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Seismic Response of Reinforced Frame Structure with Soft Stories At Different Floors

Akshay Uphade[1], Rohan Kumar Choudhary[2]

[1]*Department of structural engineering, Sandip University, Nashik, akshayuphade@rediffmail.com*
[2]*Department of structural engineering, Sandip University, Nashik, rohan.choudhary@sandipuniversity.edu.in*

Abstract— In general practice soft stories means, RC frame building structures without infill panels comprises of walls of brick, blocks and many more types of partitions. In this lateral stiffness is about less than 70% of that in story above immediately or less than 80% of average lateral stiffness of these stories above them.
The infill masonry partitions walls are rarely considered as structural system components in an analysis of reinforced concrete structure. Although it is considered as a non-behaving components parts of building unit. Even when as partition they also show structure response and although panels of partitions considered and included in analysis. Recently, it becomes important to carry out seismic behavior of frame structure with and without infill walls.
Parametric analysis of large variety of multistory building structure show that hysteric dissipation of energy in the infill are uniform in all the way in all story , dissipation and drift and structural damage are reduced dramatically , without any increase in demand of seismic force. Absence of any infill bottom story as it shows less strong and more flexible large deflection of that building tends to concentrate on that floor with effect of stress at second floor and hence collapse is unavoidable. In modern construction of multistoried building construction in India typical feature to open the first story such type of feature is unavoidable in seismically active areas. This is been verified in very numerous ways of strong earthquake excitation.

Keywords— Soft story, Piloti, Diagonal Strut, Response Spectrum Analysis, Software, Etabs.

I. INTRODUCTION

In India construction of multi-story RC frame building with first open story is a general practice. We cannot avoid this feature and is generally uses for parking of vehicles, reception, lobbies etc. Such model of building in which having upper stories of brick infill wall panel and open story is called stilt building or open story is called as stilt floor. A soft story is termed as weak story, is a story in a building that has less stiffness than the stories above or below. A soft story has less shear resistance or less ductility to resist the seismic induced stresses. Such features are highly unacceptable in building in seismically active areas. The Indian seismic code IS 1893:2002 defines the soft story as the one in which the lateral stiffness is less than 70% of that in the story immediately above or less than they are designed to perform architectural functions, masonry infill walls do resist lateral forces with substantial 80% of combined stiffness. This separation is caused due to lesser strength or raised flexibility in the initial level structure that leads to extreme deflection within the initial level that successively ends up in concentration of forces at the second level connections. If all the floors square measures close to equal in strength and stiffness , the whole building deflection below earthquake load is distributed close to equally at every floor. If the primary floor is considerably less or a lot of versatile an outsized portion of the whole building deflection tends to concentrate in this floor, with resulting concentrate in this floor, with resulting concentration of stresses at the second floor connections thus the bottom floor columns transfer the soft level into a mechanism; in this case collapse is unavoidable. To evolve the safe design for the building with the practical requirement of parking. Generally soft story means simply a frame structure without infill walls i.e. masonry wall, panels, concrete blocks. It is the one in which the lateral stiffness is less than 70% of that in the story immediately above or less than 80% of average lateral stiffness of three stories above. In this work there are two type of building models comprises of infill walls and without infill walls at different levels and then it is tested for seismic analysis by Pseudo Plastic analysis and Response Spectrum Analysis. The building model which comprises of G+15 stories in which some floors are left without infill walls to inspect how it behaves in earthquake excitation. Modelling, analysis and design of RC frame structure shall be done in Etabs software so as to compare output details on the software and then we can go with the more economical solution. The essential characteristics of soft story consist of discontinuity of strength or stiffness, which occurs at the second story level. This discontinuity is caused because of lesser strength or increased flexibility in the first story structure that results in extreme deflection in the first story, which in turn results in the concentration of forces at the second story connections. If all the floors are approximately equal in stiffness and strength, the entire structure deflection under earthquake load is distributed equally at each floor. If the first floor is significantly less strong or more flexible, a large portion of the total building deflections tends to concentrate in that floor, with consequent concentration of stresses at the second floor connections. Therefore the ground floor columns transfer the soft story into a mechanism; in that case collapse is unavoidable. So there is a need to evolve the safe design for the building with the functional requirement of parking. Whereas the total base shear as calculated by a structure during an earthquake is dependent on its natural period, the seismic force distribution is dependent on the distribution of stiffness and mass along the height.

