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Studies on Behaviour of Wall-Frame Structure Subjected to Lateral Load

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Abstract:
Shear wall is one of the most commonly used lateral load resisting in high rise building. Shear wall has high in plane stiffness and strength which can be used to simultaneously resist large horizontal load and support gravity load. Shear wall with frame is known as dual structural system or wall- frame structure which is most effective and adequate in resisting of lateral load like earthquake load. The scope of present work is to study the effect of seismic loading on placement of shear wall in medium rise building at different alternative location. The office building of medium raised is analyzed for earthquake force by considering two type of structural system. i.e. Frame system and Dual system. Generally total ten models are considered in which five are of six stories and five are of twelve stories. Effectiveness of shear wall has been studied with the help of three different models of six stories and twelve stories. Model one and six are bare frame structural system, model two and seven are full masonry infill and other three models of six story and twelve story are dual type structural system. Analysis is carried out by using standard package ETAB (Extended Three dimensional Analysis of Building System). In which Seismic analysis using both linear static and linear dynamic (Response Spectrum Method)

Key words: *Dual system, shear wall, bare frame, lateral load*

1. Introduction

The primary purpose of all kinds of structural systems used in the building type of structures is to support gravity loads. The most common loads resulting from the effect of gravity are dead load, live load and snow load. Besides these vertical loads buildings are also subjected to lateral loads caused by wind, blasting or earthquake Lateral loads can develop high stresses, produce sway movement or cause vibration Therefore, it is very important for the structure to have sufficient strength against vertical loads together with adequate stiffness to resist lateral forces.

1.1. Frames

This is a frame system of rigid beams subjected to lateral loads where the developed moments in the middle of the columns are not existent. And the shear forces will be distributed proportionally with the moment of inertia of the Columns and the lateral displacements will be proportional to these forces.

1.2. Shear Walls

These systems resist the lateral loads with the shear walls whether these walls are separated or connected by beams. The distribution of shear forces is proportional to the moment of inertia of the cross sections of the walls; the displacements in each floor or level are the result of the Flexural deformations in the walls.

1.3. Dual Systems

These systems are the result of combining the two latter systems to resist the lateral load, in these systems the shape of the deformations will differ from those frames and wall systems, where effecting interacted forces occur and change the shape of shear and moment diagrams. One of the advantages of this combination is that the frames support the walls at the top and control their displacement. Besides, the walls support the frames at the bottom and decrease their displacement. In other words, the sheer force of the frames is bigger at the top than it is at the bottom and it goes the other way round for the walls.

Generally few shear walls are located symmetrically in the building plan as per the architectural requirements of the buildings are concentrated centrally as core wall to provide the lateral load resistance and lateral stiffness required to limit the lateral deformations to acceptable levels. Many choices exist with multiple shear walls or shear wall cores (shear walls arranged in a box type structure) in a tall building with regard to their location in plan, shape, number, and arrangement

2. Description of Structural Model

For the study five different models of a twelve storey building are considered the building has three bays in X direction and three bays in Y direction with the plan dimension 9m × 9m and a storey height of 3m each in all the floors. The building is kept symmetric in both orthogonal directions in plan to avoid torsional response. The orientation and size of the column is kept same throughout the height of the structure. The building is considered to be located in the seismic zone V. The building is founded on the medium strength soil through isolated footing under the columns. Elastic moduli of concrete and masonry are taken as 27386 MPa and 5500 MPa respectively and their poisons ratio as 0.20 and 0.15 respectively.

Different types of analytical models with the understanding of the behaviour of shear wall were developed. Response reduction factor of the special moment resisting frame has been taken as 5.0 (assuming ductile detailing). The importance factor for the office building is considered and it is taken as 1.5. 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 the floor is taken as 3.5 KN/m^2. In seismic weight calculations, 50 % of the floor live loads are considered.

3. Model Considered For Analysis

Following five models are analyzed as a special moment resisting frame using equivalent static analysis and response spectrum analysis.

- **Model I:** Bare frame model, however masses of brick masonry infill walls (230mm thick) are included in the model.
- **Model II:** Building has one full brick masonry infill wall in all storeys' including ground story.
- **Model III:** Building has C- shape shear wall of 250mm thick placed symmetrical in plan, however masses of brick masonry infill walls (230mm thick) are included in the model.
- **Model IV:** Building has L-shape shear wall 230mm thick placed symmetrical in plan; however masses of brick masonry infill walls (230mm thick) are included in the model.
- **Model V:** Building has L- shape shear wall of 250mm thick placed symmetrical in plan, however masses of brick masonry infill walls (230mm thick) are included in the
- **Note:** The above mentioned models are analyzed in term of 6^{th} story building models and 12^{th} story building models.

