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Seismic analysis of High Rise R.C Building with Underneath Satellite Bus Stop including an Intermediate Service Soft Storey

Mohammed Parvez[1] Prof Vishwanath. B. Patil[2]
[1]P.G. Student [2]Associate Professor
[1,2]Department of Civil Engineering
[1,2]P.D.A.C.E. Gulbarga-585102

Abstract— Reinforced concrete (RC) frame buildings with masonry infill walls have been widely constructed for commercial, industrial and multi storey residential uses in seismic regions. Masonry infill typically consists of bricks or concrete blocks constructed between beams and columns of a reinforced concrete frame. Masonry infill walls are widely used as partitions. They are considered as non-structural elements. RC frame building with open first storey is known as soft storey, a similar soft storey effect can also appear, at intermediate storey level if a storey used as a service storey. The soft storey located in the lower part of the high rise building especially the first storey is very undesirable as it attracts severely large seismic forces. At the same time, the soft storey located in the upper part of the high rise building does not significantly affect the performance compared to the performance of the fully infill frame. To study the effect of masonry infill and different soft storey level, 10 Models of R C framed building were analyzed with different types of shear walls when subjected to earthquake loading. The results of bare frame and other building models have been compared. Analysis is carried out by ETABS software. Storey displacement, time period, story drift and Storey acceleration is calculated by ESA, RSA and THA compared for all models. The results shows that the infill wall and shear walls gives the better performance in seismic analysis of building.

Key words: High-Rise R.C Building, Story Displacement, Time Period, Storey Acceleration, Storey Drift, Shear Walls, Soft Storey

I. INTRODUCTION

A large portion of India is susceptible to damaging levels of seismic hazards. Hence, it is necessary to take in to account the seismic load for the design of high-rise structure. The different lateral load resisting systems used in high-rise building are: 1.Bare frame 2.Shear wall frame. In tall building the lateral loads due to earthquake are a matter of concern. These lateral forces can produce critical stresses in the structure, induce undesirable stresses in the structure, induce undesirable vibrations or cause excessive lateral sway of the structure. Tall buildings are the most complex built structures since there are many conflicting requirements and complex building systems to integrate. Today’s tall buildings are becoming more and more slender, leading to the possibility of more sway in comparison with earlier high-rise buildings.

Open ground storey building having only columns in the ground storey is known as soft storey. Due to some commercial and residential activity. The presence of the soft storey at ground and top storey leads to severe damage during an earthquake. To minimize the whole effect of soft storeys at ground, and top storey level of the building, (L-type, swastika-type, plus(+) type, minus(-)type, C-type) all different shape of shear wall has been used.

Reinforced concrete (RC) structural walls, conventionally known as shear walls are effective in resisting lateral loads imposed by wind or earthquakes. They provide substantial strength and stiffness as well as the deformation capacity (capacity to dissipate energy) needed for tall structures to meet seismic demand.

The main Objectives of the present study is

- To know the effect of the building with ground and intermediate soft storey when subjected to lateral seismic loading.
- To find out the deflections and storey drifts at each storey level using Equivalent method and Response Spectrum method.
- To check the strength and stiffness of each storey.
- To know the effect of ground and intermediate soft storey.

II. DESCRIPTION OF STRUCTURAL MODEL

For the study 10 different models of eleven (11) storey building are considered, the building has four bays in X direction and seven bays in Y direction with the plan dimension 40 m × 42 m and a storey height of 3.5 m each in all the floors excluding 6th and ground storey, height of 6th storey is 2m and height of ground is kept 10m. The orientation and size of column is kept same throughout the height of the structure. The building is considered to be located in seismic zone V. The building is founded on medium strength soil through isolated footing under the columns. Elastic moduli of concrete and masonry are taken as $27.386\text{x}10^6$ KN/m^2 and $3500\text{x}10^3$ KN/m^2 respectively and their poisons ratio as 0.20 and 0.15 respectively Response reduction factor for the special moment resisting frame has taken as 5.0 (assuming ductile detailing). The unit weights of concrete and masonry are taken as 25.0 KN/m^3 and 20.0 KN/m^3 respectively, the floor finish on the floors is 1.5 KN/m^2. The live load on floor is taken as 3.5 KN/m^2. In seismic weight calculations, 50 % of the floor live loads are considered. Thickness of slab, shear wall and masonry infill wall are as 0.120m, 0.20 m and 0.23m respectively.

