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Dynamic Analysis of Soft Story-High Rise Building with Shear Wall

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Abstract: **Now a day's open ground storey or soft storey is a typical feature in multistoried buildings constructions. These buildings are highly susceptible to earthquake and due to that loss of properties and casualty is there. So in this paper parametric study is performed on an example building with open ground storey to bring out the importance of explicitly recognizing the presence of soft ground storey in the analysis. Usually the most economical way to eliminate the failure of soft storey by adding shear walls. The shear walls are one of the most efficient lateral force resisting elements in high rise buildings. This paper deals with occurring of soft storey at lower level at high rise building subjected to earthquake has been studied. Also has been tried to investigate on adding of shear wall to structures in order to reduce soft storey effect on seismic response of building.**

Key word: **Soft storey, Shear Wall, Dynamic Analysis, Linear Time History Analysis, SAP 2000 v.14**

I. INTRODUCTION

Reinforced-concrete framed structure in recent time has a special feature i.e. the ground storey is left open (if a building has which is 70 % less stiff than above it, it is considered a soft storey building) [UBC-1997, IBC-2003 and ASCE-2002] for the purpose of parking etc. Such building are often called open ground storey buildings or building on stilts. Open ground storey system is being adopted in many buildings presently due to the advantage of open space to meet the economical and architectural demands. But these stilt floor used in most severely damaged or, collapsed R.C. buildings, introduced 'severe irregularity of sudden change of stiffness' between the ground storey and upper stories since they had infilled bricks walls which increase the lateral stiffness of the frame by a factor of three to four times. In such buildings the dynamic ductility demand during probable earthquake gets concentrated in the soft storey and the upper storey tends to remain elastic. Hence the building is totally collapsed due to soft storey effect.

Behavior of Soft Storey Under Earthquake:

Many building structure having parking or commercial areas in their ground stories, suffered major structural damages and collapsed in the recent earthquakes. Large open areas with less infill and exterior walls and higher floor levels at the ground level result in soft stories and hence damage. In such buildings, the stiffness of the lateral load resisting systems at those stories is quite less than the stories above or below. In Fig.1, the lateral displacement diagram of a building with a soft storey under lateral loading is shown.

During an earthquake, if abnormal inter-story drifts between adjacent stories occur, the lateral forces cannot be well distributed along the height of the structure. This situation causes the lateral forces to concentrate on the storey (or stories) having large displacement(s).

In addition, if the local ductility demands are not met in the design of such a building structure for that storey and the inter-storey drifts are not limited, a local failure mechanism or, even worse, a storey failure mechanism, which may lead to the collapse of the system Fig.2 displays the collapse mechanism of such a building structure with a soft storey under both earthquake and gravity loads.

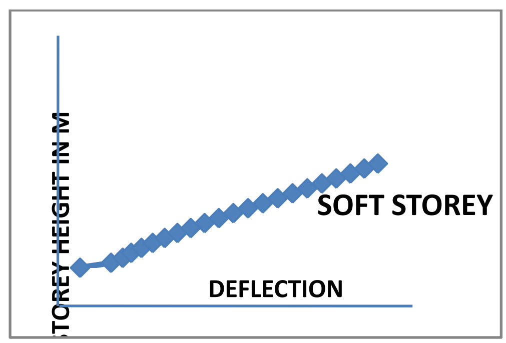

Fig. 1 Soft storey behavior of a building structure under lateral loading

Fig.2 Collapse mechanism of a building structure having a soft storey

Lateral displacement of a storey is a function of stiffness, mass and lateral force distributed on that storey. It is also known that the lateral force distribution along the height of a building is directly related to mass and stiffness of each story.

Therefore dynamic analysis procedure is required in many of the actual codes for accurate distribution of the earthquake forces along the building height, determining modal effects and local ductility demands efficiently.

Although some of the current codes define soft storey irregularity by stiffness comparison of adjacent floors, displacement based criteria for such irregularity determination is more efficient, since it covers all the mass, stiffness and force distribution concepts. RC special moment resisting frames are especially detailed to provide ductile behavior and comply with the requirements of IS code [1,2,3]. RC shear wall have been widely used as the main lateral load resisting system in medium and high rise buildings because of their high lateral stiffness.

II. PARAMETRIC DETAILS OF MODEL IS STUDIED

Basically the most economical way to eliminate of soft storey behavior is by adding Shear Wall to soft Stories.