4. Modeling of Frame Members and Shear Wall

All the structural systems are modeled as a Space Frame using ETABS (version-9.6.0) Software package. The analytical model was created in such a way that the different structural components represent as accurately as possible the characteristics like mass, strength, stiffness and deformability of the structure. Non structural components were not modeled. The various primary structural components that were modeled are as follows:

- **Beams and columns:** Beams and columns were modeled as 3D frame elements. The members were represented through the assignment of properties like cross sectional area, reinforcement details and the type of material used. It has 6 Degrees of Freedom (Ux, Uy, Uz, Rx, Ry, and Rz) for each node
- **Slab Modeling:** Slab is modeled as shell element. Kinematic constraints in the form of rigid diaphragm for each floor have been used in the present analysis. In rigid diaphragm case all the joints in the slab moves together as a single unit. Meshing was done by dividing the area into smaller rectangular segments. Meshing improves the results but increases the computational time by a large extent.
- **Modeling of shear walls:** All shear walls in the building are slender with wall height-to-length ratio well above 3 and therefore seismic response of the shear walls is expected to be dominated by flexure, as well as because modeling nonlinear behavior in ETABS pushover analysis is limited to frame elements, the shear walls were modeled as pier elements

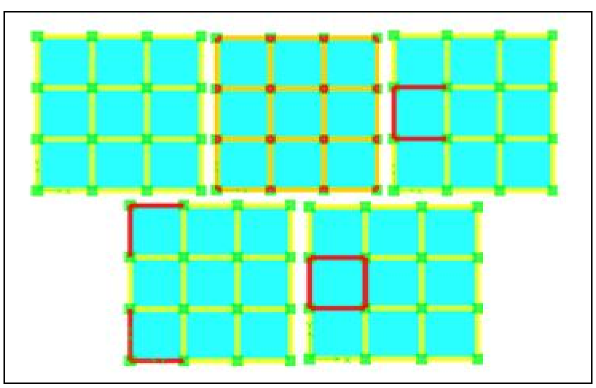


Figure: Plan of Six and Twelve Storey Reinforced Concrete Building Models

5. 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 9.6 (computer and structures) software. Lateral load calculation and its distribution along the height is done. The seismic weight is calculated using full dead load plus 50% of live load. The results obtained from analyses are compared with respect to the following parameters.

6. Fundamental Time Period

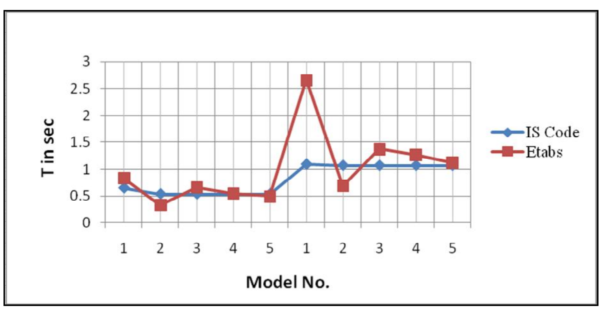
Fundamental time period (sec.)				
Model No.	**IS Code 1893-2002**		**ETABS Analysis (RSA)**	
		Longitudinal direction		
	6-story	**12-story**	**6-story**	**12-story**
1	0.655	1.102	0.84	2.668
2	0.54	1.08	0.332	0.693
3	0.54	1.08	0.669	1.38
4	0.54	1.08	0.522	1.276
5	0.54	1.08	0.498	1.129

Table 1: Comparison Of Time Period By IS Code Method And Analysis Using ETABS Software.

7. Seismic Base Shear

	ESA (ETABS)		RSA (ETABS)	
Model No.	**6 story**	**12 story**	**6 story**	**12 story**
1	1587.26	8965.48	1889.65	3475.03
2	2789.41	12362.9	5127.58	18111.01
3	1408.57	4690.13	2589.29	4214.13
4	908.63	4768.7	1670.28	1397.6
5	1850.21	4771.74	3401.12	4342.2

