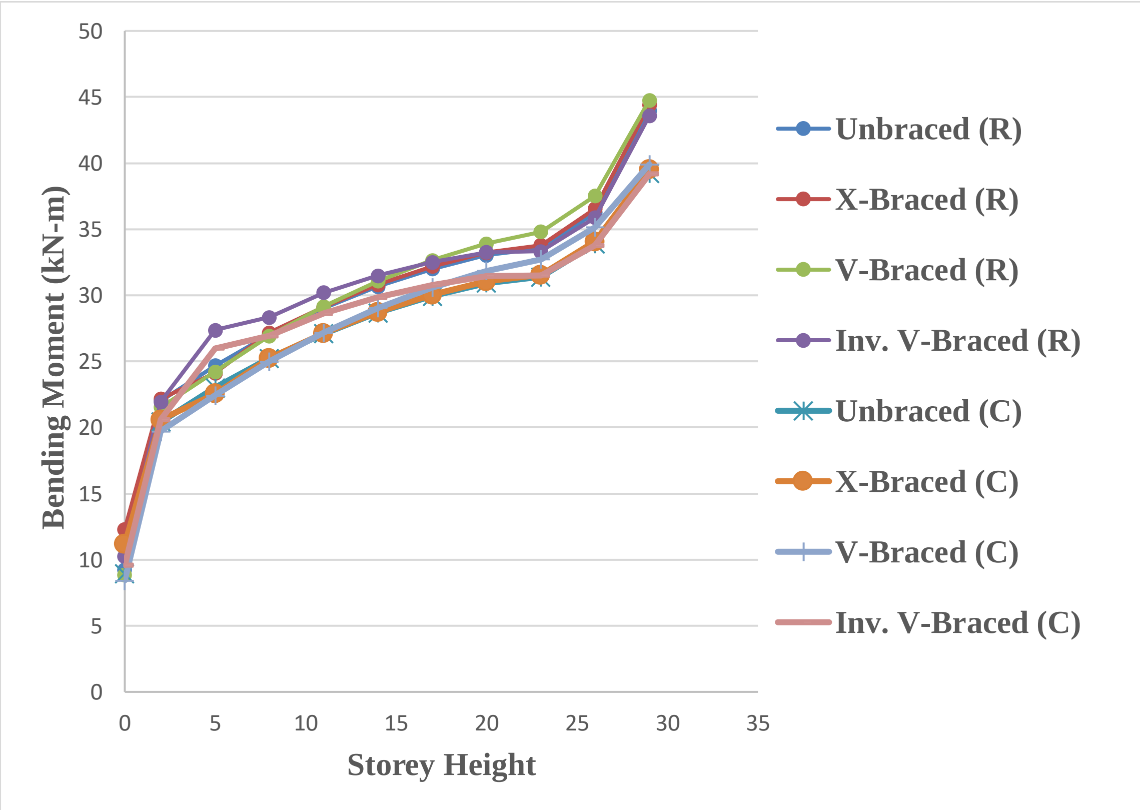
Graph 3.1 Storey Height Vs Shear Force

Table 3.2 Change in Shear Force (kN)

System	Rectangular Column		Circular Column		% Change (More/Less)	
	Bottom	Top	Bottom	Top	Bottom	Top
Unbraced	14.78	26.74	13.96	24.38	5.874	9.68
X-Braced	17.21	27	15.83	24.53	8.718	10.069
V-Braced	14.13	27.43	13.19	25	7.127	9.72
Inv. V-Braced	15.34	26.49	14.19	24.31	8.104	8.968

Table 3.3 Bending Moment (kN-m)

