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Seismic Performance Evaluation of Multi-Storeyed R C Framed Structural System with the Influence of Ground & Top Soft Storey

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ABSTRACT
Masonry infills are normally considered as non-structural elements and their stiffness contributions are generally ignored in practice. But they affect both the structural and non-structural performance of the RC buildings during earthquakes. RC frame building with open first storey is known as soft storey, which performs poorly during strong earthquake shaking. A similar soft storey effect can also appear at top storey level if a storey used as a service storey. Hence a combination of two structural system components i.e. Rigid frames and RC shear walls leads to a highly efficient system in which shear wall resist the majority of the lateral loads and the frame supports majority of the gravity loads. To study the effect of masonry infill and different soft storey level, 11 models of R C framed building were analyzed with two types of shear wall when subjected to earthquake loading. The results of bare frame and other building models have been compared, it is observed that model with swastika and L shape shear wall with core wall are showing efficient performance and hence reducing the effect of soft storey and also reducing the effect of water pressure in the top soft storey.
Keywords – bare frame, masonry infill, soft storey, shear wall

I. INTRODUCTION

There is growing responsiveness of multi-storey reinforced concrete structures, to accommodate growing population. Generally such structures have prismatic sections which are common in developing countries. In many countries situated in seismic regions, reinforced concrete frames are infilled fully or partially by brick masonry panels with or without openings. Although the infill panels significantly enhance both the stiffness and strength of the frame, their contribution is often not taken into account because of the lack of knowledge of the composite behavior of the frame and the infill. Therefore, we cannot simply neglect the structural action of infill walls particularly in seismic regions. Hence we should considered masonry infill panel as structural element. Shear walls are the main vertical structural elements with a dual role of resisting both the gravity and lateral loads. Advantages of Shear Walls in RC Buildings Properly designed and detailed buildings with shear walls have shown very good performance in past earthquakes. An Open ground storey building having only columns in the ground storey is known as soft storey. The presence of the soft storey in ground lead to severe damage during an earthquake. To minimize the effect of soft storey in ground and top storey of the building, swastika and L shape shear wall has been used. The main aim of the present study to know the effect of infill frame and influence of existence of ground and top soft storey. How the different shapes of shear walls reduces the effect of soft storey and how it can enhance the overall performance of the building.

II. DESCRIPTION OF STRUCTURAL MODELS

For the study 11 different models of an eleven storey building are considered the building has seven bays in X direction and five bays in Y direction with the plan dimension 28 m × 20 m and a storey height of 3.5 m each in all the floors. The building is kept symmetric in both mutually perpendicular directions in plan to avoid torsional effects. 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 27386 MPa and 3500 MPa 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 as 0.120m, 0.2 m and 0.23m respectively.

III. ANALYTICAL MODEL CONSIDERED FOR ANALYSIS

Model 1: Bare frame model, however masses of brick masonry infill walls (230mm thick) are included in the model.

Model 2: Building model has full brick masonry infill of 230mm thick in all the stories including ground storey and top storey.

Model 3: Building model has no brick masonry infill in ground storey and has full brick masonry infill of 230mm thick in upper stories.

Model 4: Building model has no brick masonry infill wall in storey (11th storey) and has full brick masonry infill in rest of the storeys.

Model 5: Building model has no brick masonry infill in ground storey, top storey (11th storey) and has full brick masonry infill in rest of all storeys.

Model 6: Building model has no brick masonry infill in ground and top storey. Further, swastika type of shear wall (200mm thick) is provided at corners.
Model 7: Building model is same as in model 6 and a concrete core (200mm thick) is provided at the centre.
Model 8: Building model is same as model 5.further, L shaped shear wall (200mm thick) is provided in both x and y direction.
Model 9: Building model is same as model 8 and a core wall (200mm thick) is provided at the centre.
Model 10: Building model is same as model 6. Further, including water pressure at the top soft storey.
Model 11: Building model is same as model 8. Further, including water pressure at the top soft storey.

