Seismic Evaluation of Multistorey Building with the Effect of Ground Soft Storey

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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. This research deals with multistoried buildings with open (soft) ground floor are inherently vulnerable to collapse due to earthquake load, their construction is still widespread in the developing nations. 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) as well as non-linear static (pushover) has been performed. The deflections at each storey level have been compared by performing equivalent static, response spectrum method as well as pushover method. Pushover analysis has also been performed to determine capacity, demand and performance level of the considered building models. From the above studies it has been observed that non-linear pushover analysis provide good estimate of global as well as local inelastic deformation demands and also reveals design weakness that may remain hidden in an elastic analysis and also the performance level of the structure. Models with shear wall and concrete bracings are showing efficient performance during Sever Earthquake loading.

Key words: RC Frame, Shear Wall, Soft Storey, ETABS

I. INTRODUCTION

The capacity of structural members to undergo inelastic deformations governs the structural behavior and damageability of multi-storey buildings during earthquake ground motions. From this point of view, the evaluation and design of buildings should be based on the inelastic deformations demanded by earthquakes, besides the stresses induced by the equivalent static forces as specified in several seismic regulations and codes. Although, the current practice for earthquake-resistant design is mainly governed by the principles of force-based seismic design, there have been significant attempts to incorporate the concepts of deformation-based seismic design and evaluation into the earthquake engineering practice. In general, the study of the inelastic seismic responses of buildings is not only useful to improve the guidelines and code provisions for minimizing the potential damage of buildings, but also important to provide economical design by making use of the reserved strength of the building as it experiences inelastic deformations. In recent seismic guidelines and codes in Europe and USA, the inelastic responses of the building are determined using nonlinear static methods of analysis known as the pushover methods. 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 Multi-Storeyed Structures. The different lateral load resisting systems used in Multi-Storeyed building are: 1.Bare frame 2.Brace frame 3.Shear wall frame. Because of this metro cities which are very thickly populated. Availability of land goes on decreasing and land cost also increases. To overcome this problem the use of multi-storeyed buildings is must. But such provisions increases self-weight and live load along with earthquake forces.

II. DISCRIPTION OF STRUCTURAL MODELS

In this study 8 different models has taken for analysis, the building has 5 bays in X direction and 5bays in Y direction, the plan layout is kept the same for all the models. Each building model is of 12 storeys. The height of each storey is 3.5m for all the different building models. The building is considered to be located in seismic zone V .In seismic weight calculations, 50% of floor live load is considered. Material Properties:- Young's modulus of (M30) concrete(E) 27.386×10^6 KN/m²,Density of Reinforced Concrete is 25KN/m³,modulus of elastisity of masonry 3500×10^3 KN/m²,Density of brick masonry is 20kN/m³,Assumed Floor finishes 1.5kN/m²,Imposed loads 3.5KN/m² Member properties:- Thickness of Slab is 0.125m,Column size(0.5m x 0.9m),Beam size(0.4m x 0.6m),Thickness of wall 0.23m,Thickness of concrete wall 0.20m.

III. DISCRIPTION OF ANALYTICAL MODEL CONSIDERED FOR ANALYSIS

The description of each building model is given below as fallows.

1) Model 1: Building modeled as bare frame. However, masses of the walls are included.
2) Model 2: Full infill masonry model, building has one full brick masonry wall of 230mm thick in all the storey including the ground storey.
3) Model 3: Building has one full brick infill masonry wall in all storeys except ground storey
4) 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.
5) 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.
6) 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.

7) 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.
8) 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.