Height	Nodes	Rectangular Column				Circular Column			
		Unbraced	X-Braced	V-Braced	Inv. V-Braced	Unbraced	X-Braced	V-Braced	Inv. V-Braced
0	133	9.23	12.31	8.83	10.28	8.93	11.19	8.44	9.57
2	137	22.03	22.17	21.54	21.95	20.43	20.6	19.71	20.6
5	141	24.68	24.12	24.22	27.38	23.01	22.56	22.43	26
8	145	27.04	27.19	26.94	28.34	25.23	25.25	25	26.94
11	149	29.02	29.11	29.17	30.21	27.11	27.12	27.18	28.64
14	153	30.67	30.82	31.07	31.49	28.68	28.74	29.04	29.84
17	157	32	32.19	32.65	32.5	29.95	30.04	30.59	30.78
20	161	33.03	33.24	33.92	33.25	30.94	31.05	31.85	31.46
23	165	33.53	33.78	34.82	33.34	31.4	31.53	32.72	31.52
26	169	36.25	36.55	37.53	35.87	33.88	34.06	35.14	33.77
29	173	43.98	44.41	44.76	43.6	39.25	39.53	39.9	39.17



Graph 3.2 Storey Height Vs Bending Moment

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Table 3.4 Change in Bending Moment (kN-m)

System	Rectangular Column		Circular Column		% Change (More/Less)	
	Bottom	**Top**	**Bottom**	**Top**	**Bottom**	**Top**
Unbraced	9.23	43.98	8.93	39.25	3.359	12.051
X-Braced	12.31	44.41	11.19	39.53	10.009	12.345
V-Braced	8.83	44.76	8.44	39.9	4.621	12.18
Inv. V-Braced	10.28	43.6	9.57	39.17	7.419	11.31

Table 3.5 Axial Force (kN)

Height	Nodes	Rectangular Column				Circular Column			
		Unbraced	**X-Braced**	**V-Braced**	**Inv. V-Braced**	**Unbraced**	**X-Braced**	**V-Braced**	**Inv. V-Braced**
0	133	1115.75	1153.11	1121.16	1115.8	1115.16	1153.32	1120.53	1115.06
2	137	1017.48	1055.5	1025.59	1016.49	1016.92	1055.79	1025.04	1015.8
5	141	910.6	940.63	920.5	909.8	910.09	940.79	920.03	909.18
8	145	800	823.68	811	799.68	799.6	823.75	810.6	799.12
11	149	686.4	704.42	697.56	686.25	686	704.41	697.21	685.74
14	153	570.1	583.29	580.69	570.1	569.72	583.22	580.38	569.65
17	157	451.63	460.77	460.88	451.73	451.3	460.66	460.61	451.33
20	161	331.48	337.33	338.62	331.62	331.18	337.19	338.37	331.28
23	165	210.16	213.51	214.41	210.31	209.9	213.36	214.17	210.02
26	169	87.37	89.11	87.75	87.52	87.12	88.91	87.46	87.26
29	173	73.38	75.11	73.75	73.53	73.12	74.91	73.46	73.26

