Response Spectrum Analysis of RCC Frame Building with Different Type Bracing System

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***Abstract*— Public utilities like public transport, hospitals, schools etc. are generally provided inside the city and there is limitation of the space due to which buildings are required to be constructed of higher storey to satisfy the requirements. High rise buildings are more susceptible to seismic effect due to increase in height therefore proper arrangements are provided to dissipate the energy produced by seismic effect. Bracing systems are most commonly used as high rise structures as they are economical and time efficient. In order to enhance the resistance of structure towards earthquake lateral load various arrangements like bracing, shear wall, dampers, actuators, infill walls, deep vierendeel are provided. Bracing system in structure deals with the use of most appropriate combination of these energy retarders so that most efficient and economical results are obtained. This research work is concerned with the analysis of RCC frame structures by using various arrangements of bracings. Bracings are arranged in various ways like inverted V-bracing, X-bracing. Variation in parameters (Time Period, Storey Drift, Storey Displacement and Storey Stiffness) of building due to use of bracing can be studied by response spectrum analysis of structure by using ETABS 17.0.1 software*.**

Index Terms— Bracing, RCC frame, Response Spectrum Analysis, Seismic Response etc.

I. INTRODUCTION

Using an appropriate structural system is a critical factor for good seismic performance of buildings. While moment resisting -frame is the most commonly used lateral load resisting structural system, other structural systems also are commonly used like structural walls, frame-wall system, and braced-frame system. Braced Frame Systems structural system consists of moment frames with specific bays provided with braces throughout the height of the building. Braces are provided in both plan directions such that no twisting is induced in the building owing to unsymmetrical stiffness in plan. Braces help in reducing overall lateral displacement of buildings, and in reducing bending moment and shear force demands on beams and columns in buildings. The earthquake force is transferred as axial tensile and compressive force in the brace members. The main objective of the present work is to investigate the seismic performance of a tall RCC frame building with X-Type bracing and inverted V-Type bracing, which give better performance against seismic responses. Analysis is performed by Response Spectrum Analysis using ETABS 17.0.1 software.

II. BUILDING DESCRIPTION

Description of Residential building with 28 storeys Located in Delhi (NCR) are given below

A. GEOMETRICAL PROPERTIES:

S. No	Property Description		Dimension
1.	Floor height		3m
2.	Height of building		84m
3.	Area (plan)		31.5m x 31.5m
4.	Beam dimension		300mm x 400mm
5.	Columns (Inner and Corner)	Storey 1st to 14th	500mm x 500mm
	Columns (Periphery)		300mm x 600mm
	Columns (Inner and Corner)	Storey 15th to 28th	400mm x 400mm
	Columns (Periphery)		300mm x 500mm
6.	Bracing		ISLB 175
7.	No. of bays in X-direction		7No.@4.5m
8.	No. of bays in Y-direction		7No.@4.5m
9.	Slab thickness		150mm

B. MATERIAL PROPERTIES:

S. No	Material	Grade
1.	Concrete (column, beam & slab)	M30
2.	Rebar	Fe500

C. SEISMIC DATA:

1.	Earthquake Zone – IV	Z = 0.24
2.	Damping	5%
3.	Importance Factor	1.2
4.	Type of soil	Medium soil
5.	Response Reduction Factor	5
6.	Time Period	Program calculated

D. LOADING:

1. Live load 3.5kN/m^2 as per IS 875 part-II
2. Dead load as per IS 875 part-I
3. Earthquake load as per IS 1893:2016 part-I

