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SEISMIC ANALYSIS OF TALL BUILDINGS WITH AND WITHOUT BRACINGS AND STRUTS

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Abstract - *As the population is increasing and available space is less, world is looking to make tall buildings to accommodate more people within available area. Due to this, tall buildings passion started. Due to movement of tectonic plates Indian land is divided into zones which represent the seismic ranges. These zones are reduced to* ***four*** *from* ***five****. This indicates the closeness of earthquake causing effects. If we come across the design of existing buildings we can find the lack of seismic resisting capacity. For impeccable performance of buildings we have to do the seismic analysis. Seismic analysis is performed on Three models namely "G+14 Normal Building" as Model 1, "G+14 Building with Bracings" as Model 2, "G+14 Building with Single Struts" as Model 3 using Equivalent static method, Response Spectrum Method and Time History Analysis. The Buildings are assumed to be located in Zone II and Zone III resting on Hard soil. From the static and dynamic analysis we can compare the three models for seismic parameters like Base shear, Storey Shears, Storey drift and Time period. For this comparison ETABS software package is used for modeling the Building Models by following the IS:1893(Part I)-2002.*

Key Words – Bracings, Base Shear, Equivalent static method, Response spectrum method, Storey Shear, Single Strut, Time history analysis, Time Period.

1 INTRODUCTION

The composite reinforced (RC) frame buildings are becoming most preferable for Earthquake Resistant Buildings. The composite materials that are used in composite RC frame buildings are Bracings, Struts, Shear walls, etc. These Composite RC frame buildings shows great stiffness and strength than normal RC frame buildings. Due to these advantages the composite structures are capable of resisting Earthquake effects. In order to study this composite nature of buildings, Bracings and struts are considered. In order to resist the earthquake loads the external loads are to be carried to the foundation in a most effective way without any interruption. These composite materials are installed in between the columns of the building in a diagonal manner. As the weight of the building is increased, the stiffness also increases automatically. By this increase in stiffness the strength of the building also increases, which gives the resistant towards the compression and tension values.

From these facts this study is carried over by taking three models, the first model is "G+14 Normal RC frame building", the second one is "G+14 RC frame building with Bracings", the third one "G+14 RC frame building with struts". Using ETABS software seismic analysis is carried out on these three models in four zones as per IS: 1893(part I)-2002 using Static analysis and Dynamic analysis.

Seismic Coefficient method also known as Equivalent static analysis is used as a static analysis and the response spectrum method is used to perform the dynamic analysis. A linear dynamic analysis namely time history analysis is used to apply the ground motions recorded during uttarakasi earthquake which occurred in a year 1991. From this Dynamic analysis we can get the Storey shears which are distributed more accurately compared to Equivalent static analysis. We also get the storey drifts, Base shears and time period of these three models. By using all these results the comparison is done among three models located in all four zones respectively.

1.1 DEFINITION OF BRACINGS

Bracings are the structural components which are used as compression or tension member to resist lateral loads from wind or from earthquake. These bracings can be installed either as a RC frame structure or Steel frame structure. There are many types of bracings namely V Braces, Inverted V or Chevron braces, K braces, X braces, Eccentric Braces etc., In this present study we use chevron bracings to resist the lateral loads.

1.2 DEFINITION OF STRUTS

Struts are another type of composite structural component used for resisting lateral loads. These struts are of steel or Rc frame type. Basically struts can be designed as single strut, double strut and triple strut models. These struts function effectively in dissipating the energy that released from the lateral loads and keep the structure safe. In this present study we use single strut model for comparison of Normal RC frame building and RC frame building with bracings.

1.3 SEISMIC ANALYSIS

The seismic analysis is performed on tall buildings using both static and dynamic analysis. Equivalent static analysis is used as a static method, where the Response spectrum method and Time history analysis are used as Dynamic analysis.

Equivalent static method is a preliminary method in order to find the later loads that act on building. Using seismic weight of building and the seismic horizontal acceleration coefficient the Base shear is calculated. Using code base formula this Base shear is distributed along the height of the building. This method is evaluated using IS:1893(Part I)-2002 seismic code.