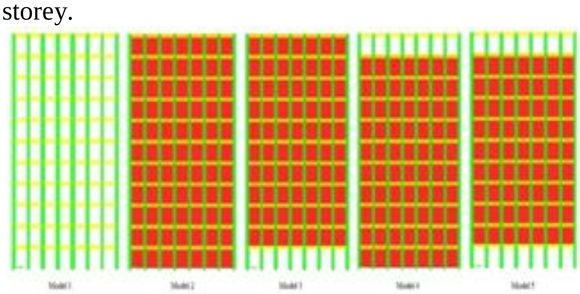

Fig 1 **:** Eleven of various building models

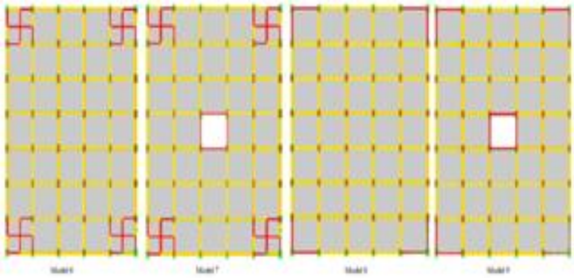

Fig 2 **:** Plan of various building models

IV. MODELING OF FRAME MEMBERS, MASONRY INFILL WALL AND SHEAR WALL

The frame elements are modeled as beam elements. The masonry infill walls are modeled as four nodded quadrilateral shell element of uniform thickness 0.23 and shear wall is modeled as pier element.

V. RESULTS AND DISCUSSION

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, Base shear, storey displacement and storey drifts, the tables and figures are shown below.

Table 1**:** Comparison of Base shear with IS code, Linear static analysis and Response spectrum analysis for various building models

Model No.	Base Shear (KN)					
	Is Code 1893-2002		Linear Static Analysis (Etabs)		Response Spectrum Analysis (Etabs)	
	Long	Tran	Long	Tran	Long	Tran
1	4931	4931	8385	8385	4942	4256
2	8899	7529	16789	16789	13534	13360
3	8730	7386	16433	16433	14744	13808
4	8561	7243	16077	16077	12924	12700
5	8392	7100	15720	15720	14138	13665
6	8869	7503	16540	16540	13678	13488
7	8848	7486	16385	16385	13423	13195
8	8429	7132	15731	15731	13332	13246
9	8409	7114	15591	15591	12996	12823
10	9220	7801	16596	16596	13760	13581
11	8781	7429	16367	16367	13843	13752

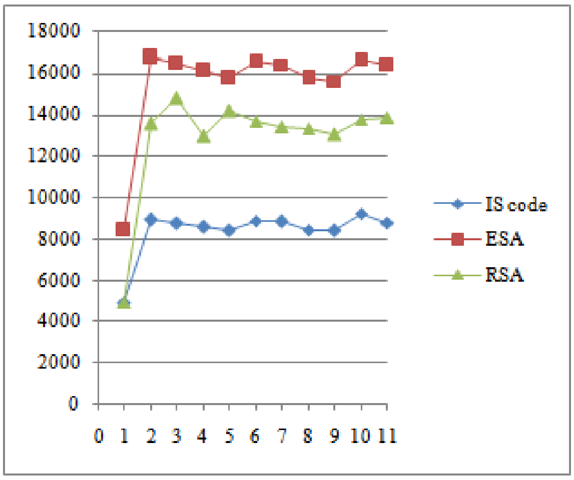

Fig 3: Comparison of base shear between IS code method, ESA and RSA for various building models

From table 1 and Fig 3 it is clearly evident that the base shear obtained from IS code procedure is least as compare with equivalent static analysis and response spectrum analysis .response spectrum analysis shows the curve fluctuate very significantly lies in between IS code and equivalent static analysis apart from bare frame model all the models are in a straight line obtained from IS code method and equivalent static analysis.

Table 2: comparison of time period between IS code and ETAB

Fundamental time period(Sec)				
	Is Code 1893-2002		Etabs Analysis	
Model No	Long	Tran	Long	Tran
1	1.159	1.159	1.7464	1.7464
2	0.655	0.774	0.4587	0.4587
3	0.655	0.774	0.6388	0.6388
4	0.655	0.774	0.4375	0.4375
5	0.655	0.774	0.6166	0.6166
6	0.655	0.774	0.4049	0.4049
7	0.655	0.774	0.3855	0.3855
8	0.655	0.774	0.4238	0.4238
9	0.655	0.774	0.3977	0.3977
10	0.655	0.774	0.4177	0.4177
11	0.655	0.774	0.4419	0.4419