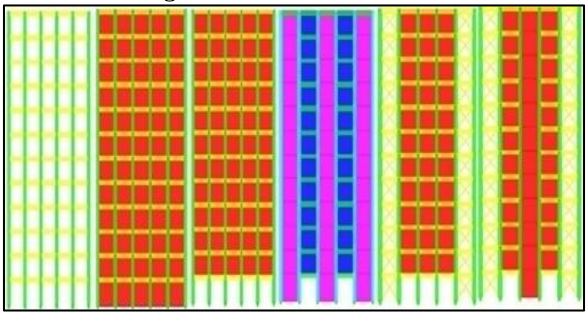

Fig. 1: Elevation of Different Building Models

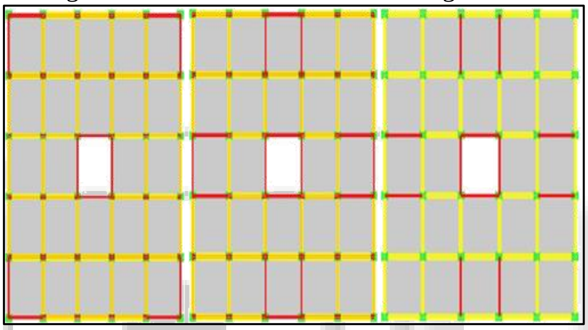

Fig. 2: Plan of Different Building Models

IV. RESULT AND DISCUSSION

	IS CODE Method		ETABS Analysis	
Model No	Longitudinal	Transverse	Longitudinal	Transverse
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 Fundamental natural time period and ETABS

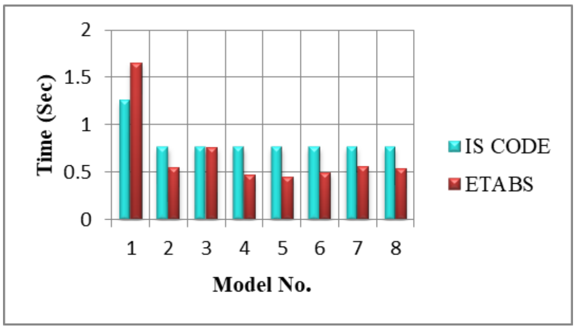

Fig. 3: Model Vs Time period for different building models along longitudinal direction

The table 1 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% and29.25% as compared with time period obtained by Is Code procedure.

	IS CODE Method	ESA (ETABS)	RSA (ETABS)
Model No	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 seismic base shear IS code, ESA (ETABS) and RSA (ETABS)

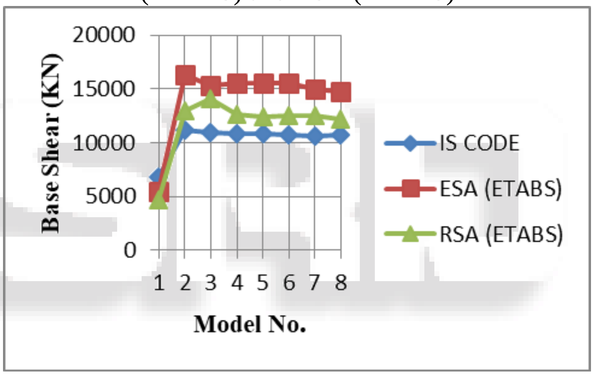

Fig 4: Model Vs Base shear for different models along longitudinal direction.

Table 2 represents the seismic base shear for various models are obtained from IS Code ESA(ETABS) and RSA (ETABS) .From the table it can be know that the seismic base shear for all models except model 1 has larger values for other 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. From fig 4 it can be concluded that IS code procedure for linear static analysis will give substantially less results of base shear as compared with base shear obtained by ESA (ETBAS) and RSA (ETABS) procedure.

STOREY	MODEL 1		MODEL 2		MODEL 3		MODEL 4		MODEL 5		MODEL 6		MODEL 7		MODEL 8	
	ESA (UX)	RSA (UX)	ESA (UX)	RSA (UX)	ESA (UX)	RSA (UX)	ESA (UX)	RSA (UX)	ESA (UX)	RSA (UX)	ESA (UX)	RSA (UX)	ESA (UX)	RSA (UX)	ESA (UX)	RSA (UX)
12	51.12	35.87	15.1	10.31	18.36	14.19	10.81	7.54	10.11	6.96	11.77	8.18	14.6	10.35	14.49	10.23
11	49.65	35	14.22	9.75	17.47	13.6	10.15	7.12	9.44	6.54	11.02	7.7	13.72	9.77	13.61	9.66
10	47.34	33.65	13.16	9.09	16.42	12.91	9.39	6.64	8.69	6.06	10.16	7.15	12.69	9.12	12.59	9.01
9	44.16	31.76	11.95	8.34	15.22	12.13	8.54	6.1	7.85	5.53	9.21	6.55	11.55	8.39	11.46	8.28
8	40.2	29.37	10.62	7.51	13.92	11.27	7.61	5.5	6.96	4.95	8.19	5.88	10.33	7.59	10.23	7.49
7	35.63	26.51	9.22	6.61	12.55	10.34	6.63	4.86	6.02	4.34	7.12	5.18	9.04	6.74	8.95	6.64
6	30.57	23.24	7.78	5.66	11.14	9.35	5.62	4.18	5.07	3.7	6.017	4.43	7.72	5.84	7.63	5.75
5	25.18	19.6	6.33	4.67	9.72	8.32	4.6	3.47	4.11	3.04	4.91	3.67	6.41	4.93	6.31	4.83
4	19.58	15.6	4.9	3.68	8.32	7.27	3.6	2.76	3.17	2.38	3.83	2.91	5.12	4.01	5.02	3.91
3	13.89	11.33	3.53	2.69	6.98	6.22	2.64	2.05	2.29	1.74	2.79	2.16	3.89	3.1	3.79	3.01
2	8.32	6.92	2.25	1.74	5.73	5.2	1.75	1.38	1.47	1.14	1.84	1.44	2.76	2.24	2.65	2.91
1	3.29	2.78	1.07	0.84	4.32	3.96	0.94	0.75	0.75	0.59	0.97	0.77	1.66	1.37	1.56	1.28