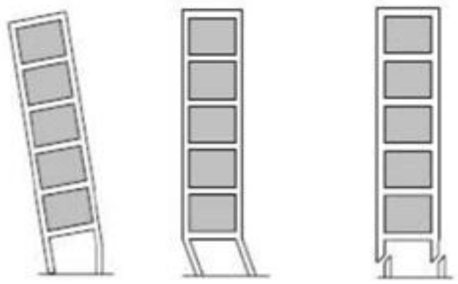

Fig No.1
Failure types of soft story building

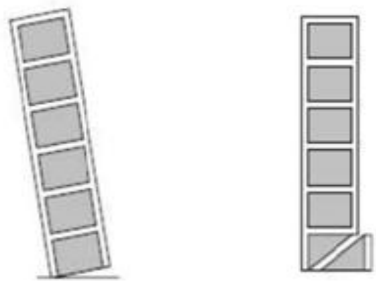

Fig No.2
Failure types of soft story with walls

A. Failure Criteria and Mechanism of Soft Story Structure

In the Inspections of earthquake damage have shown that structural systems with a soft story can lead to serious problems during severe earthquake ground shaking [13]. For instance, Figure 3 and 4 illustrate such damages. Figure 3 shows the failure mechanism of soft story building. These are: a) Bending (tensile yielding of bar), b) collapse of first story (yield in column), and c) collapse of first story (shear failure of column). As for a soft story with walls, two types of failure mechanism are observed in a frame with a wall: a) bending (bending yield at wall bottom), and b) shear collapse of first story (shear failure). The failure mechanism of the frame with wall is predominant and therefore controls the failure mechanism of the whole system (building).

B. Masonry Infill Panels and Walls

Masonry infill panels are found in most existing concrete frame structure systems. These masonry walls which are constructed after completion of concrete frames are considered as non-structural part. That they are designed to perform functions as masonry infill walls do resist lateral forces action. In addition to this walls have a significant strength and stiffness and they have considerable effect on the response of the structural system. There is a general acceptance with among of the researchers that infill frames have considerable strength as compared to frames without infill walls. There is a presence of the infill walls increases the lateral stiffness significantly. Due to the change in mass and stiffness of the structural system, the dynamic properties change as well. Infill panels have an important effect on the stiffness and resistance of buildings. However, the effects of the infill panel's walls on the building response under earthquake loading are complex. In many countries in seismic regions, reinforced concrete frames are infill fully or partially by brick masonry panels with or without panels. Although the infill panels considerably enhance both the strength and stiffness of the frame, their contribution is not taken into account because lack of knowledge of the composite behaviour of the frame and the infill.

C. Objectives of study

- The objectives of this work is to focus on seismic performance of RC frame structure with soft stories and to find and inspect the failure pattern of soft story building with analytical studies by using Etabs software.
- To describe the performance characteristics such as stiffness, axial force, shear force, bending moment, etc. at soft story at different level.
- Checking suitability of soft story at different floor level.
- Suggesting remedial measure to minimize the stress generated at soft story in earthquake.