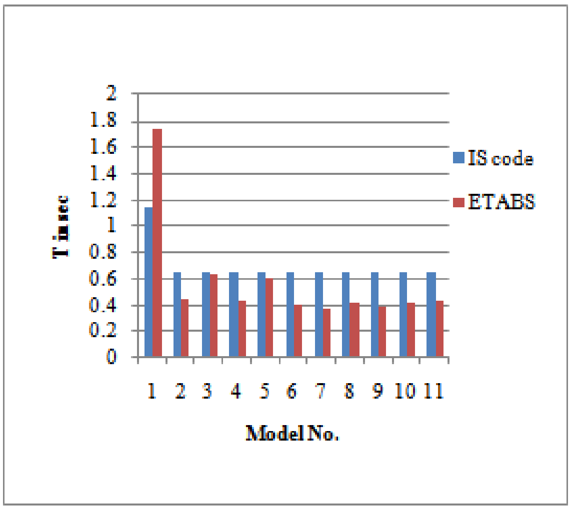

Fig 4: Model Vs Time period for different building model along longitudinal direction

When the structural action of infill is taken the fundamental natural time got reduced 30% when compare with bare frame model shown in table1,it also shows natural time period for bare frame model from ETABS is 50.64% more than the IS code method .time period of structure increases when soft storey is at ground level and get decreases as it moves up.

STOREY DRIFT											
	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7	MODEL 8	MODEL 9	MODEL 10	MODEL 11
STOREY	**Ux**	**Ux**	**Ux**	**Ux**	**Ux**	**Ux**	**Ux**	**Ux**	**Ux**	**Ux**	**Ux**
11	0.703	0.175	0.183	0.338	0.341	0.216	0.194	0.226	0.2	0.231	0.239
10	1.103	0.226	0.232	0.208	0.213	0.184	0.172	0.18	0.171	0.212	0.202
9	1.533	0.269	0.274	0.239	0.244	0.206	0.192	0.205	0.193	0.22	0.226
8	1.909	0.301	0.305	0.274	0.278	0.231	0.214	0.232	0.217	0.243	0.251
7	2.207	0.322	0.326	0.298	0.302	0.251	0.232	0.252	0.234	0.261	0.269
6	2.424	0.334	0.338	0.312	0.315	0.263	0.242	0.264	0.245	0.272	0.28
5	2.562	0.336	0.34	0.316	0.319	0.267	0.246	0.269	0.248	0.275	0.283
4	2.61	0.329	0.334	0.312	0.315	0.264	0.242	0.266	0.244	0.27	0.279
3	2.523	0.315	0.316	0.299	0.3	0.25	0.228	0.254	0.232	0.26	0.266
2	2.158	0.295	0.358	0.281	0.341	0.236	0.211	0.25	0.221	0.269	0.261
1	1.08	0.234	0.791	0.223	0.756	0.238	0.198	0.32	0.247	0.266	0.333

Table 3: Storey Drifts

STOREY DISPLACEMENT											
	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7	MODEL 8	MODEL 9	MODEL 10	MODEL 11
STOREY	Ux	Ux	Ux	Ux	Ux	Ux	Ux	Ux	Ux	Ux	Ux
11	72.841	10.971	13.286	10.854	13.038	9.072	8.248	9.513	8.582	9.39	10.111
10	70.38	10.357	12.647	9.669	11.844	8.323	7.579	8.723	7.883	8.593	9.275
9	66.521	9.567	11.835	8.941	11.097	7.685	6.982	8.092	7.284	7.915	8.568
8	61.156	8.627	10.876	8.106	10.245	6.969	6.315	7.375	6.608	7.156	7.778
7	54.474	7.574	9.808	7.146	9.27	6.166	5.57	6.563	5.85	6.316	6.9
6	46.75	6.447	8.666	6.102	8.214	5.294	4.764	5.682	5.031	5.415	5.958
5	38.264	5.279	7.484	5.011	7.111	4.378	3.921	4.757	4.175	4.476	4.979
4	29.298	4.104	6.295	3.904	5.993	3.446	3.065	3.817	3.307	3.526	3.988
3	20.165	2.952	5.128	2.813	4.889	2.527	2.223	2.886	2.452	2.592	3.011
2	11.333	1.85	4.021	1.766	3.839	1.655	1.429	1.995	1.639	1.707	2.08
1	3.781	0.817	2.769	0.781	2.647	0.831	0.693	1.12	0.866	0.883	1.166