III. PLAN AND 3D VIEW OF BUILDING FOR DIFFERENT MODELS

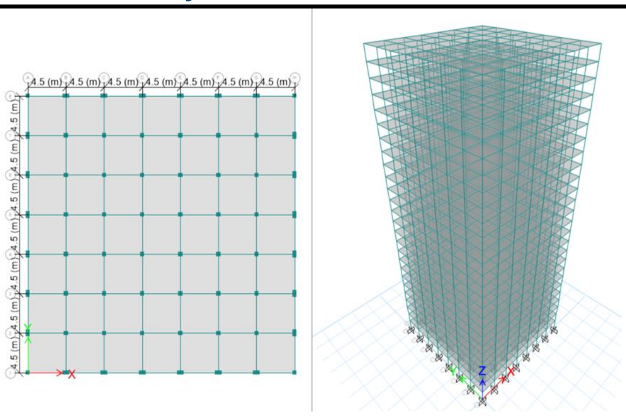

Figure1: Model 1 without bracing

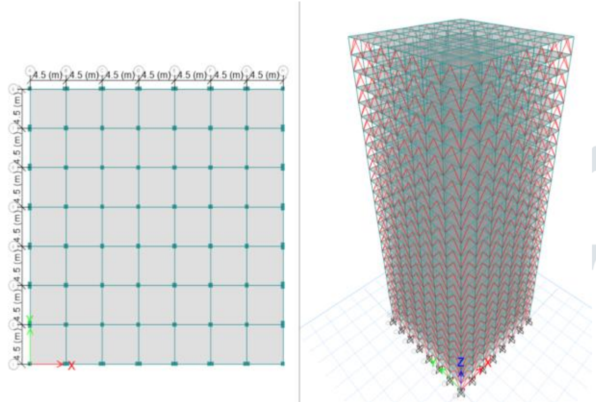

Figure2: Model 2 with inverted v-type bracing

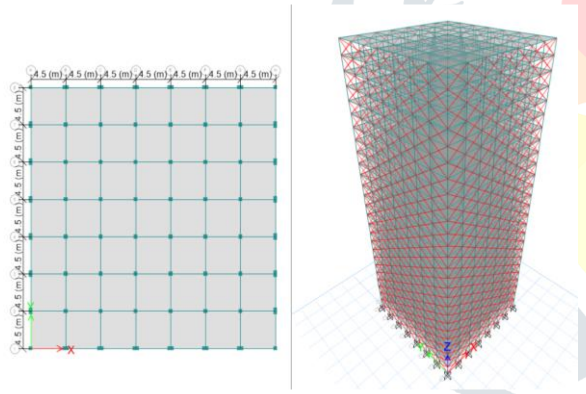

Figure3: Model 3 with x-type bracing

IV. METHOD OF ANALYSIS

A response spectrum is simply a plot of the peak response (displacement, velocity or acceleration) of a number of SDOF systems of varying natural period that are forced into motion by the same base vibration. The resulting plot can then be used to find the response of any structure, knowing its natural period. The plan shape used for analysis is "Square" shape tall building.

V. ANALYSIS RESULTS

The analysis of all the models that include RCC frame and RCC frame with bracing system has been done and results are shown below. The parameters which were studied are on the behavior of building during seismic excitation are Time period, Storey displacement, Storey drift and Storey stiffness.

(a) Natural Time Period

Mode	MODEL 1 (sec)	MODEL 2 (sec)	MODEL 3 (sec)
1	6.005	3.994	3.747
2	6.005	3.994	3.747
3	5.343	2.408	2.144
4	2.065	1.325	1.228
5	2.065	1.325	1.228
6	1.845	0.811	0.721
7	1.182	0.742	0.681
8	1.182	0.742	0.681
9	1.077	0.524	0.479
10	0.842	0.524	0.479
11	0.842	0.485	0.431
12	0.767	0.401	0.367

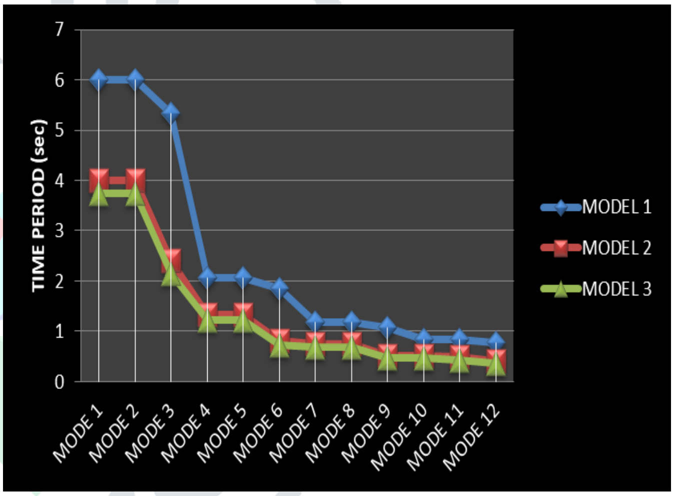

Figure4: Natural Time Period v/s Mode

All the objects of structure have a tendency to vibrate. The rate at which it wants to vibrate is its fundamental time period (natural time period) or un-damped free vibration of a structure. Structures that are weighty (with larger mass m) and flexibility (with smaller stiffness k) have greater natural time period than light and rigid structures.

