Lateral Load Analysis of Shear Wall and Concrete Braced Multi-Storeyed R.C Frame with the Effect of Ground Soft Storey

Ismail Sab[1] Prof .S.M. Hashmi[2]
[1]P.G student (Structural Engineering) [2]Associate professor
[1,2]Department of Civil Engineering
[1,2]K B N C E Gulbarga-585104

Abstract— Generally RC framed structures are designed without regards to structural action of masonry infill walls present. Masonry infill walls are widely used as partitions. These buildings are generally designed as framed structures without regard to structural action of masonry infill walls. They are considered as non- structural elements. RC frame building with open first storey is known as soft storey, which performs poorly during strong earthquake shaking. Past earthquakes are evident that collapses due to soft storeys are most often in RC buildings. In the soft storey, columns are severely stressed and unable to provide adequate shear resistance during the earthquake. . In this study, 3D analytical model of twelve storeyed buildings have been generated for different buildings Models and analyzed using structural analysis tool 'ETABS'. To study the effect of infill, ground soft, bare frame and models with ground soft having concrete core wall and shear walls and concrete bracings at different positions during earthquake; seismic analysis using both linear static, linear dynamic (response spectrum method) has been performed. The analytical model of the building includes all important components that influence the mass, strength, stiffness and deformability of the structure.

Key words: Concrete bracing, Masonry infill, shear wall, soft storey

I. INTRODUCTION

In the present practice of structural design in India, masonry infill panels are treated as non- structural element and their strength and stiffness contribution are neglected. In fact the presence of infill wall changes the behavior of the frame action in to truss action, thus changing the lateral load transfer mechanism. Performance of buildings in the past earthquakes clearly illustrates that the presence of infill walls has significant structural implications. Therefore, we cannot simply neglect the structural contribution of infill walls particularly in seismic regions where, the frame–infill interaction may cause significant increase in both stiffness and strength of the frame in spite of the presence of openings.

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. It has become increasingly common to combine the moment resisting framed structure for resisting gravity loads and the RC shear walls for resisting lateral loads in tall building structures. The first approach is realized with the introduction of steel and concrete braces in steel structures and in RC structures. However, the use of steel bracing and concrete barcing systems for RC buildings may have both practical and economic advantages. In particular, this system offers advantages such as the ability to accommodate openings and the minimal added weight of the structure. Furthermore, if it is realized with external steel systems (External Bracing) the minimum disruption to the full operationally of the building is obtained.

The consequence of the presence of a soft storey either in the ground storey or in the upper storey, may lead to a dangerous sway mechanism in the soft storey due to formation of plastic hinges at the top and bottom end of the columns, as these columns are subjected to relatively large cyclic deformations.

The main Objectives of the present study is

- To know the effect of infill in the frame.
- To know the effect of concrete shear wall and concrete bracings.
- To know the effect of ground soft storey.
- And also to know how shear wall and concrete bracings system helps to reduce the effect of soft ground storey.

II. DESCRIPTION OF STRUCTURAL MODEL

For the study 8 different models of twelve (12) storey building are considered the building has five bays in X direction and five bays in Y direction with the plan dimension 25 m × 20 m and a storey height of 3.5 m each in all the floors with ground storey as 4m high.The building is kept symmetric in both orthogonal directions in plan to avoid torsional response. 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 0.125m, 0.2 m and 0.23m respectively.

III. MODEL CONSIDERED FOR ANALYSIS

Following eight (8) models are analyzed in ETABS9.7 as special moment resisting frame using equivalent static analysis, response spectrum analysis.

A. Model 1:

Building modelled as bare frame. However, masses of the walls are included.

B. Model 2:

Full infill masonry model, building has one full brick masonry wall of 230mm thick in all the storey including the ground storey.

C. Model 3:

Building has one full brick infill masonry wall in all storeys except ground storey

D. Model 4:

Building model is as same as model 3, Further L type R.C shear walls (200mm thick) is provided at the corners in X and Y direction and a core wall at centre.

E. Model 5:

Building model is as same as model 3, Further C type R.C shear walls (200mm thick) is provided in mid bay in longitudinal and transverse direction with central core wall.

F. Model 6:

Building model is as same as model 3, Further Planar R.C shear walls (200mm thick) is provided in mid bay in longitudinal and transverse direction with central core wall.

G. Model 7:

Building model is as same as model 3, further concrete X bracings (230mm X 230mm thick) is provided at corners in longitudinal and transverse direction with central core wall.