Table 3: Lateral Displacement along longitudinal direction

STOREY	MODEL 1		MODEL 2		MODEL 3		MODEL 4		MODEL 5		MODEL 6		MODEL 7		MODEL 8	
	ESA (UX)	RSA (UX)	ESA (UX)	RSA (UX)	ESA (UX)	RSA (UX)	ESA (UX)	RSA (UX)	ESA (UX)	RSA (UX)	ESA (UX)	RSA (UX)	ESA (UX)	RSA (UX)	ESA (UX)	RSA (UX)
12	0.42	0.29	0.25	0.16	0.25	0.17	0.18	0.12	0.19	0.12	0.21	0.13	0.25	0.16	0.25	0.16
11	0.65	0.46	0.3	0.19	0.3	0.19	0.21	0.13	0.21	0.13	0.24	0.15	0.29	0.18	0.29	0.18
10	0.91	0.64	0.34	0.21	0.34	0.22	0.24	0.15	0.23	0.15	0.27	0.17	0.32	0.21	0.32	0.21
9	1.13	0.79	0.37	0.24	0.37	0.24	0.26	0.17	0.25	0.16	0.29	0.19	0.35	0.23	0.35	0.23
8	1.3	0.91	0.4	0.26	0.39	0.27	0.28	0.18	0.26	0.17	0.3	0.2	0.36	0.24	0.36	0.24
7	1.44	1.01	0.41	0.27	0.4	0.28	0.28	0.19	0.27	0.18	0.31	0.21	0.37	0.25	0.37	0.25
6	1.54	1.09	0.41	0.28	0.4	0.29	0.29	0.2	0.27	0.18	0.31	0.21	0.37	0.26	0.37	0.26
5	1.6	1.17	0.4	0.28	0.39	0.3	0.28	0.2	0.26	0.18	0.3	0.22	0.36	0.26	0.36	0.26
4	1.62	1.23	0.39	0.28	0.38	0.3	0.27	0.2	0.25	0.18	0.29	0.21	0.35	0.26	0.35	0.26
3	1.59	1.26	0.36	0.27	0.35	0.29	0.25	0.19	0.23	0.17	0.27	0.2	0.32	0.24	0.32	0.24
2	1.43	1.18	0.33	0.25	0.4	0.35	0.23	0.18	0.2	0.15	0.24	0.19	0.31	0.24	0.31	0.24
1	0.82	0.69	0.26	0.21	1.08	0.99	0.23	0.18	0.18	0.14	0.24	0.19	0.41	0.34	0.39	0.32

Table 4: Lateral Drift along longitudinal direction

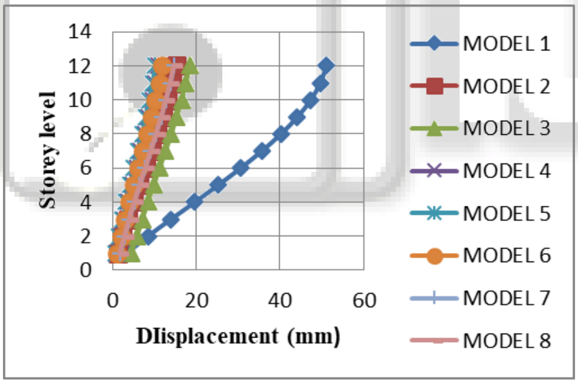

Fig. 5: Comparison of storey Displacement for different building models along longitudinal direction (ESA).