II. LITERATURE REVIEW

Arlekar J. N., Jain S. K. and Murty C.V.R [1] studied the seismic response of exampled RC buildings with soft first storyin seismically active area like Jabalpur. Different RC Building models are used for analysis. Linear elastic analysis is performed for the nine models of the building using ETABS analysis package. The frame members are modeled with rigid end zones, the walls are modeled as panel elements, and the floors are modeled as diaphragms rigid in-plane. The soil flexibility is introduced as linear Winkler springs under the footing. The natural period of the building is calculated by the expression, $T=0.09\ H/\sqrt{D}$ given in IS: 1893-1984, wherein H is the height and D is the base dimension of the building in the considered direction of vibration. The lateral load calculation and its distribution along the height are done as per IS: 1893-1984. The seismic weight is calculated using full dead load plus 25% of live load. Dynamic analysis of the building models is performed on ETABS. The lateral loads generated by ETABS correspond to the seismic zone III and the 5% damped response spectrum given in IS: 1893-1984. The natural period values are calculated by ETABS, by solving the Eigen value problem of the model. Thus, the total earthquake load generated and their distributions along the height correspond to the mass and stiffness distribution as modelled by ETABS. Here, as in the equivalent static analysis, the seismic mass is calculated using full dead load plus 25% of live load. From Analysis, Result such as storystiffness of first and second storey's for different building models, Lateral Displacement Profile of storydrift to height for different building models by Equivalent Static Analysis and Multi- Modal Dynamic Analysis, Displacement at first floor, maximum forces in first story columns and average of Seismic Performance of RC Frame Building with Soft Stories At Different Level and Its Improving Measures the maximum forces in the columns of the storey's above for different models is given in this research paper.

Iwabuchi K., Fukuyama H. and Suwada H.[2], proposes a new technique for structural control of RC buildings with soft storyby using ductile short columns as response control devices placed beside the existing columns at the soft storey. This device is made by High Performance Fiber Reinforced Cementations Composite (HPFRCC), which exhibits multiple cracking and strain-hardening characteristics in the uniaxial tensile stress. In this paper the authors was conducted a substructure pseudo-dynamic test carried out on a 12- storysoft storyRC building with seismic response control elements placed beside the existing columns on the first floor in order to investigate the feasibility and advantages of the structural control by HPFRCC devices, and to confirm effectiveness of the seismic response analyses. As the result of the experiment, the seismic response of the RC buildings with soft story was successfully controlled as expected by using HPFRCC device, and the reliability of the analytical tool has also been clarified by comparing the experimental results with analytical results

Nagae T and Hayashi S. [3], In 1995 Hyougoken Nanbu Earthquake, the soft-first- storybuildings suffered significant damage because the buildings had to consume most of energy by the soft-first-story columns. As a preventive measure for such failure, increasing the size column size is more effective but while strengthening the column as per traditional design, the foundation should be stronger than the superstructure, i.e., the foundation should not suffer damages during great earthquakes. In their research, they proposed an alternative design to the traditional design by which they reduces the reinforcement of foundation members and forces yielding in the foundation. To consider the effect of the yielding foundation on the seismic response of the superstructure, soft-first-storybuildings supported by pile foundations were analyzed. Analysis is based on the calculations of ground response, soil- pile interaction, pile building interaction, and building response all in one numerical calculation. 12 story buildings supported by the pile foundation were analyzed for considering influences of the yielding foundation on the superstructure during the great earthquake. The yielding of grade beam and the yielding of pile were defined as the yielding of foundation, and the strengths of grade beam and pile were changed as the parameters. For the model of the analysis, a 2-D frame structure model was connected with a free ground column by nonlinear soil (p-y) springs. The results from the dynamic analyses showed that the yielding of grade beam and the yielding of pile can reduce the seismic response of the soft first story during the great earthquake. And also it was indicated that the energy consumption of the soil in the vicinity of pile decreases the total energy consumption of the structure, and the yielding of foundation derive not just the energy consumption of the foundation members but also the extra energy consumption of the soil in the vicinity of the pile.