H. Model 8:

Building model is as same as model 3, further concrete X bracings (230mmX230mm thick) in C shaped is provided in mid bay in longitudinal and transverse direction along with central core wall.

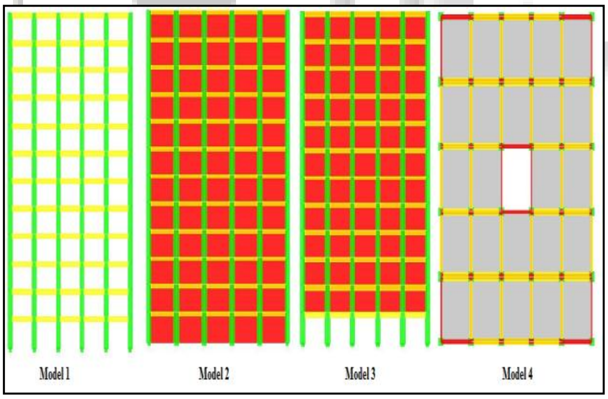

Fig. 1: Plan and Elevation of different building models

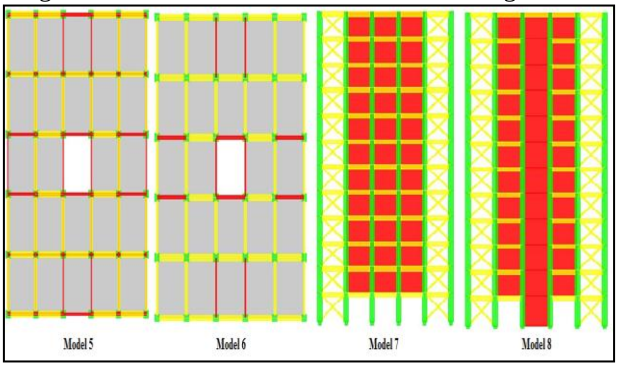

Fig. 2: Plan and Elevation of different building models

IV. MODELING OF FRAME MEMBERS, AND SHEAR WALL

The frame elements are modelled as beam elements, slab is modelled as rigid (in-plane) diaphragm and shear wall is modelled with Mid-Pier frame.

V. MODELLING OF MASONRY INFILL IN ETABS

A. As Four Nodded Quadrilateral Shell Element

In this technique the masonry infill is modelled as four nodded quadrilateral shell element (with in-plane stiffness) of uniform thickness of 0.23mm. The four-node element uses an Iso-parametric formulation that includes both rotational and translational degrees of freedom. (Ref fig 1)

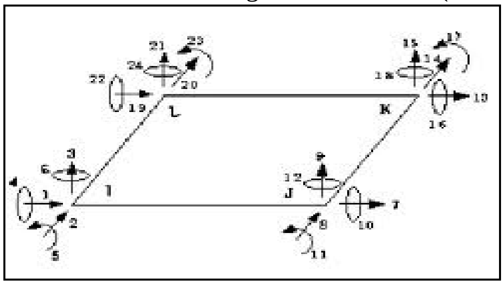

Fig. 3: Four Nodded Quadrilateral Element.

VI. ANALYSIS OF THE BUILDING

Equivalent static and response spectrum analyses has been performed as per IS 1893 (part-1) 2002 for each model using ETABS 9.7 software. Lateral load calculation and its distribution along the height is done.

VII. FUNDAMENTAL TIME PERIOD

Fundamental time period(Sec)				
	Is Code 1893-2002		ETABS Analysis	
Model No.	Longi	Trans	Longi	Trans
1	1.25	1.25	1.6541	1.6541
2	0.765	0.855	0.5482	0.5482
3	0.765	0.855	0.7610	0.7610
4	0.765	0.855	0.4684	0.4684
5	0.765	0.855	0.4493	0.4493
6	0.765	0.855	0.4925	0.4925
7	0.765	0.855	0.5537	0.5537
8	0.765	0.855	0.5412	0.5412

Table 1 Comparison of time period between IS code method and using ETABS for various models.