Response spectrum analysis is an improved method over equivalent static analysis to find the accurate lateral loads of a building. The base shears that are evaluated from equivalent static method and the response spectrum method are matched because in this analysis we use the bare frame but in practical sense wall loads also add to the seismic weight of the building. For getting the desired seismic parameters we match the base shear values in these methods.

Time history analysis is a dynamic analysis, this analysis is done by applying data over incremental steps as a function of acceleration, force, moment or displacement. The closer the spacing of time steps, the more accurate the solution will be. The background of this time history analysis depends on eigen values generated for the structure based on response to time history. Considering to be more realistic compared to response spectrum analysis. Most useful for very long or very tall structures (flexible structures). In this present study the ground motions recorded during the earthquake occurred at uttarakasi during 1991.

2 OBJECTIVE AND SCOPE OF STUDY

In this present study a G+14 Normal Building , G+14 Building with Bracings and G+14 Building with struts are compared using seismic parameters Storey Shears, Base shears, Time period, and Storey Drift which are derived from Equivalent static Method, Response spectrum method and Time history analysis. From this study we can design the tall buildings for the earthquake loads using composite structural materials.

3 MODELING OF BUILDING

Here a G+14 storey Normal RC frame Building is modeled by using ETABS software. The detailed features of the normal building are given below.

3.1. Features of building

- Floors = G + 14
- Bays in X-direction = 5
- Bays in Y-direction = 3
- Bay width in X-direction = 3 m
- Bay width in Y-direction = 5m
- Live load on slab= 3.0 kN/m^2(all floors except terrace floor) =1.5 kN/m^2(terrace floor)
- Dead load on slab =1.225 kN/m^2(all floors except terrace floor)= 1.224 kN/m^2(terrace floor)
- Storey height = 3 m
- Thickness of slab = 0.125 m
- Grade of concrete = M_{25}
- Grade of steel = Fe415
- Wall Thickness = 0.23 m (exterior wall)
  = 0.12 m (interior wall)

3.2 SEISMIC WEIGHT OF BUILDING

The seismic weight of Normal RC frame building is calculated on the basis of the total dead load of structure and the live loads applied. As per the Indian Standard code 1893 that is earthquake code of clause 7.4 states that the seismic weight of building is equal to the sum of full dead load and appropriate amount of imposed load as specified in of IS 875(Part 2). As per Code IS 875 it states that if the imposed load that is live load on a floor is less than 3 kN/m^2 then the imposed load is taken as 25 % of imposed load, if the imposed load on a floor is greater than 3 kN/m^2 then the imposed loads is taken as 50 % of imposed loads.

The seismic weight of building = 41772.44 kN

3.3. DIMENSIONS OF BEAMS AND COLUMNS

For G+14 building by applying the dead load and live load the structure will be modeled for minimum sizes of beams and columns. After the application of earthquake forces in X and Y directions the structure will be unsafe with the available sizes of beams and columns. So for that purpose the sizes of beams and columns are increased to withstand the lateral forces applied by the earthquake.

- Size of beam = 0.4 m X 0.3 m
- Size of column = 0.45 m X 0.4 m

The plan and the dimensions for all three models will be same which gives same seismic data which is used for the seismic analysis.