For investigation on effect of different arrangement of brick infill and shear wall arrangement on building in seismic response of structure with soft storey at bottom, four models are designed with different conditions.

For modeling G+20 storey regular building consisting of one bare RC frame, second soft storey with brick infill in upper storey, third brick infill at corner (L shape) up to ground floor (to increase the stiffness of ground floor) and last model is to providing shear wall at corner (L shape) from ground floor to throughout height of the building. The dynamic analysis (linear time history analysis) has been done by using Bhuj earthquake (26th Jan 2001) data with 3D modeling in SAP 2000 V14. These models consists of five base of 4.5 m each in global X-direction (5 x 4.5 = 22.5 m) and three base of 3 m each in global Z-direction (3 x 3 = 9 m). The plan area of building is 22.5 m x 9 m. The supports of the columns are assumed to be fixed. The linear time history analysis (in global X-direction only) is to be analyzed using Bhuj earthquake acceleration data. The plan of the building is shown in the Fig. 3 below.

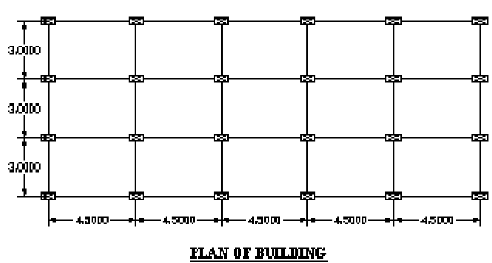

Fig. 3 Plan of Building with soft storey at bottom floor

Details of Structural Elements and Material Used:

No. of Stories	G + 20
Beam Size	230 mm x 600 mm
Column Size	300 mm x 750 mm
Thickness of Slab	125 mm
Thickness of Shear Wall	230 mm
External Brick Wall	230 mm
Internal Brick Wall	100 mm
Floor to Floor Height	3.0 m
Grade of Concrete	M 25
Grade of Steel	Fe 415
Density of Concrete	25 KN/m^3
Density of Brick Wall	20 KN/m^3
Models of Elasticity of Concrete	2.5 x 10^7 KN/m^2
Poisson's Ratio of Concrete	0.20
Poisson's Ratio of Steel	0.30
Poisson's Ratio of Brick Wall	0.20

Building is assumed to be falls under seismic zone III

III. DETAILS OF THE MODELS

1. Structure is Bare Frame without any lateral load resisting system. The plan is shown below Fig. 4**.**

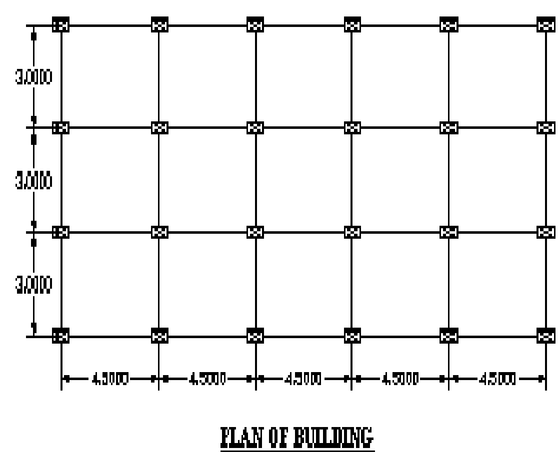

Fig. 4 Bare Frame

2. Model II is soft storey frame with brick infill at upper storey.

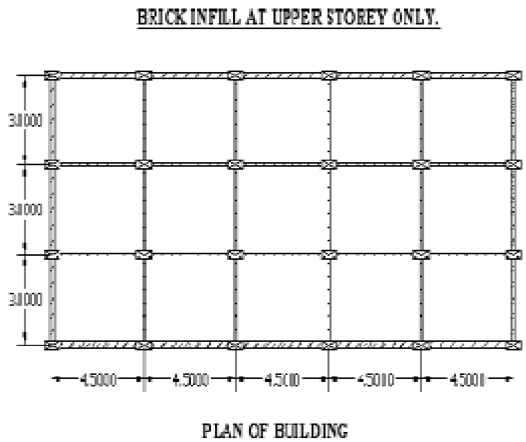

Fig. 5 Soft Storey at Ground Floor & Brick Infill at Upper Storey

3. Model III is soft storey at bottom is changed by adding brick infill at the all corners and the Shear Wall as a lift at the central core.