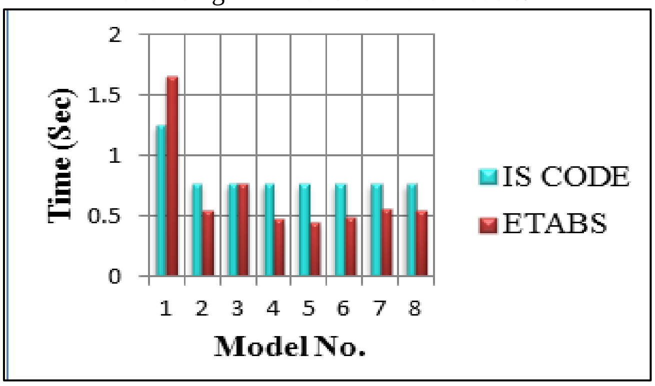

Fig. 4: Model Vs Time period for different building models along longitudinal direction

VIII. COMPARISON OF BASE SHEAR

Model no	Base shear (KN) IS Code	ESA (ETABS)	RSA (ETABS)
	Longitudinal	Longitudinal	Longitudinal
1	6823.153	5443.6	4707.35
2	11158.82	16322.65	12953.49
3	10956.12	15308.94	14113.05
4	10887.21	15552.04	12663.31
5	10870.68	15490.64	12402.31
6	10709.16	15564.35	12563.59
7	10643.07	15026.76	12523.01
8	10709.9	14724.61	12169.37

Table 2: Comparison of Base shear with IS Code Equivalent Static (ESA) and Response Spectrum (RSA) Analysis Along longitudinal direction..

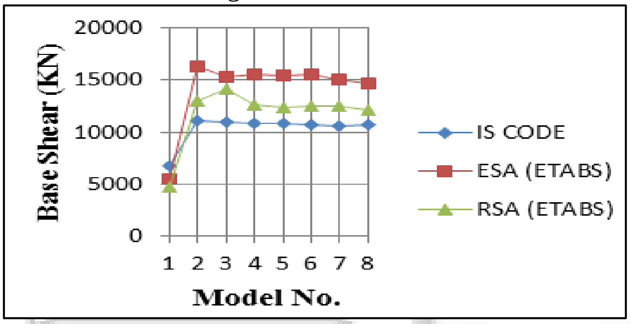

Fig. 5: Comparison of Base shear with IS Code Equivalent Static (ESA) and Response Spectrum (RSA) Analysis Along longitudinal direction.

Model no	Base shear (KN) IS Code	ESA (ETABS)	RSA (ETABS)
	Transverse	Transverse	Transverse
1	6823.153	5443.6	4370.37
2	9996.442	16322.65	12922.27
3	9814.862	15308.94	11019.75
4	9753.128	15552.04	12636.01
5	9738.313	15490.64	12305.14
6	9593.622	15564.35	12502.48
7	9534.417	15026.76	12458.91
8	9594.286	14724.61	12155.35

Table 3: Comparison of Base shear with IS Code Equivalent Static (ESA) and Response Spectrum (RSA) Analysis along Transverse direction.

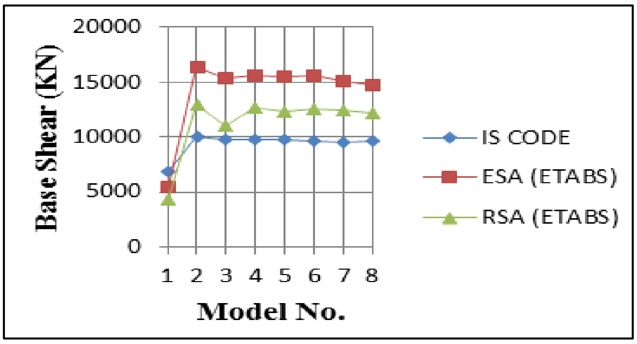

Fig. 6: Comparison of Base shear with IS Code Equivalent Static (ESA) and Response Spectrum (RSA) Analysis along Transverse direction.

IX. STOREY DISPLACEMENT

	Storey Displacement (mm)							
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Storey	Ux	Ux	Ux	Ux	Ux	Ux	Ux	Ux
12	51.12568	15.10712	18.36491	10.8104	10.11074	11.77792	14.60917	14.49587
11	49.65321	14.22188	17.47607	10.15361	9.443932	11.0241	13.72091	13.61351
10	47.34899	13.16141	16.42282	9.395959	8.691142	10.16889	12.69834	12.59627
9	44.1638	11.95009	15.228	8.544747	7.859417	9.219779	11.55866	11.46096
8	40.20908	10.62554	13.92694	7.618002	6.965287	8.195926	10.33049	10.23573
7	35.63212	9.22406	12.55368	6.63711	6.028487	7.120201	9.043543	8.950096
6	30.57952	7.781117	11.14151	5.625174	5.070427	6.017236	7.727936	7.63413
5	25.18699	6.330828	9.722437	4.605987	4.113235	4.912216	6.413255	6.317573
4	19.58092	4.905631	8.327085	3.603777	3.179527	3.830527	5.128249	5.029506
3	13.89394	3.536017	6.981985	2.643217	2.292535	2.7977	3.899873	3.7975
2	8.320057	2.250942	5.738683	1.753727	1.479275	1.843675	2.762285	2.655938
1	3.294716	1.073084	4.321935	0.942563	0.754614	0.97603	1.668907	1.56602