(b) Max. Storey Displacement

Storey	MODEL 1 (mm)	MODEL 2 (mm)	MODEL 3 (mm)
1	6.351	3.067	2.875
2	17.156	7.447	6.87
3	28.939	12.021	11.038
4	41.009	16.737	15.357
5	53.214	21.579	19.81
6	65.507	26.53	24.381
7	77.856	31.573	29.053
8	90.233	36.693	33.809
9	102.606	41.87	38.632

10	114.942	47.087	43.505
11	127.203	52.326	48.409
12	139.352	57.565	53.325
13	151.347	62.783	58.234
14	163.157	67.898	63.059
15	177.228	73.409	68.2
16	190.961	78.784	73.233
17	204.261	84.055	78.184
18	217.059	89.192	83.024
19	229.281	94.165	87.726
20	240.852	98.945	92.261
21	251.689	103.501	96.604
22	261.712	107.803	100.725
23	270.833	111.82	104.597
24	278.965	115.52	108.194
25	286.015	118.875	111.487
26	291.89	121.852	114.45
27	296.499	124.422	117.057
28	299.804	126.556	119.283

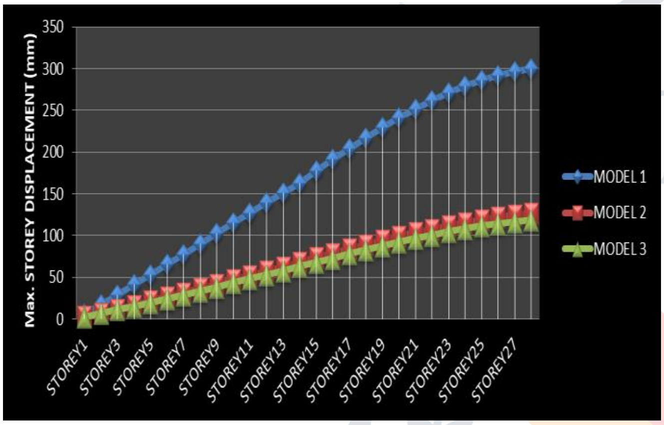

Figure5: Comparison of maximum storey displacement

The Maximum storey displacement observed in model 1 is 299.804 which is under permissible limit of **EN8-2004 code** i.e. 0.004 times of structure height (i.e. 336mm). The maximum storey displacement model 2 is 126.556 mm, model 3 is 119.283 mm. The percentage of reduction in max. storey displacement of model 2 and model 3 is respectively 57.78% and 60.21%.

(c) Storey Drift

Storey	MODEL 1 (mm)	MODEL 2 (mm)	MODEL 3 (mm)
1	6.351	3.067	2.875
2	10.805	4.381	3.995
3	11.783	4.611	4.168
4	12.07	4.8	4.319
5	12.205	4.972	4.453
6	12.293	5.128	4.571
7	12.349	5.267	4.672
8	12.377	5.389	4.756
9	12.373	5.494	4.823
10	12.336	5.58	4.873
11	12.262	5.646	4.904
12	12.148	5.692	4.916
13	11.995	5.716	4.909
14	11.81	5.656	4.825
15	14.071	6.093	5.142
16	13.733	6.001	5.033
17	13.3	5.939	4.951
18	12.798	5.846	4.84
19	12.222	5.722	4.702
20	11.57	5.565	4.536
21	10.838	5.377	4.342
22	10.023	5.156	4.121
23	9.121	4.901	3.872
24	8.131	4.613	3.596
25	7.05	4.291	3.293
26	5.875	3.936	2.963
27	4.609	3.547	2.607
28	3.305	3.125	2.226

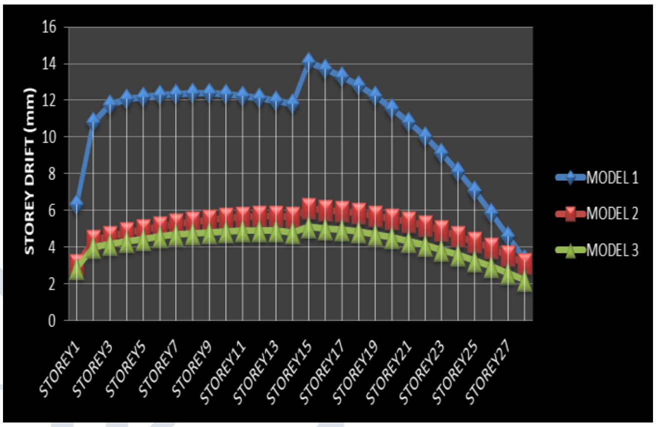

Figure6: Comparison of storey drift

The storey drift observed at 15th storey in model 1 is 14.071 mm which exceed **IS 1893:2016** recommended value 0.004 times of structure height (i.e. 12 mm). The storey drift of model 2 is 6.093 mm, model 3 is 5.142 mm. The percentage of reduction in storey drift of model 2, model 3 is respectively 56.69% and 63.34%.