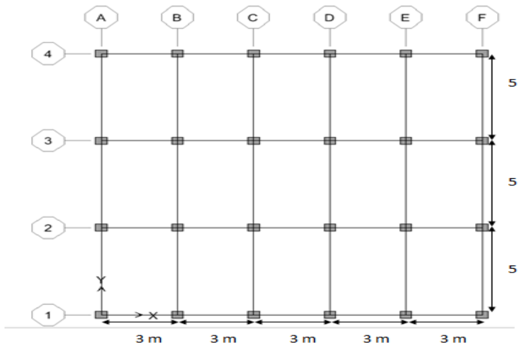

Fig 1: Showing the plan of a G+14 building

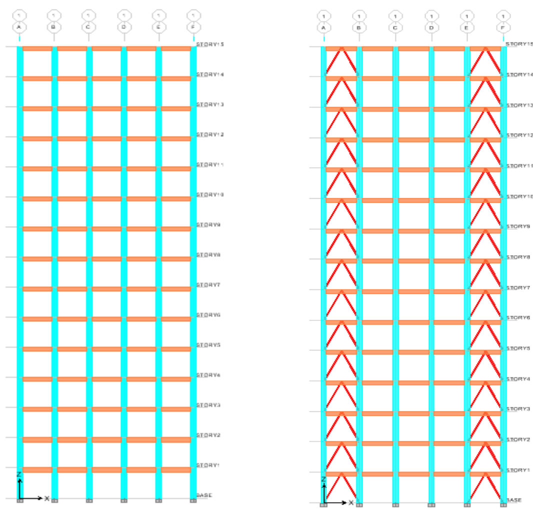

Fig 2: Showing the elevation in XZ view of Model 1 & Model 2

Modes	Model 1	Model 2	Model 3
Mode 1	3.17452	2.21614	1.07631
Mode 2	2.61573	2.04759	1.00718
Mode 3	2.48905	1.42403	0.45986

- Bracings used are Chevron Type with Dimensions as 0.11 m X 0.11 m X 0.01 m. (Width X Depth X Thickness). The Bracing model is IS Double angle section.

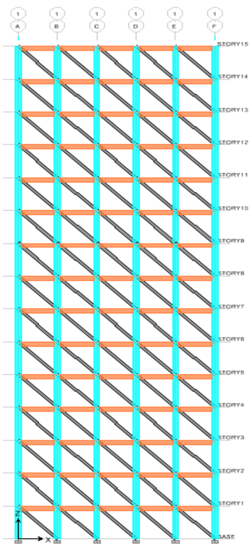

Fig 3: Showing the elevation in XZ view of a Model 3

The width of the single strut is given below

Table 1: Parameters of diagonal strut.

Level	Strut type		w_d (m)	l_d (m)	A_d (m^2)
Floor	External	X	0.732	5.45	0.1685
		Y	0.682	3.97	0.1569
	Internal	X	0.862	5.45	0.1034
		Y	0.802	3.97	0.0963

4. RESULTS & DISCUSSIONS

4.1 TIME PERIOD:

Table 2: Time periods of first three modes in all models

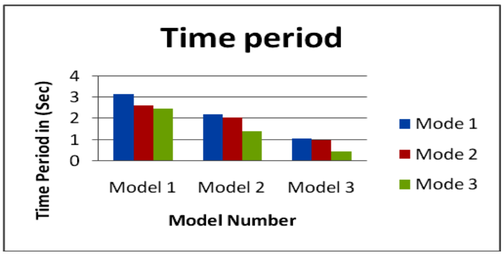

Chart 1: Showing Time periods of first three modes

- The Time periods of first three modes in all three models are compared which resulted Model 3 with less Time period which is less effected to earthquake effects compared to other buildings.

4.2 STOREY DRIFTS:

Table 3: Storey Drifts for all models in Zone II

Storey	Model 1			Model 2			Model 3		
	EQ	RS	TH	EQ	RS	TH	EQ	RS	TH
Terrace	0.237	0.196	0.134	0.283	0.218	0.187	0.115	0.085	0.097
Storey 14	0.350	0.292	0.167	0.351	0.276	0.196	0.119	0.088	0.115
Storey 13	0.462	0.369	0.148	0.412	0.321	0.173	0.124	0.091	0.114
Storey 12	0.559	0.427	0.152	0.465	0.353	0.189	0.127	0.093	0.104
Storey 11	0.638	0.470	0.156	0.509	0.377	0.188	0.128	0.094	0.084
Storey 10	0.703	0.507	0.168	0.545	0.394	0.186	0.129	0.095	0.075
Storey 9	0.754	0.538	0.189	0.570	0.407	0.204	0.126	0.091	0.092
Storey 8	0.791	0.567	0.175	0.584	0.417	0.174	0.123	0.089	0.097
Storey 7	0.815	0.590	0.154	0.588	0.422	0.191	0.118	0.086	0.096
Storey 6	0.829	0.611	0.167	0.581	0.423	0.187	0.111	0.081	0.093
Storey 5	0.833	0.628	0.758	0.562	0.419	0.188	0.102	0.076	0.083
Storey 4	0.828	0.645	0.184	0.531	0.409	0.191	0.092	0.069	0.066
Storey 3	0.812	0.658	0.157	0.486	0.395	0.176	0.080	0.063	0.068
Storey 2	0.763	0.648	0.174	0.425	0.368	0.164	0.067	0.055	0.078
Storey 1	0.492	0.435	0.153	0.276	0.255	0.170	0.051	0.044	0.105