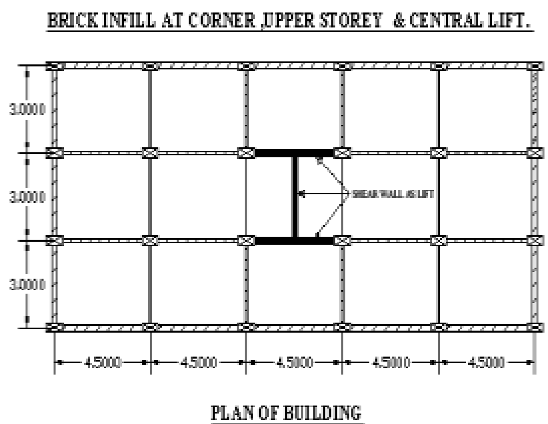

Fig. 6 Brick infill at Corner of Soft Storey and Shear Wall as a Lift at the Central Core

4. Model IV is Shear Wall at corners instead of brick infill and central lift.

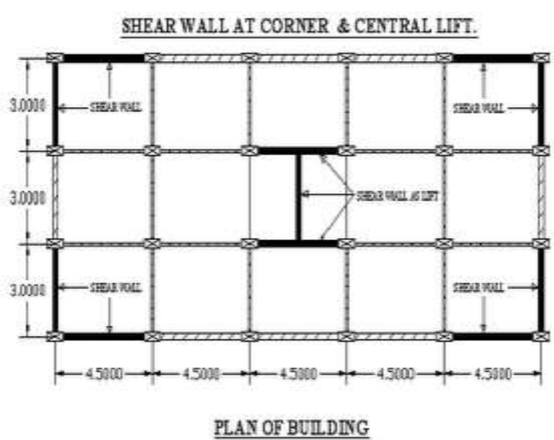

Fig. 7 Shear Wall at corners and central lift.

IV. RESULTS AND DISCUSSIONS

Variation of Period for Various Models:

As noticed from Table 1, the values of the period for various model are very much differ as per the setting parameters. The natural periods of building for different mode are clearly mentioned here. And also the detailed representation is shown in Fig. 8 below.

As per the data given and graphical representation, Model 2 having more period as compared to Model 3 and Model 4. For more detail here Model 4's period is 150 % less than Model 2.

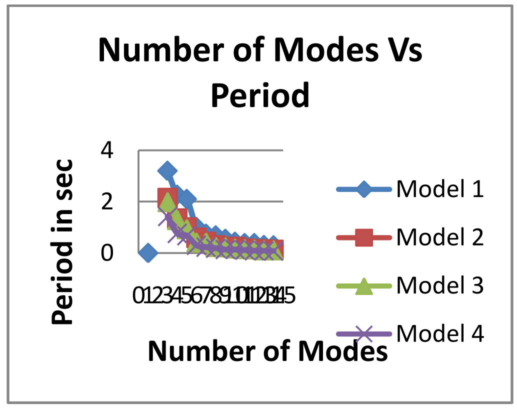

Fig. 8 Time period in Sec Vs Number of Modes

Variation of Frequency for Various Models:

As per the basic theory we know the frequency is reciprocal of time i.e. period. So for the various model period increases the frequency goes on decreases.

And the detailed representation is shown in Fig.9.

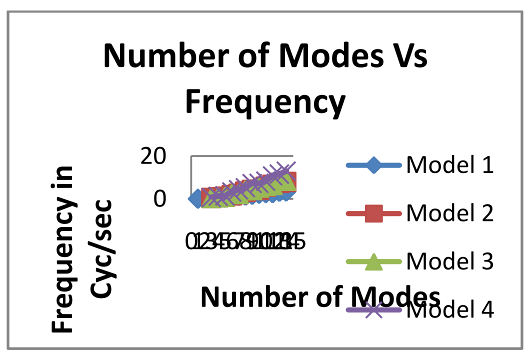

Fig. 9 Frequency in Cyc/ Sec Vs. No. of Modes

Variation of Displacement for Various Models:

Analysis of Displacement of different models at various storey levels due to earthquake force.

As noticed from table 3, the values of displacement for various models i.e. Model I, Model II, Model III and Model IV are dissimilar.