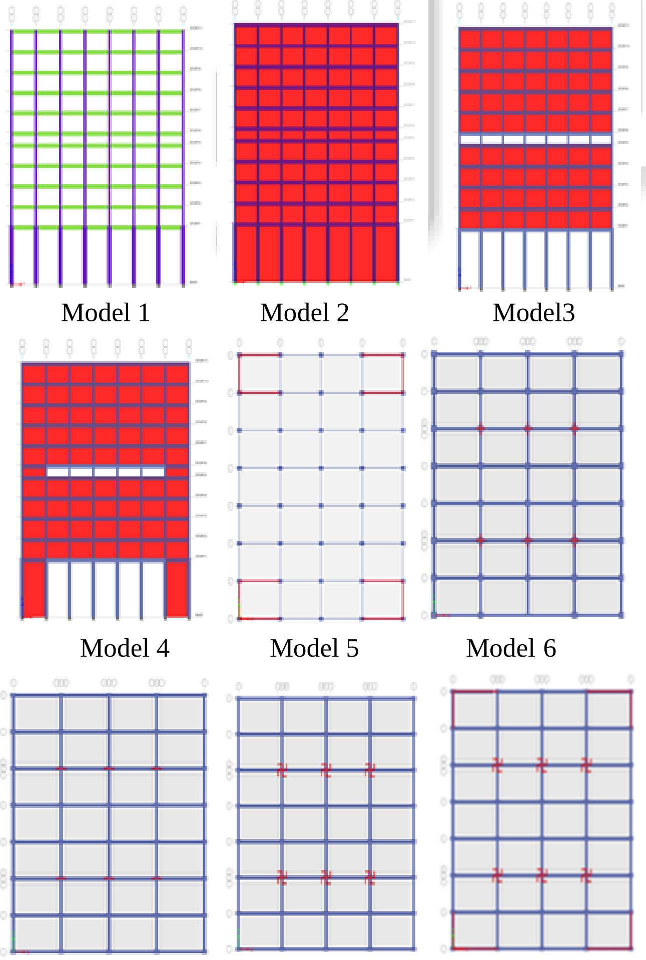
Column size (Ground storey) = (1m x 1m)
Column size (other stories) = (0.6m x 1m)
Beam size = (0.45m x 0.7m)

III. MODELS CONSIDERED FOR ANALYSIS

Following 10 models are analyzed by equivalent static method response spectrum method and time history analysis method using ETABS software.

- Model 1: Building modeled as bare frame. However, masses of the walls are included.

- Model 2: Building has full brick masonry infill of 230mm thick in all the stories including ground storey and intermediate storey.
- Model 3: Building has no brick masonry infill in ground storey, intermediate storey (6th storey) and has full brick masonry infill of 230mm thick in upper stories.
- Model 4: Building has no brick masonry infill in ground storey, intermediate storey (6th storey) and has L shaped shear wall (200mm thick) in x and y directions at corners.
- Model 5: Building model is same as in model 4 and has C shaped shear wall (200mm thick) in x and y directions at corners.
- Model 6: Building has no brick masonry infill in ground and intermediate storey. Further, + shaped shear wall (200mm thick) of length 1mtr is provided at centre of the plan.
- Model 7: Building model is same as in model 6, but replaced by – shaped shear wall (200mm thick) of length 1mtr is provided at centre of the plan.
- Model 8: Building model is same as in model 6, but replaced by swastika shear wall of length 1mtr in each direction.
- Model 9: Building model is same as in model 8. Further an addition of L shaped shear wall is provided at corners.
- Model 10: Building model is same as in model 7 but shear wall is provided in opposite direction.