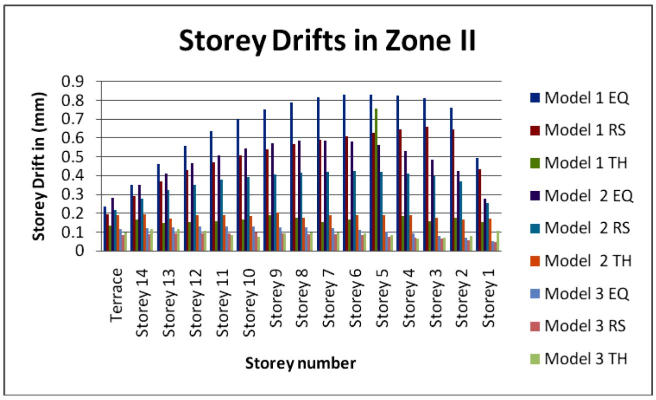

Chart 2: Showing Storey Drift in Zone II

- The maximum value of Storey Drift of Model 1 located in Zone II is 0.833 mm and minimum value is 0.134 mm where as for model 2 the maximum value is 0.588 mm, minimum value is 0.170 mm and for Model 3 the maximum value is 0129 mm, minimum value is 0.066 mm.
- We can see clearly that the Storey drift is decreased in Model 3 compared to Model 1 and Model 2. The G+14 building with struts gives higher strength toward the lateral loads.

Table 4: Storey Drifts for all models in Zone III

Storey	Model 1			Model 2			Model 3		
	EQ	RS	TH	EQ	RS	TH	EQ	RS	TH
Terrace	0.379	0.313	0.134	0.452	0.348	0.187	0.184	0.135	0.097
Storey 14	0.561	0.466	0.167	0.562	0.441	0.196	0.192	0.141	0.115
Storey 13	0.739	0.591	0.148	0.659	0.513	0.173	0.198	0.146	0.114
Storey 12	0.894	0.683	0.152	0.745	0.565	0.189	0.203	0.149	0.104
Storey 11	1.02	0.752	0.156	0.816	0.603	0.188	0.205	0.150	0.084
Storey 10	1.125	0.811	0.168	0.872	0.631	0.186	0.204	0.149	0.075
Storey 9	1.206	0.862	0.189	0.912	0.652	0.204	0.202	0.147	0.092
Storey 8	1.264	0.906	0.175	0.936	0.667	0.174	0.196	0.143	0.097

Storey 7	1.304	0.945	0.154	0.930	0.675	0.191	0.188	0.137	0.096
Storey 6	1.326	0.978	0.167	0.900	0.677	0.187	0.177	0.130	0.093
Storey 5	1.333	1.006	0.758	0.847	0.670	0.188	0.163	0.122	0.083
Storey 4	1.325	1.032	0.184	0.778	0.656	0.191	0.147	0.112	0.066
Storey 3	1.300	1.054	0.157	0.679	0.631	0.176	0.128	0.100	0.068
Storey 2	1.221	1.038	0.174	0.592	0.588	0.164	0.167	0.874	0.078
Storey 1	0.787	0.695	0.153	0.442	0.407	0.170	0.081	0.699	0.105

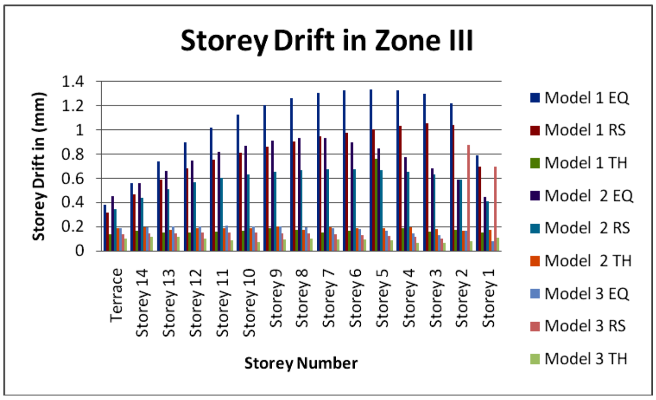

Chart 3: Showing Storey Drift in Zone III

- The maximum value of storey drift for Model 1 in Zone III is 1.325 mm and minimum value is 0.134 mm, where as for Model 2 maximum value is 0.936, minimum value is 0.170 mm and for Model 3 maximum value is 0.205 mm, minimum value is 0.066 mm.
- The drift values in Zone III increases compared to Zone II in all Models. Model 3 shows higher resistance towards lateral loads