(d) Storey Stiffness

Storey	MODEL 1 (kN/m)	MODEL 2 (kN/m)	MODEL 3 (kN/m)
1	1383640.309	2738075.398	3111734.416
2	817670.803	1921057.003	2243394.323
3	751170.488	1851936.508	2162830.08
4	732892.615	1802417.496	2092962.612
5	723077.247	1755257.096	2027696.68
6	715201.165	1710742.522	1967377.758
7	708160.866	1669631.167	1912191.602
8	701643.31	1631616.778	1861434.385
9	695304.174	1595731.574	1814174.031
10	688764.217	1561262.776	1769968.811
11	681795.442	1528243.376	1728860.032
12	674467.007	1497228.154	1690735.791
13	667104.713	1469304.682	1655105.001
14	659869.973	1461464.748	1639634.194
15	536235.434	1313983.624	1488752.062
16	531803.791	1304560.243	1468865.415
17	528379.467	1282068.494	1435579.193
18	524239.411	1260762.447	1405573.709
19	519047.256	1240048.637	1377771.67
20	512902.294	1219821.151	1350867.086
21	506480.158	1200862.65	1324103.587
22	500590.349	1184010.378	1297312.413
23	495338.741	1167900.597	1268910.26
24	489359.994	1146525.97	1232691.149
25	479478.369	1107843.209	1175237.17
26	459890.737	1031765.575	1073739.543
27	417800.716	882768.319	891082.502
28	310525.088	585778.23	563129.326

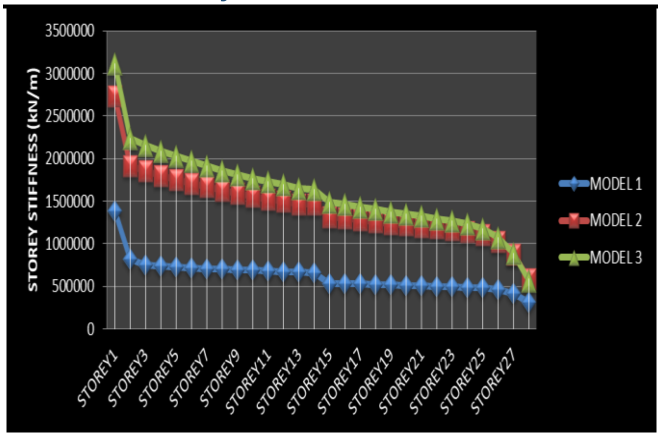

Figure7: comparison of maximum storey stiffness

The maximum value of stiffness observed in model 3, so model 3 gives better response among all models. The storey stiffness of model 2 is 1.97 times, model 3 is 2.24 times more than the model 1.

VI. CONCLUSION

In this paper the different braced buildings are studied and the seismic parameters in terms of Time period, Maximum storey displacement, Storey drift and storey stiffness are compared. The following conclusions are summarized based on analysis:

1. In this research work model 1 shows maximum time period while model 3 shows minimum time period which means that model 1 is most flexible and model 3 is least flexible.

2. The maximum displacement of the building was found to be minimum in X-type bracing while Model 1 shows maximum displacement and is at verge of failure as per standards. Model 1 showed higher storey displacement that it is more prone to damage during earthquake as compared to other braced buildings.

3. Model 1 is showing failure in the drift. While other models are satisfying criteria maximum allowed storey drift as per Indian standards.

4. In tall buildings, the storey stiffness is one of the important factor. So for this purpose bracing system are adopted to enhance this parameter. Model 3(X-type bracing) showing maximum stiffness while Model 1 has minimum stiffness.

5. It can also be observed that as we move upward the storey stiffness decreased in all three model so no soft storey effect is observed in any model.

6. A sudden change in the stiffness has been observed at 15th storey due to change in column size at 15 storey.

7. From the above discuss it can be concluded that X-type bracing shows best result when compared with inverted V-type and bare RCC frame and V-type bracing showing better result than bare RCC frame structure.

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