Model 1 Model 2 Model3
Model 4 Model 5 Model 6
Model 7 Model 8 Model 9

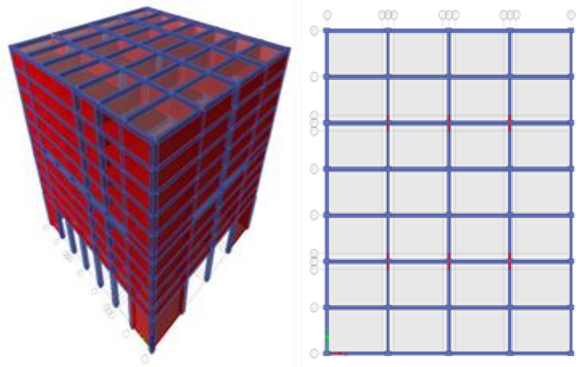

Model 9 Model 10

Fig. 1: Models

IV. RESULTS AND DISCUSSION

A. *Fundamental Time Period*

In this paper the results of the selected building models studies are presented. Analysis were carried out using ETABS and different parameters studied such as Fundamental natural time period, Storey acceleration and comparison of Storey displacement, Base shear with ETABS, the tables and figures are shown below.

Fundamental time period(Sec)	
MODEL NO.	**Time Period**
1	2.8369
2	0.7588
3	1.5684
4	0.5363
5	0.5245
6	1.2622
7	0.5856
8	1.1907
9	0.4678
10	0.5394

Table 1: Fundamental time period for various models

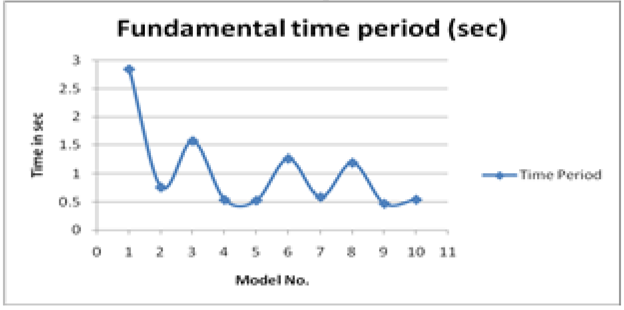


Fig. 2: Chart 1.Time period Vs Model No. of all models.

B. *Base Shear in KN*

Seismic Base Shear (KN)		
Model No	Equivalent Static Analysis	
	x-direction	y-direction
1	9541.89	10873.23
2	14752.17	14389.6
3	14737.37	14376.17
4	43881.17	43881.17
5	39171.41	39171.41
6	20571.8	20710.58
7	39884.81	37052.63
8	24216.6	23606.98

9	59935.06	59935.06
10	39884.81	39884.81

Table 2: Comparison of highest values of seismic base shear of different models by table and chart below.

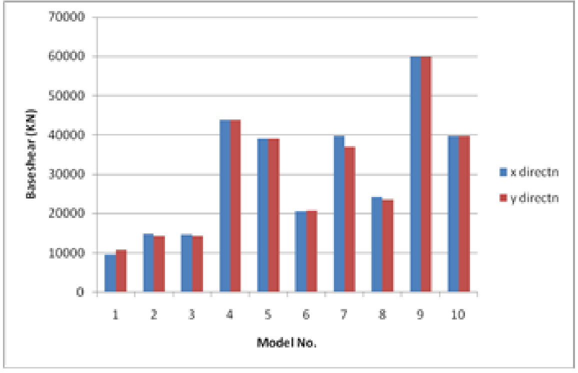


Fig. 3: Model Vs Base shear for different models

C. *Storey Acceleration*

	MODEL 1	
STOREY ACCELERATION		
Storey	ux	uy
11	364.4	362.782
10	291.11	315.42
9	249.64	273.56
8	238.22	252.076
7	232.09	250.038
6	223.62	246.401
5	217.27	242.025
4	213.57	238.849
3	206.55	210.884
2	199.77	191.788
1	182.71	180.134

Table 3(a)

	MODEL 2	
STOREY ACCELERATION		
Storey	ux	uy
11	1140.7	958.644
10	1071.85	897.068
9	990.161	822.959
8	909.962	753.905
7	838.798	697.761
6	775.861	654.587
5	742.7	633.874
4	680.702	593.125
3	619.401	552.538
2	551.231	503.445
1	461.307	431.711

Table 3(b)

	MODEL 3	
STOREY ACCELERATION		
Storey	ux	uy
11	350	355.66
10	344.89	348.28
9	338.97	339.47
8	332.71	330.28
7	326.64	321.47
6	320.24	313.11
5	314.11	305.41
4	309.44	300.53
3	304.87	295.74
2	300.53	290.38
1	290.31	280.07