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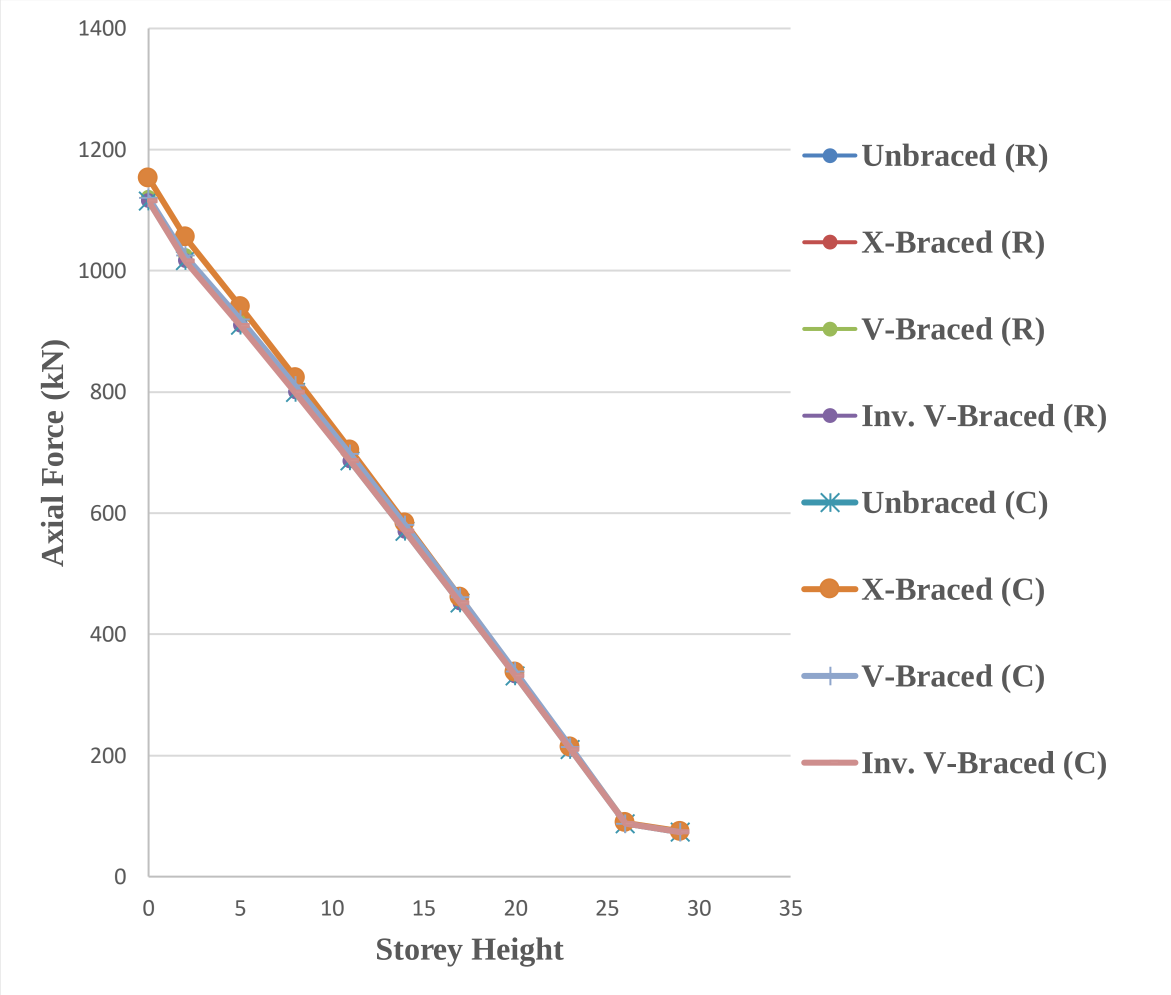