Table 4: Storey Displacement

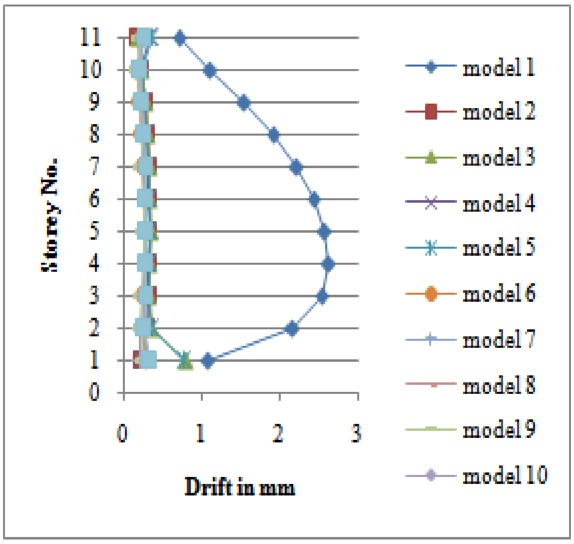

Fig 5: comparison of storey drift for different building models

When masonry infill stiffness taken into consideration, Model 2 shows considerable reduction in storey drift .Model3 storey drifts is increase by 57.52% as compared with model 2.when shear wall is added either in swastika or L shape the storey drift are considerably reduced hence provision of concrete wall will reduce the soft storey effect [refer Table 3 and Fig 5].

From [Fig 6 and Table 4] shows bare frame model has highest displacement in all the building models.

When masonry stiffness taken into consideration model 2 shows considerable reduction in displacement .The displacement value linearly vary from ground to top floor in both the directions. When comparison is made for model 2, model 3, model 4, model 5 with the bare frame model 1 , the percentage of reduction in displacement are 84.93%, 81.76%, 85.09%, 82.09%. Similarly When a comparison is made for different building models with shear wall .i.e. model6, model7, model8, model9, , model10 and model11. the percentage of reduction in storey displacement for top stories are 87.54%,88.67%, 86.93%, 88.21%,87.10% and 86.11% as compare with bare frame.

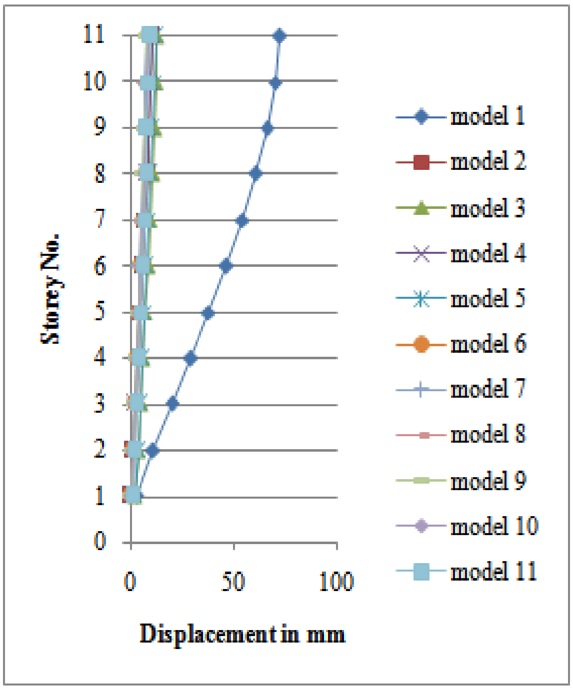

Fig 6: Storey Vs Displacement for different building models

4.1 COMPARISON BETWEEN ETABS AND SAP2000

A comparative study has been made for ETABS9.7 non-linear and SAP2000v15, for comparison all 11 building models have been analyzed for Equivalent Static method and Response Spectrum method.