Table 4: Storey Displacement for various building models along longitudinal direction

X. STOREY DRIFT

	Storey Drift (mm)							
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Storey	Ux	Ux	Ux	Ux	Ux	Ux	Ux	Ux
12	0.421	0.253	0.254	0.188	0.191	0.215	0.254	0.252
11	0.658	0.303	0.301	0.216	0.215	0.244	0.292	0.291
10	0.91	0.346	0.341	0.243	0.238	0.271	0.326	0.324
9	1.13	0.378	0.372	0.265	0.255	0.293	0.351	0.35
8	1.308	0.4	0.392	0.28	0.268	0.307	0.368	0.367
7	1.444	0.412	0.403	0.289	0.274	0.315	0.376	0.376
6	1.541	0.414	0.405	0.291	0.273	0.316	0.376	0.376
5	1.602	0.407	0.399	0.286	0.267	0.309	0.367	0.368
4	1.625	0.391	0.384	0.274	0.253	0.295	0.351	0.352
3	1.593	0.367	0.355	0.254	0.232	0.273	0.325	0.326
2	1.436	0.337	0.405	0.232	0.207	0.248	0.312	0.311
1	0.824	0.268	1.08	0.236	0.189	0.244	0.417	0.392

Table 5: Storey Drifts for various building models

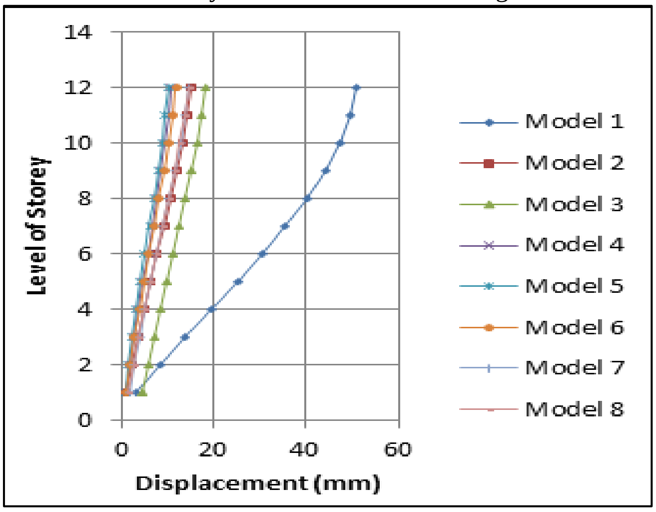

Fig. 7: Comparison of storey Displacement for different building models along longitudinal direction

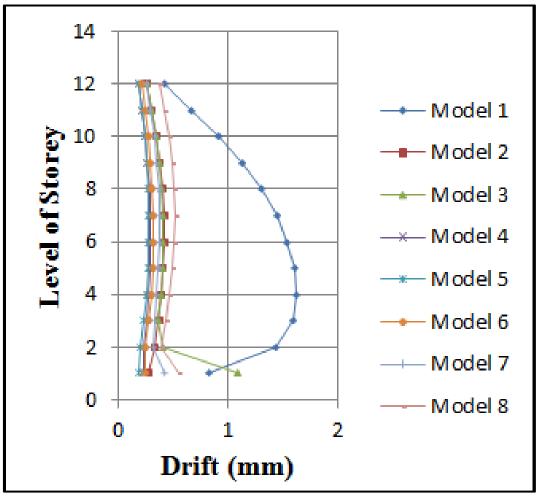

Fig. 8: Comparison of storey drift for different building models along longitudinal direction