4.3 STOREY SHEARS:

Table 5: Storey Shear for all Models in Zone II

Storey	Model 1			Model 2			Model 3		
	EQ	RS	TH	EQ	RS	TH	EQ	RS	TH
Terrace	56.65	78.43	695.94	56.65	81.59	169.92	56.65	64.68	80.18
Storey 14	148.88	167.47	708.85	148.88	172.82	178.09	148.88	148.31	92.60
Storey 13	228.41	224.62	748.63	228.41	232.55	195.14	228.41	210.75	95.14
Storey 12	296.17	265.21	785.60	296.17	270.71	197.65	296.17	255.09	95.78
Storey 11	353.11	297.28	891.66	353.11	297.50	200.68	353.11	286.09	97.77
Storey 10	400.17	325.85	893.31	400.17	320.07	202.94	400.17	308.94	103.04
Storey 9	438.29	353.06	904.37	438.29	342.31	206.62	438.29	328.64	105.36
Storey 8	468.41	377.99	974.45	468.41	364.35	207.81	468.41	349.48	106.19
Storey 7	491.47	402.16	979.37	491.47	385.93	208.33	491.47	374.12	107.03
Storey 6	508.41	424.37	986.26	508.41	406.81	215.46	508.41	403.20	107.17
Storey 5	520.17	445.51	987.67	520.17	429.10	216.05	520.17	435.29	108.61
Storey 4	527.70	467.38	1018.6	527.70	454.61	221.52	527.70	467.86	108.69
Storey 3	531.94	490.39	1049.5	531.94	484.29	231.69	531.94	497.62	120.11
Storey 2	533.82	517.23	1158.6	533.82	513.91	246.63	533.82	521.06	140.93
Storey 1	534.29	535.29	1414.1	534.29	535.28	318.48	534.29	534.30	155.24

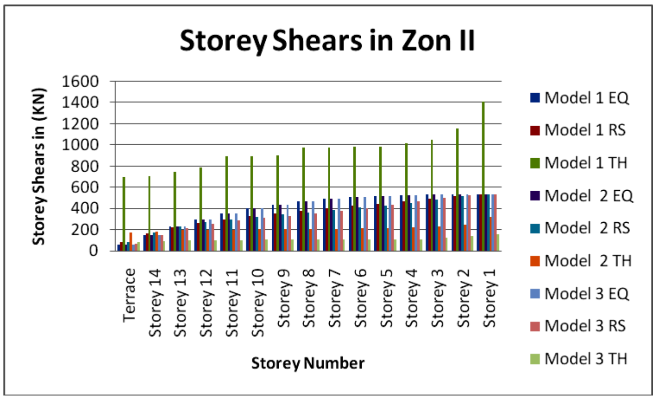

Chart 4: Showing Storey Shears in Zone II

- The storey shears obtained from the equivalent static analysis are not well distributed along the height of building where as in Response spectrum analysis the storey shears are distributed precisely to make the building stable. We can observe the shear values in Model 3 are acceptable in higher seismic region.