The parameters such as fundamental time period, Base shear and Storey Displacement have been compared for each different building model.due to space restrictions in this paper the values are not shown, only fig has been shown below

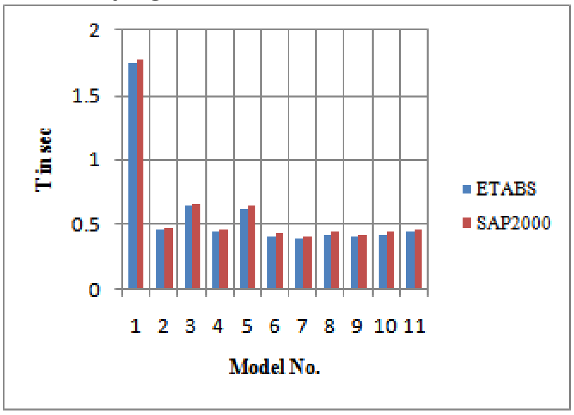

Fig 7: Model Vs Time period for different building models

From the above Fig7 it is observed that the values of time period obtained from ETABS analysis for infill panel as compared with values of time period obtained by SAP2000 having very small marginal difference for all building models. it can be seen that Sap2000 gives some higher values of base shear for equivalent static analysis for model 1 to 11 with percentage increment 1.21%,3.37%, 3.48%, 3.52%, 3.59%, 5.39%, 4.81%, 3.33%, 3.44%, 5.10%, 3.57%, 4.61%, 3.21% as compare with ETABS.

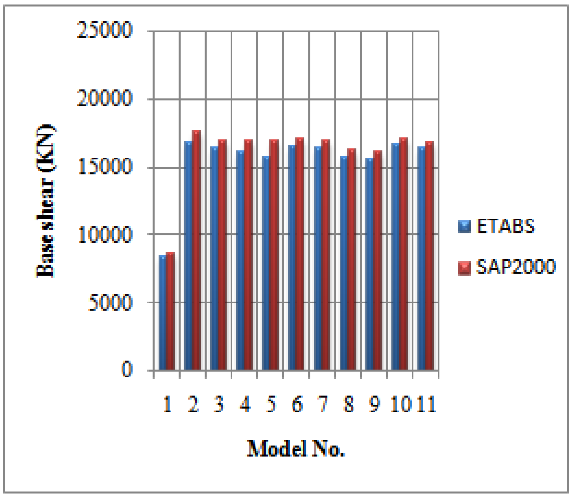

Fig 8: Model Vs Base shear for different models along longitudinal direction

Seismic base shear for various models obtained from equivalent static analysis (with ETABS) and from equivalent static analysis (with SAP2000). From the Fig 8 it can be observed that the seismic base shear for all the models has smaller values for models (with ETABS) as compare to that of the values for models (with sap2000).the reduced percentage from model 1 to model 11 are 5%, 3%, 5%, 7%, 3%, 3%, 3%, 3%, 3%, 3% and 3% respectively. Similarly in case of value obtained from Response spectrum analysis (with ETABS) and Response spectrum analysis (with SAP2000).

VI. CONCLUSION

1. IS 1893-2002 gives empirical formulae for bare frame and for fully infill frame but it does not gives any empirical relationship to determine the fundamental natural time period for soft storey building, Therefore the software like ETABS and SAP2000 must be used to determine the fundamental time period.
2. IS 1893-2002 procedure gives considerably least base shear values, as compared with ETABS for equivalent static and dynamic analysis.
3. Building with ground and top soft storeys shows similar effect as ground soft storey, when subjected to seismic loading. The effect of ground and top soft storey got reduce when we add shear wall in different shapes such as swastika and L in the corner of the building in X and Y direction, hence provision of shear wall in swastika and L- shape canl allow parking facility at bottom storey and can allow top soft storey as a service storey.
4. When we add water pressure in the top soft storey of analytical model10, the seismic behavior of analytical model10 is as similar as analytical model6.therefore effect of water pressure at top soft storey is very much less during seismic lateral loading.
5. Storey drifts and storey displacement considerably reduces when the structural action of masonry infill and shear wall is considered.
6. A comparison is made between ETABS 9.7 and SAP2000V15, the results are obtained for fundamental natural time period, seismic base shear and joint displacement are approximately same hence modeling and analyzing in either of the structural program can easily done.

From the above results it can be seen that the presence of masonry infill wall and shear wall effect the overall behavior of the structure when subjected to lateral seismic loading. Hence their stiffness contribution should be taken in analysis and design procedures.

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