Table 2: Comparison of Seismic Base Shear



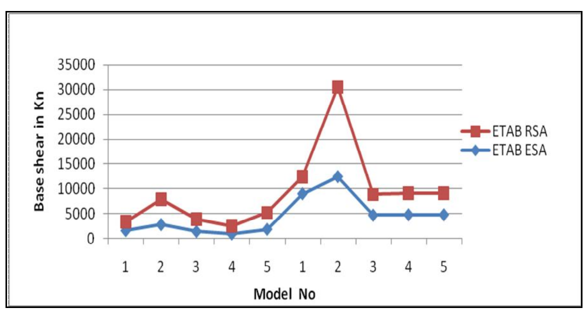


Figure 1: Fundamental time period v/s 6 & 12 story models
&
Figure 2: Design base shear v/s 6 & 12 story models along longitudinal direction

8. Storey Drift

	Storey Drift (mm)				
	Model 1	Model 2	Model 3	Model 4	Model 5
Storey	Ux	ux	ux	ux	ux
6	0.86	0.19	0.57	0.36	0.61
5	1.28	0.23	0.59	0.37	0.63
4	1.62	0.25	0.57	0.36	0.61
3	1.78	0.25	0.51	0.32	0.54
2	1.65	0.23	0.45	0.24	0.41
1	0.89	0.18	0.23	0.11	0.2

Table 3: Storey Drift for 6 Story Models along Longitudinal Direction

	Storey Drift (mm)				
	Model 1	Model 2	Model 3	Model 4	Model 5
Storey	Ux	ux	ux	ux	ux
12	3.4	0.34	1.65	1.59	1.59
11	4.4	0.45	1.74	1.65	1.64
10	5.6	0.5	1.83	1.71	1.85
9	4.32	0.54	1.91	1.82	1.86
8	7.69	0.56	1.96	1.86	1.88
7	8.42	0.58	1.95	1.78	1.85
6	8.89	0.57	1.9	1.65	1.81
5	9.06	0.56	1.74	1.49	1.69
4	8.8	0.53	1.54	1.3	1.51
3	8.01	0.49	1.33	1.24	1.25
2	6.2	0.43	0.97	0.94	0.91
1	2.7	0.4	0.44	0.43	0.42

Table 4: Storey Drift for 12 Story Models along Longitudinal Direction

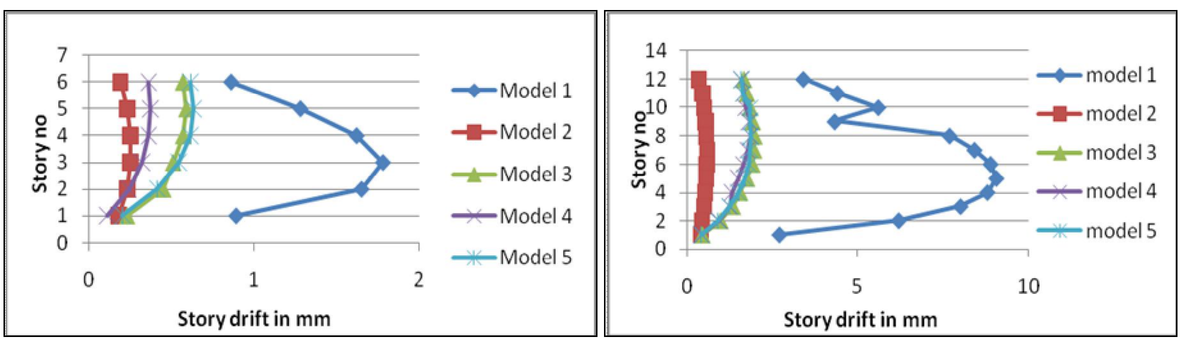


Figure 3: Storey Vs Storey drift for 6 story models along longitudinal direction
&
Figure 4: Storey Vs Storey drift for 12 story models along longitudinal direction

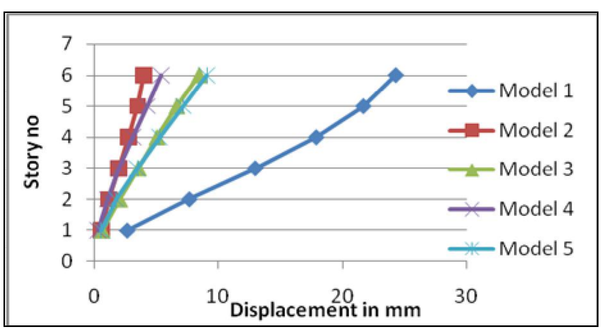
9. Storey Displacement

	Storey Displacement (mm)				
	Model 1	Model 2	Model 3	Model 4	Model 5
Storey	ux	ux	ux	ux	ux
6	24.3	4	8.5	5.4	9.1
5	21.7	3.5	6.7	4.3	7.2
4	17.9	2.8	5.1	3.1	5.3
3	13	2	3.6	2	3.5
2	7.7	1.2	2.1	1.1	1.8
1	2.7	0.6	0.7	0.3	0.6