XI. RESULTS AND DISCUSSIONS

It is observed that the time periods obtained by IS code and by ETABS analysis are differing. The table shows natural period for bare frame model from ETABS is 24.4% is more than the IS code method. For models with soft storey i.e. models 3 obtained from ETABS are more than that of obtained from IS code method. for models with shear walls i.e. model 4,5, and 6 time period obtained from ETABS is reduced by 38.8%, 41.26% and 35.62% respectively as compared with IS code procedure. For concrete bracings models i.e. Model 7 and 8 the time period obtained by ETABS is reduced by 27.62% and 29.25% as compared with time period obtained by Is Code procedure. For soft storey Model the fundamental natural time period is increased by 27.96% in case of EATBS analysis when compared with full infill brick model. [Ref table 1 and Fig 4]

seismic base shear for various models are obtained from IS Code ESA(ETABS) and RSA (ETABS) .From the table it can be known that the seismic base shear for all models except model 1 has larger values for models. The increased percentage for models from 2 to 8 are 66.65%, 64.45%, 65.0%, 64.85%, 65.0%, 63.77% and 63.03% respectively in ESA (ETABS). Similarly in case of RSA .the percentage of increased for models from 2 to 8 are63.65%, 66.64%, 62.83%, 62.05%, 62.53%, 62.41%, and 61.13% respectively .Hence it can be concluded that masonry infill has got structural importance and will impart considerable strength and stiffness to the building structures. [Ref table 2and 3 Fig 5 and 6]

Model 1 shows highest storey drift then the other models. When masonry infill stiffness taken into consideration, Model 2 (full brick infill) shows considerable reduction in storey drift, For model 3(Ground soft storey), The storey drift is increased by 75.18% in case of ESA and 78.73% in case of RSA as compared with full in filled model at storey 1along longitudinal direction. Also it is observed that models with concrete shear wall core wall and concrete bracings gives lesser storey drift, For example model4, model5, model6, model7 and model8, the percentage of reduction in storey drift are 82.09%, 83.2%, 80.6%, 76.86% and 76.86% for ESA (ETABS) and 83.8%, 85.06%, 82.7%, 79.13% and 79.05% for RSA (ETABS) along longitudinal direction as compared with bare frame model. [Refer table 5 Fig 8].

Model 1(bare frame) model shows highest storey displacement values in all different building models model 2 (full brick infill) shows considerable reduction in storey displacement. When a comparison is made for building model 2 and model3with bare frame model, the percentage of reduction in storey displacement for top stories are 70.45% and 64.20% in case of ESA and 71.26% and 60.42% in case RSA respectively along longitudinal direction. Also it is observed that the storey displacement is considerably reduced for different models with concrete core, shear walls and Different bracings systems. When a comparison is made for different building models with shear wall and bracings systems .i.e. model4, model5, model6, model7 and model8. the percentage of reduction in storey displacement for top stories are 78.86%, 80.30%, 77.0%, 71.15% and 71.64% respectively in case of ESA(ETABS) and 78.95%, 80.57%, 77.2%, 71.2% and 71.5% respectively in case of RSA(ETABS) in longitudinal direction. And the some variation is there in transverse direction. [Refer table 4, Fig 7]

Thus it can be concluded that addition of infill and concrete shear wall considerably decreases drift and displacement in RC buildings

XII. CONCLUSIONS

- Fundamental natural period decreases when effect of infill wall, concrete shear wall and concrete bracings are considered.
- As the soft stories Exist at Ground storey, the fundamental time period of the structure is increases; hence existence soft storey can make the structure to be flexible in nature
- Seismic base shear considerably more for masonry infill, shear wall and Concrete bracings models as compared with bare frame model. Hence consideration of masonry infill stiffness, shear wall and Concrete bracings increases Strength of the structure.
- The presence of masonry infill influences the overall behaviour of structures when subjected to lateral forces. Joint displacements and storey drifts are considerably reduced while contribution of infill brick wall is taken into account.
- When Shear wall and concrete bracings are compared in the form of lateral load resisting element, both system are giving desirable results, depending upon the importance of design and architectural requirements they can be incorporated in the building.
- X concrete bracings can be a good solution for managing ground soft storey when they are located at the periphery of plan in longitudinal and transverse direction.
- Models with soft stories have got highest storey drift values at soft stories levels, which leads to dangerous sway mechanism. Therefore providing shear wall is essential so as to avoid soft storey failure.

- The presence of concrete core wall at the centre has not affected much on the overall behaviour of the structure when subjected to lateral forces, as compared to other models like shear wall at corners.
- Shear wall at outer periphery are showing great performance during seismic loading.

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