Table 3(c)

	MODEL 4	
STOREY ACCELERATION		
Storey	ux	uy
11	1296.72	1267.7
10	1168.56	1151.2
9	1042.55	1039.6
8	934.247	942.64
7	847.548	855.98
6	747.303	751.81
5	650.658	652.44
4	524.967	536.21
3	327.846	345.23
2	290.43	284.89
1	250.32	244.65

Table 3(d)

	MODEL 5	
STOREY ACCELERATION		
Storey	ux	uy
11	1323.8	1267.6
10	1178.76	1151.7
9	1039.78	1038.6
8	923.18	940.29
7	831.559	852.94
6	734.003	751.15
5	647.994	652.64
4	517.664	536.67
3	319.016	346.36
2	282.47	265.3
1	236.922	220.63

Table 3(e)

	MODEL 6	
STOREY ACCELERATION		
Storey	ux	uy
11	534.22	555.8
10	521.4	537.4
9	506.4	515.5

8	490.46	492.9
7	474.86	471.4
6	457.99	450.8
5	443.25	435.5
4	430.79	422.3
3	418.75	408.9
2	407.51	395.2
1	374.82	358.6

Table 3(f)

	MODEL 7	
STOREY ACCELERATION		
Storey	ux	uy
11	1250.3	1196.9
10	1136.7	1088
9	1023.9	979.22
8	928.4	894.63
7	857.61	829.05
6	757.58	744.52
5	648.81	644.19
4	528.61	537.23
3	335.26	357.18
2	303.15	298.79
1	265.02	241.39

Table 3(g)

	MODEL 8	
STOREY ACCELERATION		
Storey	ux	uy
11	595.697	612.93
10	576.096	587.4
9	553.421	557.67
8	529.76	527.49
7	506.957	499.44
6	483.295	473.53
5	465.617	457.22
4	450.589	443.41
3	436.048	428.79
2	419.953	410.99
1	373.425	358.35

Table 3(h)

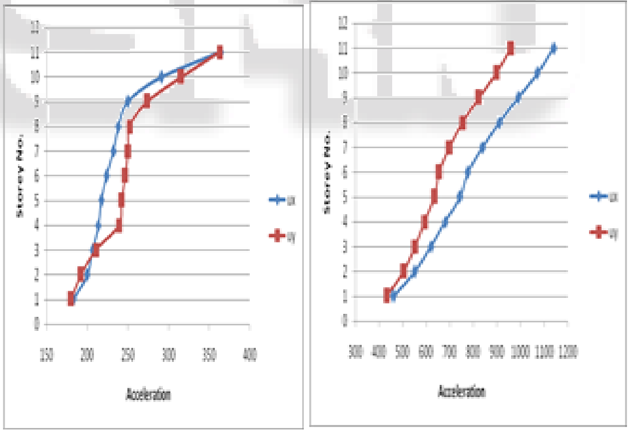
	MODEL 9	
STOREY ACCELERATION		
Storey	ux	uy
11	1293.15	1268.1
10	1160.12	1146.4
9	1032.43	1029.9
8	922.044	925.82
7	836.23	838.5
6	735.29	734.86
5	646.226	649.36
4	513.936	521.44
3	312.853	321.36
2	299.62	287.96
1	223.9	210.14

Table 3(i)

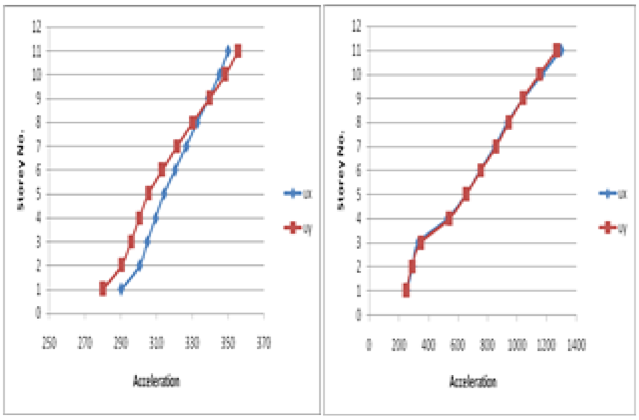
	MODEL 10	
STOREY ACCELERATION		
Storey	ux	uy
11	1245.5	1247
10	1130.9	1137
9	1015.5	1027
8	921.95	931.8
7	852.95	853.4
6	758.87	755.1
5	648.21	656.9
4	530.8	541.5
3	341.19	349.3
2	310.19	302.6
1	287.36	276.2