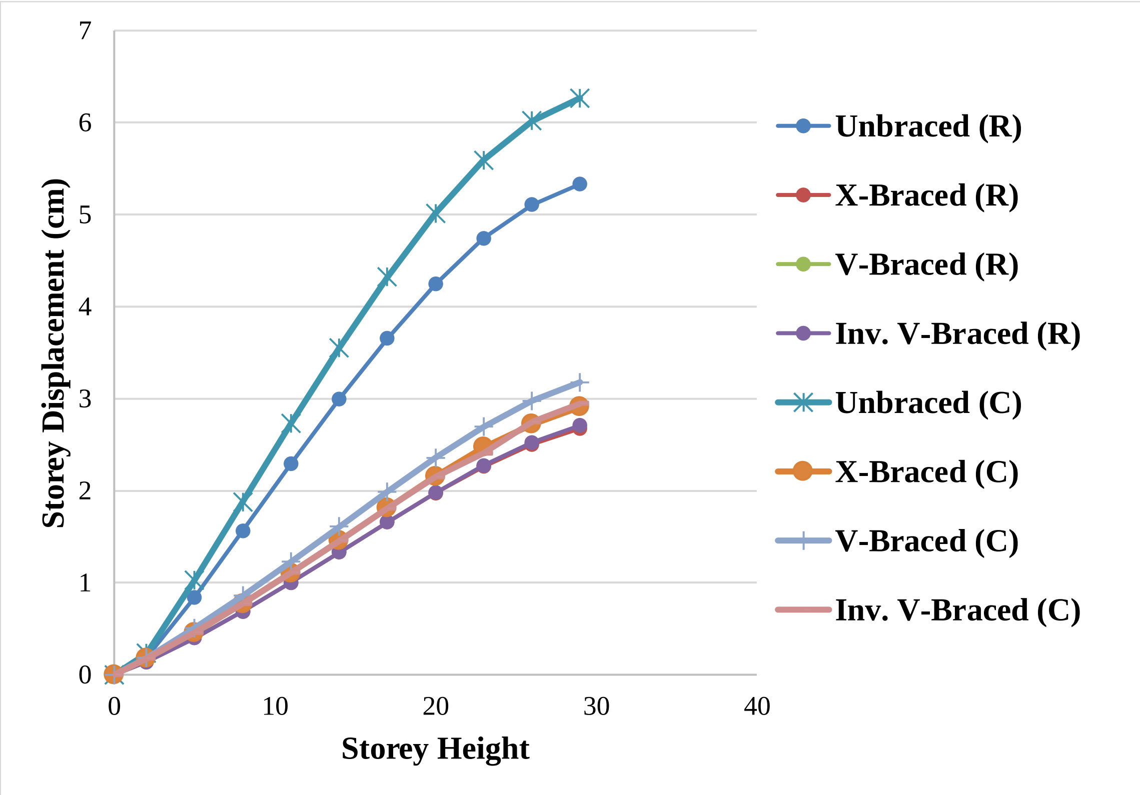
Graph 3.3 Storey Height Vs Axial Force

Table 3.6 Change in Axial Force (kN)

System	**Rectangular Column**		**Circular Column**		**% Change (More/Less)**	
	Bottom	**Top**	**Bottom**	**Top**	**Bottom**	**Top**
Unbraced	1115.75	73.38	1115.16	73.12	0.053	0.356
X-Braced	1153.11	75.11	1153.32	74.91	0.018	0.267
V-Braced	1121.16	73.75	1120.53	73.46	0.056	0.395
Inv. V-Braced	1115.8	73.53	1115.06	73.26	0.066	0.369

Table 3.7 Storey Displacement (cm)

Height	Nodes	Rectangular Column				Circular Column			
		Unbraced	X-Braced	V-Braced	Inv. V-Braced	Unbraced	X-Braced	V-Braced	Inv. V-Braced
0	133	0	0	0	0	0	0	0	0
2	137	0.189	0.139	0.144	0.138	0.232	0.177	0.182	0.177
5	141	0.839	0.397	0.438	0.397	1.028	0.459	0.505	0.458
8	145	1.565	0.687	0.765	0.689	1.877	0.77	0.856	0.771
11	149	2.292	1	1.11	1	2.729	1.105	1.227	1.107
14	153	2.995	1.329	1.465	1.331	3.552	1.455	1.608	1.456
17	157	3.655	1.659	1.819	1.659	4.322	1.81	1.989	1.808
20	161	4.246	1.975	2.158	1.979	5.012	2.154	2.356	2.149
23	165	4.741	2.263	2.467	2.273	5.59	2.473	2.693	2.406
26	169	5.109	2.503	2.728	2.523	6.017	2.722	2.977	2.745
29	173	5.332	2.677	2.913	2.709	6.267	2.909	3.179	2.946