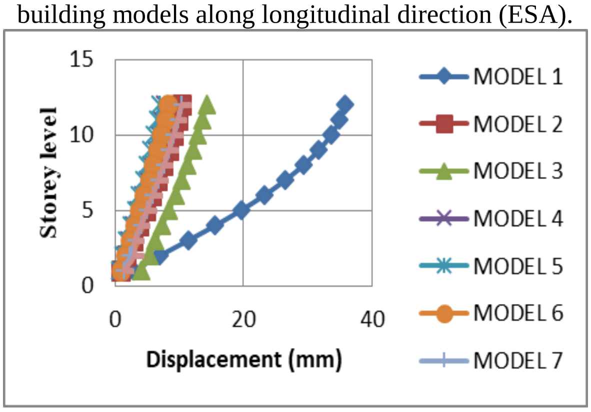

Fig. 6: Comparison of storey Displacement for different building models along longitudinal direction (RSA).

From table 5and Fig 6 it is observed that, bare frame model shows highest storey displacement values in all different building models When a comparison is made for building model 2 and model 3with 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. 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. Therefore it can be concluded that influence of brick masonry infill stiffness can considerably reduce storey displacement. Models with concrete bracings are showing some lesser reduction of top storey displacement along longitudinal.

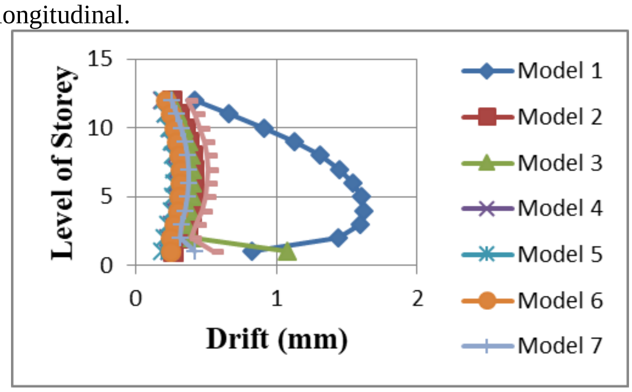

Fig. 7: Comparison of storey drift for different building models along longitudinal direction (ESA)

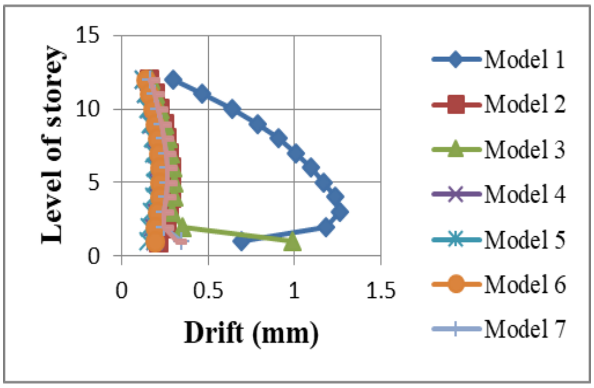

Fig. 8: Comparison of storey drift for different building models along longitudinal direction (RSA).

From the table 7 and Fig 8, it can be seen that the bare frame model (model 1) yields higher drifts values as compared with the other models The drift values gradually increase from storey 1 to storey 5 and start decreasing up to 12 storey in longitudinal direction as shown table 6.12.Also the drift in both the directions satisfy the permissible drift limit i.e. 0.004*h = 0.004*3.5 = 0.014m = 14mm. 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 infilled 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.

V. Conclusion

1) Fundamental natural period decreases when effect of infill wall, concrete shear wall and concrete bracings are considered.
2) 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.
3) The seismic base shear obtained by IS Code is not in a good agreement with the values obtained from Equivalent static and Response spectrum analysis using ETABS
4) Storey drifts are found within the limit as specified by code (IS 1893-2002 Part-1).
5) Bare frame structures are having highest response reduction factor as compared to infill frame structures. It indicates that bare frame structures are capable of resisting the forces still after first hinge.
6) 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.
7) 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.
8) 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.

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