Table 3(j)

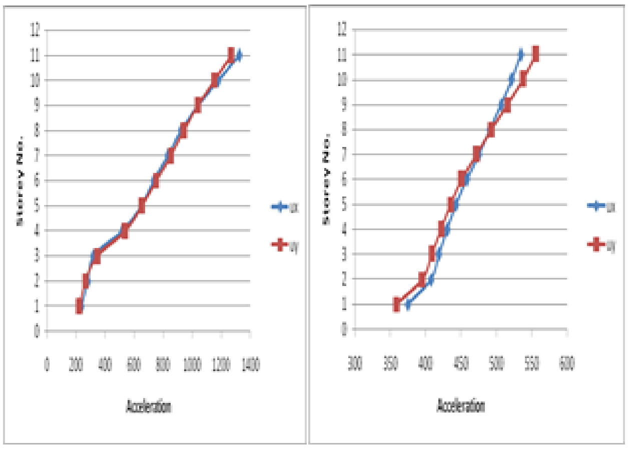
Table 3: Comparison of storey acceleration of different models by table and chart below



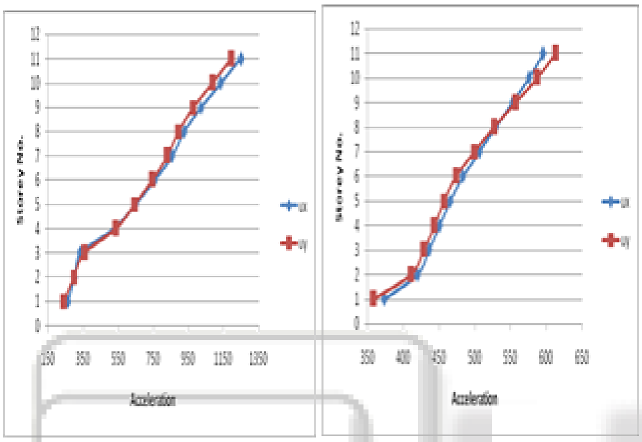
Model 1 Model 2



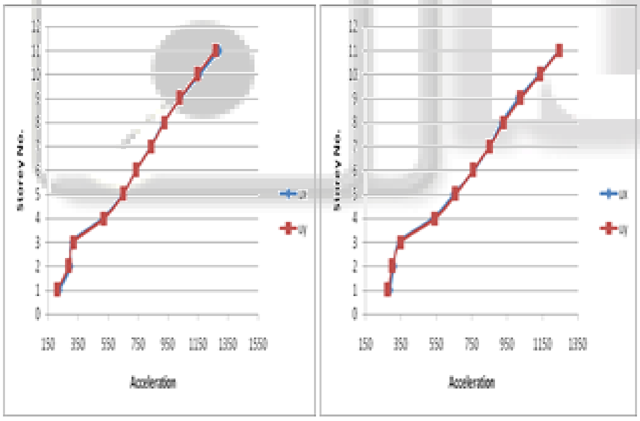
Model 3 Model 4



Model 5 Model 6



Model 7 Model 8



Model 9 Model 10

Fig. 4: Chart 2. Storey No. Vs acceleration of all models

D. *Storey Displacement*

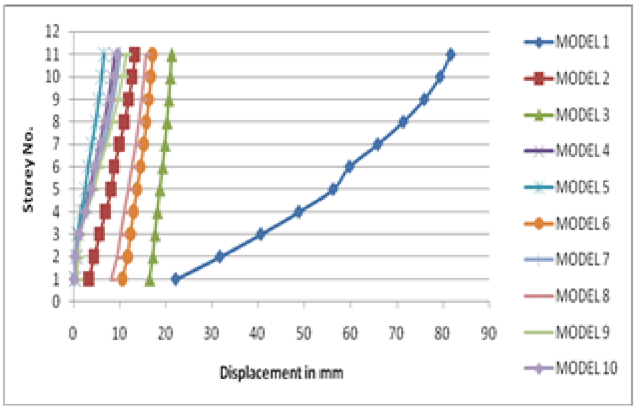


Fig. 5: Chart 3: Storey displacement Vs storey for different models along x direction by ESA