Graph 3.4 Storey Height Vs Storey Displacement

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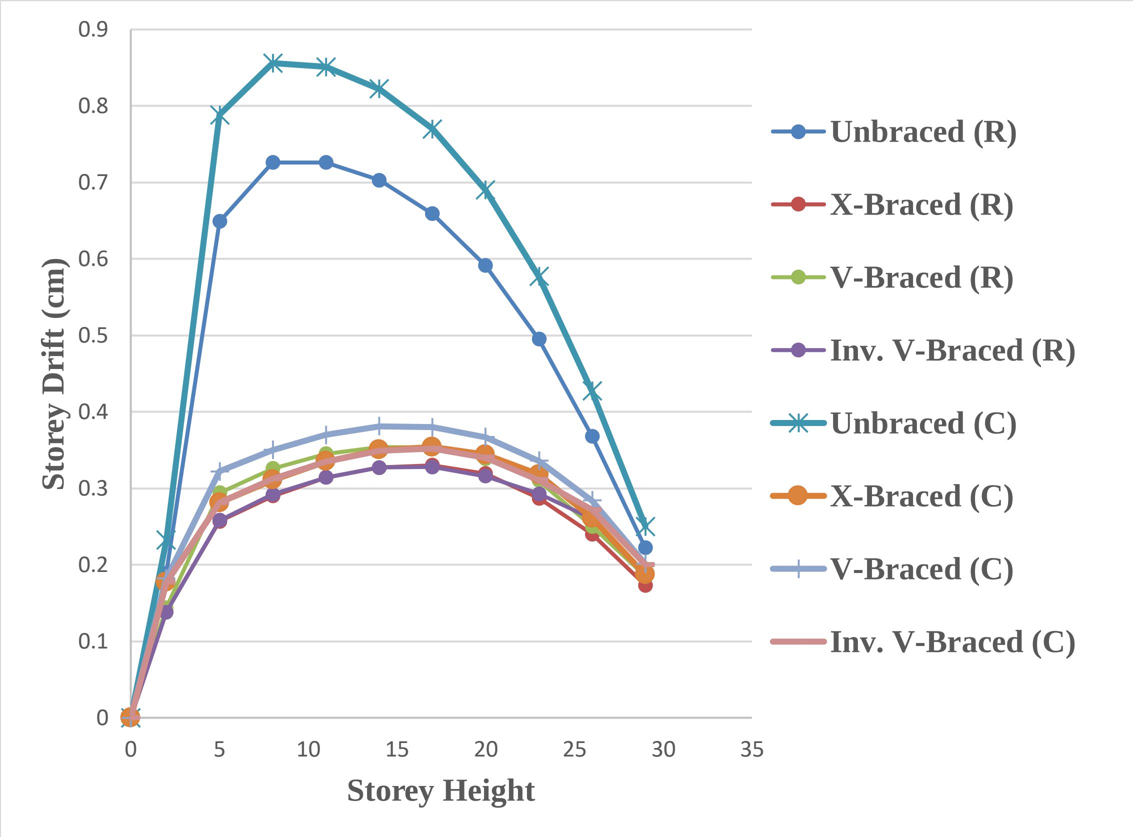
Table 3.8 Change in Storey Displacement (cm)

System	Rectangular Column	Circular Column	% Reduction
Unbraced	5.332	6.267	14.919
X-Braced	2.677	2.909	7.975
V-Braced	2.913	3.179	8.367
Inv. V-Braced	2.709	2.946	8.045

Table 3.9 Storey Drift (cm)

Height	Nodes	Rectangular Column				Circular Column			
		Unbraced	X-Braced	V-Braced	Inv. V-Braced	Unbraced	X-Braced	V-Braced	Inv. V-Braced
0	133	0	0	0	0	0	0	0	0
2	137	0.189	0.139	0.144	0.138	0.232	0.177	0.182	0.177
5	141	0.649	0.257	0.294	0.258	0.7882	0.281	0.322	0.281
8	145	0.726	0.29	0.326	0.292	0.856	0.311	0.35	0.312
11	149	0.726	0.314	0.345	0.314	0.851	0.335	0.37	0.335
14	153	0.703	0.327	0.354	0.327	0.822	0.35	0.381	0.349
17	157	0.659	0.33	0.353	0.328	0.77	0.354	0.38	0.352
20	161	0.591	0.319	0.339	0.316	0.69	0.344	0.367	0.34
23	165	0.495	0.287	0.31	0.293	0.577	0.318	0.336	0.311
26	169	0.368	0.24	0.25	0.26	0.427	0.261	0.284	0.272
29	173	0.222	0.173	0.185	0.186	0.25	0.187	0.201	0.2