Table 5: Displacement for Each Model along Longitudinal Direction

	Storey Displacement (mm)				
	Model 1	Model 2	Model 3	Model 4	Model 5
Storey	ux	ux	ux	ux	ux
12	240.6	17.9	57.3	54.3	55
11	230.2	16.7	52.4	49.6	50.2
10	216.7	15.4	47.8	41.8	45.1
9	199.8	13.9	41.2	37.12	42.9
8	179.6	12.01	35.1	30.9	39.7
7	156.5	10.7	30	25.14	30.2
6	131.2	8.46	24.1	18.02	21.5
5	104.6	6.45	15.9	14.9	15.2
4	77.4	5.02	11.5	11.2	11.02
3	50.9	3.14	7.9	7.8	7.7
2	26.8	2.4	4.2	4	4
1	8.2	1.1	1.3	1.3	1.3

Table 6: Displacement for Each Model along Longitudinal Direction



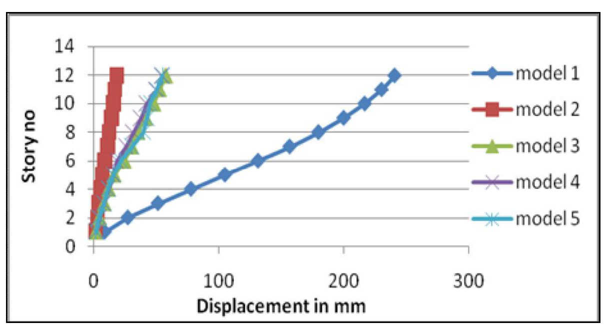


Figure 5: Storey Vs Displacement for 6 story models along longitudinal direction
&
Figure 6: Storey Vs Displacement for 12 story models along longitudinal direction

10. Results and Discussion

It is observed that model I gives higher time period both in 6 and 12 story models compared to other models. Also time period is almost twice for 6 story models from ETABS compared to IS code but in 12 story models except model I all other model gives same relation. The least time period among 6 and 12 story models, for model-2 is 0.332 and 0.693, and maximum for model 1 0.84 and 2.668..It shows that the use of full infill reduces time period. Model v shows in 6 and 12 story models 40.7% and 57.6% decrease in

time period as compare to bare frames. Thus the provision of shear wall justifies the reduction in time period. It is also observed that lateral stiffness in different models under consideration are increasing with the addition of infill and shear wall .
The seismic base shear values obtained from ESA (ETAS) for various models do not have much difference compared to RSA values. From both methods model 2 in both category models gives max base shear compare to all other models. Further RSA yields more effective base shear values compared to ESA.
The storey drift and story displacement value is maximum for model I in 6 and 12 story building models because it's a bare frame model. The least story drift and story displacement is obtained by model 2 (full infill) among all models but in comparison of shear wall models in both 6 and 12 story models, model 5 (L shape shear wall) gives least drift and displacement values. Hence due to presence of infill wall and shear wall story drift and displacement are controlled.
In 6 story models the maximum story drift for model I and II lies in same story, for story 3. And shear wall models III, IV, and V maximum drift occurred at story 5. In the same way for 12 story models max story drift for model I at story 5 and model II at story 7 and for all other models the story drift lies at story 8. Hence its noted that the same behavior can be observed for story displacement.
Thus it can be concluded that addition of infill and shear wall at various location in plan act as drift and displacement controlled elements in RC buildings.

11. Conclusion

ETABS is used as a tool for analyzing the effect of infill and shear wall for 6 and 12 story building models on the structural behavior. It is observed that, ETABS provide overestimated value of fundamental period for bare frame model as compare to IS code method. IS code describes very insufficient guidelines about infill and shear wall design procedures. Software like ETABS gives more detail and advance modeling and analysis technique. For 12 story models all parameter like time period, design base shear, story drift and displacement are higher compare to 6 story models. The lateral stiffness in different models under consideration are increasing with the addition of infill and providing shear wall at different location in building plan compared to situation when infill is not provided (in case of bare frame). The storey drift for all models satisfy the permissible limit 0.004*h where h is the storey height, as per IS 1893. According to relative values of all parameters, it can be concluded that provision of infill wall and shear wall enhances the performance in terms of storey displacement and drift control and increase in lateral stiffness.

12. Acknowledgment

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