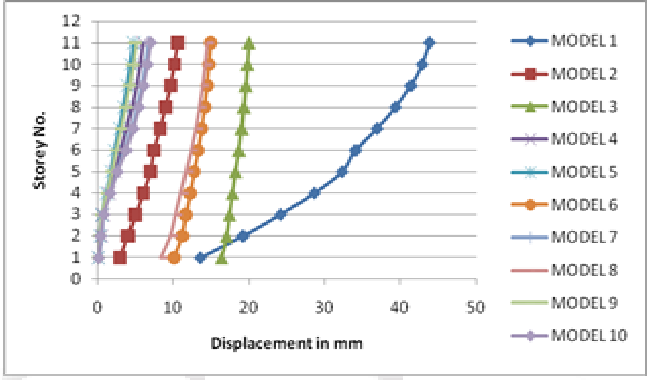


Fig. 6: Chart 4: Storey displacement Vs storey for different models along x direction by RSA

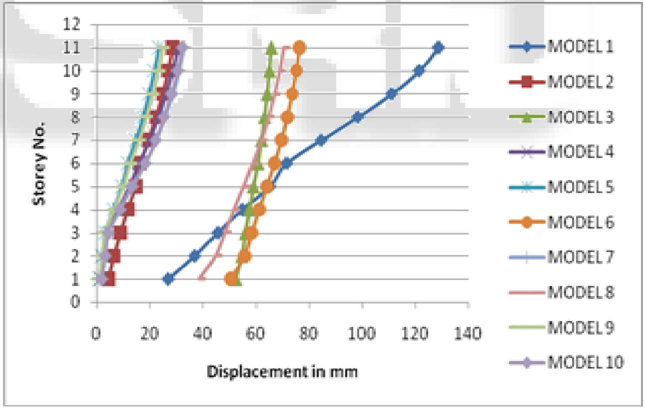


Fig. 7: Chart 5: Storey displacement Vs storey for different models along x direction by RSA

Storey	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7	MODEL 8	MODEL 9	MODEL 10
11	81.6212	13.34778	21.3165	8.9267	6.549	17.1251	10.098942	15.72577	11.4433	9.50467
10	79.2988	12.73635	21.0471	8.3333	6.0416	16.7763	9.485271	15.31722	10.6309	8.88415
9	75.8848	11.94758	20.7081	7.5751	5.4296	16.3338	8.684018	14.80343	9.62306	8.05758
8	71.3192	11.00658	20.3075	6.66513	4.7225	15.8071	7.714168	14.19224	8.43263	7.05535
7	65.792	9.952454	19.8676	5.64346	3.944	15.2259	6.636459	13.51059	7.10248	5.91921
6	59.6762	8.797299	19.3453	4.47186	3.0891	14.5186	5.307706	12.68359	5.58649	4.67287
5	56.1422	8.143253	18.7348	3.43986	2.454	13.7661	3.8482	11.8806	4.37774	3.97064
4	48.816	6.898893	18.1887	2.21103	1.5771	13.0221	2.44969	11.00884	2.79588	2.6239
3	40.5769	5.661419	17.6792	1.05579	0.747	12.3425	1.191706	10.21689	1.31752	1.27298
2	31.6942	4.438651	17.2079	0.94182	0.4105	11.7219	0.72045	9.43943	1.0148	0.38741

1	22.1192	3.2534	16.4716	0.4315	0.2099	10.5987	0.5982	8.131274	0.71042	0.11764

Table 4: Comparison of storey displacement between all models along x-direction by ESA