Graph 3.5 Storey Height Vs Storey Drift

Table 3.10 Change in Storey Drift (cm)

System	Rectangular Column	Circular Column	% Reduction
Unbraced	0.222	0.25	11.2
X-Braced	0.173	0.187	7.487
V-Braced	0.185	0.201	7.96
Inv. V-Braced	0.186	0.20	7.0

IV. RESULTS ANALYSIS

- Table 3.1 shows the shear forces at top and ground storeys for all the structural systems i.e. unbraced, X-braced, V-braced and inverted V-braced structural systems for rectangular columns and for circular columns models respectively. The shear forces of the structure for various types of bracing systems are compared. It can be seen that the shear forces at base levels in rectangular column models are 14.78 kN, 17.21 kN, 14.13 kN, 15.34 kN and circular column models are 13.96 kN, 15.83 kN, 13.19 kN, 14.19 kN for unbraced, X-braced, V-braced and inverted V-braced structural systems respectively. It can also be seen that the shear forces at top levels in rectangular column models are 26.74 kN, 27 kN, 27.43 kN, 26.49 kN and circular column models are 24.38 kN, 24.53 kN, 25 kN, 24.31 kN for unbraced, X-braced, V-braced and inverted V-braced structural systems respectively.

- Table 3.2 shows the % change in shear force after comparing RC multistorey building models of rectangular columns with circular columns models. % change in shear force at bottom levels are 5.574%, 8.718%, 7.127%, 8.104% for unbraced, X-braced, V-braced and inverted V-braced structural systems respectively whereas 9.68%, 10.069%, 9.72%, 8.968% for unbraced, X-braced, V-braced and inverted V-braced structural systems respectively at top levels.

- Table 3.3 show the bending moment at top and ground stories for all the structural systems i.e. unbraced, X-braced, V-braced and inverted V-braced structural systems for rectangular columns and for circular columns models respectively. The bending moments of the structure for various types of bracing systems are compared. It can be seen that the bending moment at bottom levels in rectangular column models are 9.23 kN-m, 12.31 kN-m, 8.83 kN-m, 10.28 kN-m and circular column models are 8.93 kN-m, 11.19 kN-m, 8.44 kN-m, 9.57 kN-m for unbraced, X-braced, V-braced and inverted V-braced structural systems respectively. It can also be seen that the shear forces at top levels in rectangular column models are 43.98 kN-m, 44.41 kN-m, 44.76 kN-m, 43.6 kN-m and circular column models are 39.25 kN-m, 39.53 kN-m, 39.9 kN-m, 39.17 kN-m for unbraced, X-braced, V-braced and inverted V-braced structural systems respectively.

- Table 3.4 shows the % change in bending moment after comparing RC multistorey building models of rectangular columns with circular columns models. % change in bending moment at bottom levels are 3.359%, 10.009%, 4.621%, 7.419% for unbraced, X-braced, V-braced and inverted V-braced structural systems respectively whereas 12.051%, 12.345%, 12.18%, 11.31% for unbraced, X-braced, V-braced and inverted V-braced structural systems respectively at top levels.

- Table 3.5 show the axial force at top and ground stories for all the structural systems i.e. unbraced, X-braced, V-braced and inverted V-braced structural systems for rectangular columns and for circular columns models respectively. The axial forces of the structure for various types of bracing systems are compared. It can be seen that the axial forces at bottom levels in rectangular column models are 1115.75 kN, 1153.11 kN, 1121.16 kN, 1115.8 kN and circular column models are 1115.16 kN, 1153.32 kN, 1120.53 kN, 1115.06 kN for unbraced, X-braced, V-braced and inverted V-braced structural systems respectively. It can also be seen that the axial forces at top levels in rectangular column models are 73.38 kN, 75.11 kN, 73.75 kN, 73.53 kN and circular column models are 73.12 kN, 74.91 kN, 73.46 kN, 73.26 kN for unbraced, X-braced, V-braced and inverted V-braced structural systems respectively.