Table 6: Storey Shear for all Models in Zone III

Storey	Model 1			Model 2			Model 3		
	EQ	RS	TH	EQ	RS	TH	EQ	RS	TH
Terrace	90.64	125.49	695.94	90.64	130.53	169.92	90.64	103.48	80.18
Storey 14	238.21	267.94	708.85	238.21	276.50	178.09	238.21	237.29	92.60
Storey 13	365.45	359.39	748.63	365.45	372.06	195.14	365.45	337.20	95.14
Storey 12	473.87	424.34	785.60	473.87	433.11	197.65	473.87	408.14	95.78
Storey 11	564.97	475.65	891.66	564.97	475.97	200.68	564.97	457.75	97.77
Storey 10	640.26	521.36	893.31	640.26	512.09	202.94	640.26	494.31	103.04
Storey 9	701.25	564.89	904.37	701.25	547.67	206.62	701.25	525.83	105.36
Storey 8	749.44	604.78	974.45	749.44	582.93	207.81	749.44	559.17	106.19
Storey 7	786.33	643.45	979.37	786.33	617.45	208.33	786.33	598.59	107.03
Storey 6	813.43	678.99	986.26	813.43	650.86	215.46	813.43	645.12	107.17
Storey 5	832.25	712.82	987.67	832.25	686.53	216.05	832.25	696.47	108.61
Storey 4	844.30	747.80	1018.6	844.30	727.33	221.52	844.30	748.58	108.69
Storey 3	851.08	784.62	1049.5	851.08	774.83	231.69	851.08	796.19	120.11
Storey 2	854.09	827.58	1158.6	854.09	822.21	246.63	854.09	833.70	140.93
Storey 1	854.84	856.46	1414.1	854.84	854.81	318.48	854.84	854.86	155.24

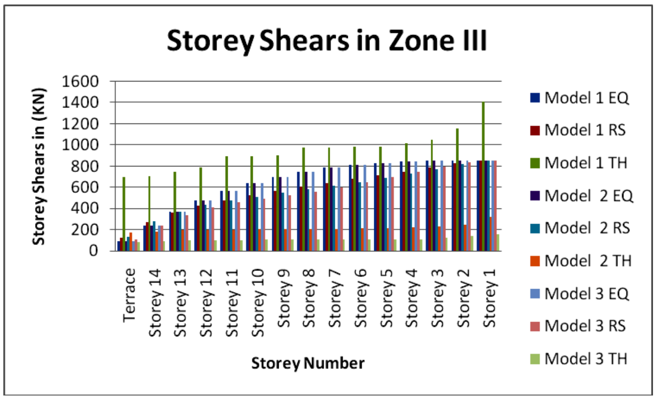

Chart 5: Showing Storey shears in Zone III

- As discussed above the Storey shears evaluated using Response spectrum method are acceptable compared to other methods. The G+14 building with struts gives the higher seismic strength compared to remaining models.

4.4 BASE SHEAR:

Table 7: Maximum Base shear Values

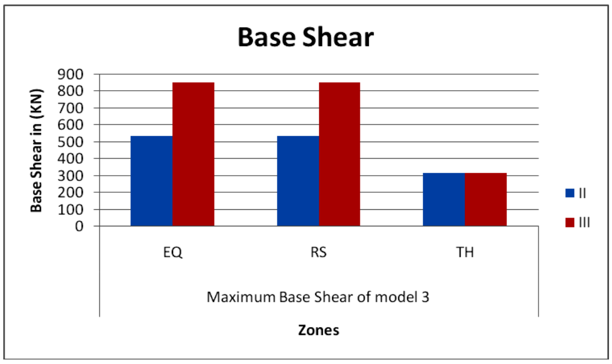

Chart 6: Showing Base Shears in Zone II and Zone III

5. CONCLUSION:

In this present study the seismic analysis comparison is done for Normal Building, Building with Bracings and Building with Struts. The analysis is carried out using the Seismic coefficient method, Response spectrum method and the Time History analysis. The comparison is made by using the values obtained for storey drift, Base shear, Storey shears and Time period of buildings.

- From the results obtained for the storey drifts shows that Model 3 i.e., the Building with struts undergoes minimum drift values compared to other models.
- The shears obtained in each storey nothing but storey shears are precisely distributed for model 3 which shows the satisfactory strength results towards earthquake effects in all zones.
- The Time period of the normal building is very high compared to other two buildings which ultimately results for large displacements.
- To overcome this struts and bracings technology is used and it also showed the good response in reducing the Time period of building.
- The Time period of Model 2 is decreased compared to Model 1, but Model 3 is showed less Time period than Model 2. This results less deflection values in Model 3 under Earthquake loads.

Zones	Maximum Base Shear of model 3		
	EQ	RS	TH
II	534.29	534.30	318.48 as per records from uttarakasi earthquake
III	854.84	854.86	

- From above results we can conclude that the strut model is more efficient towards earthquake loads. As these struts are arranged throughout the structure the economy and load of the building may be more when compared to other buildings.
- Building with Bracings also showed better results in resisting the earthquake loads which is economical compared to Building with struts.

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