Storey	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7	MODEL 8	MODEL 9	MODEL 10
11	43.8846	10.6627	19.98662	5.918604	4.75925	14.9628	6.64569	14.47856	4.9992	6.98088
10	42.9041	10.2377	19.81484	5.542894	4.40961	14.7365	6.263672	14.19913	4.6587	6.5758
9	41.4497	9.69817	19.6052	5.062803	3.98402	14.4578	5.765104	13.85209	4.2361	6.04989
8	39.464	9.04792	19.3555	4.47893	3.48438	14.124	5.152385	13.43254	3.731	5.40706
7	36.9888	8.30285	19.07361	3.811907	2.92475	13.7459	4.457769	12.94926	3.1577	4.68098
6	34.1391	7.46205	18.72367	3.032246	2.29954	13.2659	3.578519	12.33551	2.493	3.78429
5	32.4169	6.97139	18.30091	2.336568	1.82918	12.7421	2.595987	11.71964	1.9569	2.68468
4	28.6803	6.00875	17.90529	1.503332	1.17736	12.1997	1.652659	11.02908	1.2511	1.72382
3	24.2667	5.01633	17.50821	0.716816	0.55728	11.6714	0.802519	10.36376	0.5889	0.8453
2	19.266	3.99932	17.1228	0.54352	0.30126	11.169	0.56148	9.673044	0.3248	0.41983
1	13.6055	2.9748	16.43884	0.114508	0.08925	10.1387	0.151404	8.385238	0.1006	0.16392

Table 5: Comparison of storey displacement between all models along x-direction by RSA

Storey	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7	MODEL 8	MODEL 9	MODEL 10
11	128.834	28.5439	65.8049	30.4589	23.260156	76.45685	32.6977	70.3827	25.06645	32.09213
10	121.546	26.9479	65.1244	28.5735	21.59599	75.21328	30.9191	68.8615	23.37566	30.34316
9	111.233	24.8163	64.2794	26.1692	19.581049	73.66409	28.6097	66.9463	21.28283	28.09829
8	98.4796	22.2423	63.27	23.2422	17.220782	71.80224	25.7556	64.6249	18.79319	25.33754
7	84.6839	19.3851	62.1387	19.8983	14.569888	69.69957	22.4943	61.9662	15.97461	22.17831
6	71.6315	16.3426	60.7555	15.9797	11.582156	67.05039	18.31	58.6309	12.7023	18.20062
5	65.3739	14.6935	59.1028	12.4528	9.305138	64.16452	13.557	55.3127	10.05051	13.22684
4	54.9282	11.7073	57.5952	8.16899	6.104028	61.22154	8.86503	51.6529	6.526435	8.741288
3	45.7061	8.95025	56.1408	3.98112	2.954547	58.40705	4.40714	48.2207	3.130717	4.404515
2	36.9994	6.46875	54.764	2.0054	1.8562	55.75706	3.1052	44.7492	2.04598	3.263
1	27.0228	4.36097	52.4892	1.2235	0.9562	50.55825	1.8629	38.6405	0.8536	1.8423

Table 6: Comparison of storey displacement between all models along x-direction by THA

Storey	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
11	0.002083	0.000456	0.000194	0.000539	0.000475	0.000355	0.000508	0.000435	0.000483	0.0005
10	0.002946	0.000609	0.000241	0.000687	0.000576	0.000443	0.00066	0.000547	0.000598	0.000641
9	0.003644	0.000735	0.000288	0.000836	0.000674	0.000532	0.000815	0.000663	0.000711	0.000789
8	0.003942	0.000816	0.000323	0.000955	0.000757	0.000601	0.000932	0.00076	0.000805	0.000903
7	0.003729	0.000869	0.000395	0.00112	0.000854	0.000757	0.001196	0.000953	0.000935	0.001136
6	0.003129	0.000825	0.000826	0.001763	0.001139	0.001443	0.002376	0.001659	0.001326	0.002487
5	0.002984	0.000853	0.000431	0.001224	0.000915	0.000841	0.001341	0.001046	0.001007	0.001282
4	0.002635	0.000788	0.000416	0.001197	0.0009	0.000804	0.001274	0.000981	0.00097	0.001239
3	0.002488	0.000709	0.000393	0.001137	0.000844	0.000757	0.001259	0.000992	0.000894	0.001258
2	0.00285	0.000602	0.00065	0.000089	0.000082	0.001485	0.00012	0.001745	0.0001	0.000101
1	0.002702	0.000436	0.005249	0.000031	0.000029	0.005056	0.000042	0.003864	0.000035	0.000035

Table 7: Comparison of storey drift between all models along x-direction by THA

Table 1 shows the time period is obtained by ETABS analysis, time period for model 2 reduces by 73.25% as compared to bare frame model 1. For model with intermediate soft storey i.e. models 3 increased by 51.62% is more than that of obtained from model 2.For models with shear walls i.e. model 4,5,6,7,8,9 and 10 time period reduced by 65.81%, 66.56%, 19.52%, 62.66%, 24.08%, 70.17% and 65.61% respectively as compared with model 3. Thus it can be clearly understand that from table 1 and fig 2, presence of brick infill and concrete walls considerably reduces the time period of building as shown in chart 1.