- Table 3.6 shows the % change in axial force after comparing RC multistorey building models of rectangular columns with circular columns models. % change in shear force at bottom levels are 0.053%, 0.018%, 0.056%, 0.066% for unbraced, X-braced, V-braced and inverted V-braced structural systems respectively whereas 0.356%, 0.267%, 0.395%, 0.369% for unbraced, X-braced, V-braced and inverted V-braced structural systems respectively at top levels.

- Table 3.7 show the maximum storey displacement for seismic load for all the structural systems i.e. unbraced, X-braced, V-braced and inverted V-braced structural systems for rectangular columns and for circular columns models respectively. The storey displacements of the structure for various types of bracing systems are compared. It can be seen that the storey displacement in rectangular column models are 5.332cm, 2.677cm, 2.913cm, 2.709cm from top to bottom for unbraced, X-braced, V-braced and inverted V-braced structural systems respectively whereas in circular column models are 6.267cm, 2.909cm, 3.179cm, 2.946cm for unbraced, X-braced, V-braced and inverted V-braced structural systems respectively.

- Table 3.8 shows the % change in storey displacement after comparing RC multistorey building models of rectangular columns with circular columns models. % reduction in storey displacement from top to bottom levels are 14.919%, 7.975%, 8.367%, 8.045% for unbraced, X-braced, V-braced and inverted V-braced structural systems respectively.

- Table 3.9 show the storey drifts for seismic load for all the structural systems i.e. unbraced, X-braced, V-braced and inverted V-braced structural systems for rectangular columns and for circular columns models respectively. The storey drifts of the structure for various types of bracing systems are compared. It can be seen that the storey drift from top to bottom levels in rectangular column models are 0.222cm, 0.173cm, 0.185cm, 0.186cm for unbraced, X-braced, V-braced and inverted V-braced structural systems respectively whereas in circular column models are 0.25cm, 0.187cm, 0.201cm, 0.20cm for unbraced, X-braced, V-braced and inverted V-braced structural systems respectively.

- Table 3.10 shows the % change in storey drift after comparing RC multistorey building models of rectangular columns with circular columns models. % reduction in storey drift from top to bottom levels are 11.20%, 7.487%, 7.960%, 7.00% for unbraced, X-braced, V-braced and inverted V-braced structural systems respectively.

V. CONCLUSION

- Bracing system reduces not only bending moment but also shear force in the columns and also transfer the lateral loads through axial load mechanism to the foundation. Range of % change of shear force for bottom 5.5 to 8.8% and for top 8.9 to 10% whereas for bending moment 3.3 to 10% for bottom and 11.3 to 12.4% for top.
- Bracing system increases the axial loading in the column. Building model with X-bracing system having more axial load compare with different types of specified bracing system. Range of % change of axial load 0.01 to 0.07% for bottom and 0.2 to 0.4% for top.
- The concept of bracing is one of the advantageous concepts which can be used to strengthen the structure and also model with X-bracing is found to give better storey drift. Range of % change of storey drift is 7 to 11.2%.
- Bracing system increases the stiffness of the structure and reduces the displacement. The performance of the X-braced system is better than the other specified bracing system. Storey displacement % change range is 7.9 to 11.2%.
- After the analysis of the RC multistorey building models with different types of structural system, it has been concluded that the storey displacement of the structure decreases after the application of bracing system. The maximum reduction in the displacement happens in X-bracing system.
- Performance of the building increases after the application of X-type bracing system.
- In the final conclusion it can conclude that X-type bracing system is better than other specified bracing system. Especially in case of rectangular columns model compare with circular columns model.

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