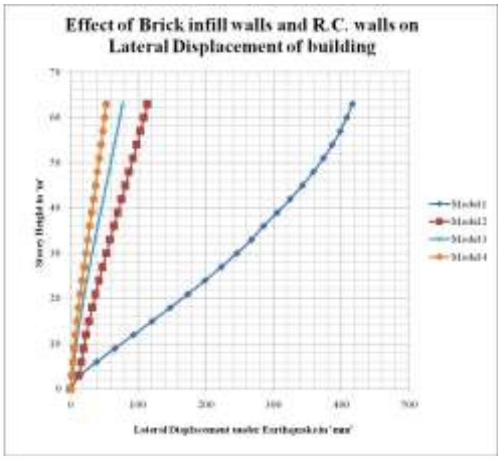

Fig. 10 Displacement Vs Storey Height

Model I, illustrate the lateral displacement 14.17 for bottom storey and for the top 416.3. Here we observe the stiffness for all story shows very much less i.e. displacement is too much high. Model II demonstrate the lateral displacement 11.86 for ground storey and 114 mm for top one. As a put side by side the percentage for the lateral displacement is better for Model II around 16.30 % at the ground storey and 72.61 for upper storey.

And for the increase the stiffness we revolutionize in the models and analyze the lateral displacement of Model III, IV are 3.3 and 1.64 for the bottom storey 77.05 and 52.86 respectively. As an evaluate the percentage for the lateral displacement for Model III, IV are around 76.71 % and 88.42 % at the ground storey and 81.49 % and 87.30 % for upper storey with respect to Model I. And here made the same calculation for the analysis of linear displacement with the Model II is 72.17 % and 86.17 % for the bottom storey and 29.63 % and 53.63 % for the top one.

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Table 1: Comparison for Model Periods of Various Model

Output Case	Step Num	Model 1	Model 2	Model 3	Model 4
		Period in Sec			
Text	Unitless				
MODAL	1	3.205227	2.142172	1.99685	1.420063
MODAL	2	2.269965	1.347551	1.294961	0.767416
MODAL	3	2.105736	0.990195	0.938011	0.676732
MODAL	4	1.011072	0.590753	0.424527	0.303786
MODAL	5	0.748401	0.438821	0.413717	0.231711
MODAL	6	0.683337	0.301101	0.244692	0.188359
MODAL	7	0.548925	0.23839	0.235182	0.13799
MODAL	8	0.435606	0.237919	0.187317	0.136794
MODAL	9	0.385159	0.178116	0.164223	0.119396
MODAL	10	0.38438	0.151909	0.152362	0.091994
MODAL	11	0.307003	0.134879	0.117238	0.086013
MODAL	12	0.295343	0.127272	0.117212	0.076668

Table 2: Comparison for Model Frequency of Various Model

Output Case	Step Num	Model 1	Model 2	Model 3	Model 4
		Frequency in Cyc/ Sec			
Text	Unitless				
MODAL	1	0.31199	0.46682	0.50079	0.70419
MODAL	2	0.44054	0.74209	0.77222	1.3031
MODAL	3	0.47489	1.0099	1.0661	1.4777
MODAL	4	0.98905	1.6928	2.3556	3.2918
MODAL	5	1.3362	2.2788	2.4171	4.3157
MODAL	6	1.4634	3.3211	4.0868	5.309
MODAL	7	1.8217	4.1948	4.252	7.2469
MODAL	8	2.2957	4.2031	5.3386	7.3103
MODAL	9	2.5963	5.6143	6.0893	8.3755
MODAL	10	2.6016	6.5829	6.5633	10.87
MODAL	11	3.2573	7.4141	8.5297	11.626
MODAL	12	3.3859	7.8572	8.5316	13.043

Table 3: Lateral Displacement of different models at different storey level

HEIGHT in M	Displacement in mm			
	Model I	Model II	Model V	Model VI
0	0	0	0	0
3	14.17	11.86	3.3	1.64
6	38.96	16.33	5.62	3.38
9	66.06	19.58	8.03	5.29
12	93.53	23.5	10.82	7.39
15	120.8	27.79	13.89	9.66
18	147.6	32.4	17.21	12.08
21	173.6	37.28	20.73	14.63
24	199	42.39	24.42	17.28
27	223.1	47.68	28.27	20.01
30	246	53.12	32.22	22.8
33	267.4	58.68	36.27	25.64
36	285.1	64.31	40.39	28.49
39	305.5	69.98	44.54	31.36
42	324.7	75.68	48.72	34.21
45	342.5	81.35	52.89	37.04
48	358.9	86.99	57.05	39.82
51	373.7	92.58	61.17	42.55
54	386.9	98.08	65.24	45.22
57	398.4	103.5	69.25	47.82
60	408.2	108.8	73.2	50.36
63	416.3	114	77.05	52.86