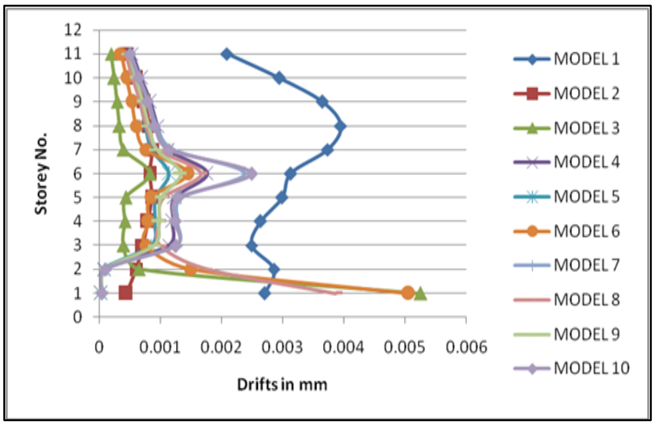


Fig. 8: Chart 6: Storey drift Vs storey for different models along x direction by THA

Table 2 shows comparison of highest values of seismic base shear of different models in which Model 9 (swastika shear wall at centre and L shaped shear wall at corners) yields the highest base shear value from all models (in x-direction and y-direction). Therefore it has been found that calculation of earthquake forces by considering building by ordinary frame will leads to underestimation of base shear (refer table 2, fig 3).

Table 3 shows the comparison of the storey acceleration values of all models in x and y-direction of all storeys by RSA, the acceleration values and are lower for the bare frame model as compare to the other models. When masonry infill stiffness taken into consideration, Model 2 (full brick infill excluding bottom storey) shows considerable increase in storey acceleration than model 1.It is observed that, the model with shear wall yields comparatively greater storey acceleration which is represented in chart 2

Table 4, 5 and 6 shows Model 1(bare frame) has highest storey displacement values in all different building models, model 2 (full brick infill) shows considerable reduction in storey displacement with a maximum reduction of 83.66% compared with model 1 and model 5 shows 91.92% reduction in displacement value compared with model 1 (refer table 4,5,6 and chart 3,4,5).Thus it can be concluded that addition of infill and concrete shear wall act as drift and displacement controlled elements in RC buildings.

Table 7 shows the comparison of the drift values of all the model in x-direction of all storeys by THA, from that it can be seen that the storey drift in all storey for models (with shear wall) has lower values as compare to that for models (without shear wall). When masonry infill stiffness taken into consideration, Model 2 (full brick infill) shows considerable reduction in storey drift. For model 3, drift is maximum at bottom storey and goes on reducing at storey 6 then it increases suddenly due to introduction of another soft storey (intermediate short service storey). It is observed that, the model with shear wall yields comparatively lesser storey drift. Hence it can be concluded that providing shear wall at corners in X and Y direction significantly reduces the drift in the storeys. Model 5 with C type of shear wall yield considerable lesser drift than other types of shear wall (refer table 7, chart 6).

V. CONCLUSIONS

- The soft story effect is less at intermediate location of the building. A service storey of lesser height can be safer for building at higher level.
- Fundamental time period decreases when the stiffness of masonry infill and concrete shear wall is considered.
- The storey drifts are found within the limit as specified by the code IS 1893(Part-1):2002.
- C shaped shear wall shows considerably lesser storey drift by THA method of analysis is considered.
- More than 50% reduction in storey displacement observed by introduction of different types of shear wall.
- C shaped shear wall shows considerably lesser storey displacement.
- The acceleration increases when effect of infill wall and shear walls are considered.
- Providing shear wall at all end corners of the building in X and Y direction significantly improves all parameters in the analysis.
- Seismic base shear is considerably more for masonry infill and shear wall models as compared with bare frame model.
- Consideration of stiffness of masonry infill and shear wall, greatly influences the overall structure.

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