Verma M. B. and Zuhair M [4] studied the parametric performance on an example building with a soft first storey. They describe the performance characteristics such as stiffness, shear force, binding moments and drift in this paper. The effects of shear wall, masonry infill, cross bracing and stiffened column on above parameter also been studied for an example building with soft first story with the help of five different mathematical model. In their study they used a 3D analytical model which represents all components of structure that influence the mass, strength, stiffness and deformability. They use SAP 2000 finite element software for 3D model analysis. The walls are modeled by using equivalent strut approach. The results of this analysis are presented in this paper by comprising these five models. Finally they conclude the use of cross bracing significantly increases the first story stiffness. The first story stiffness comes out to be 70% of second story stiffness. The use of cross bracings reduces the moments by 50-60% as compared to soft story model. Shear wall are found to be most effective in reducing the stiffness irregularity, story drift and strength demand in the first storey. When shear wall introducing, the stiffness of first story increased to 80% and moments are reduce by 50%.

III. METHODOLOGY

In this present work Tuned mass damper is placed on its top to study its effects on Storey drift, storey displacement and story shear and analysis with and without the tuned mass damper in ETAB 2016.by using response spectrum.
For investigation following assumptions are adopted.

- Columns are assumed as inextensible.
- The slab is assumed as rigid.
- Self-weight of the columns is neglected.

A. Problem statement

To study the behavior of RC frame building with soft stories, the structure with symmetric plan is selected. Height of each typical story is 2.85m. The building has dimensions of (24m x 40m) and is asymmetric in orthogonal directions. The building is to be located in seismic zone III and it has 15 stories. It is assume to be built on hard soil strata. In the analysis ordinary special RC moment-resisting frame (OMRF) is considered.

B. Modelling and analysis

- 1. Size of all beams = 230mm x 450mm (Depends on structural requirements)
- Size of all beams = 230mm x 600mm (Depends on structural requirements)
- 2. Size of all columns = 300mm x 600mm (Depends on structural requirements)
- 3. Slab thickness = 150mm
- 4. Wall thickness = 230mm
- 5. Story Height = 3000mm
- 6. Unit weight of concrete = 25 kN/m3
- 7. Unit weight of brick masonry = 19 kN/m3
- 8. M 25 Grade Concrete.
- 9. Modulus of Elasticity of concrete [17] =5000√fck = 25000 N/mm2
- 10. Modulus of Elasticity of brick masonry [1] = 6300 N/mm2
- 11. Poisons Ratio of concrete = 0.3
- 12. Poisons Ratio of masonry = 0.25
- 13. SBC of Soil – 300kn/sqmt

C. Modelling of building

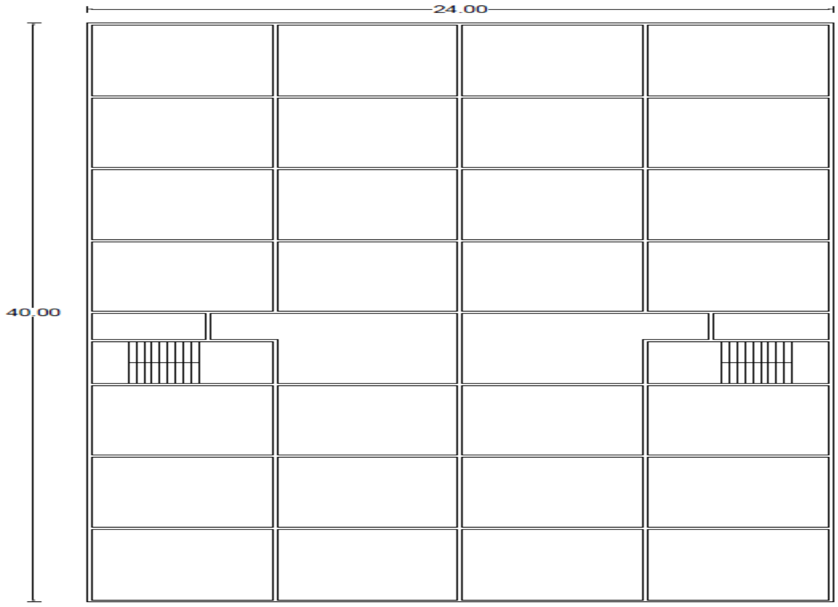

Fig No. 3 Typical floor plan

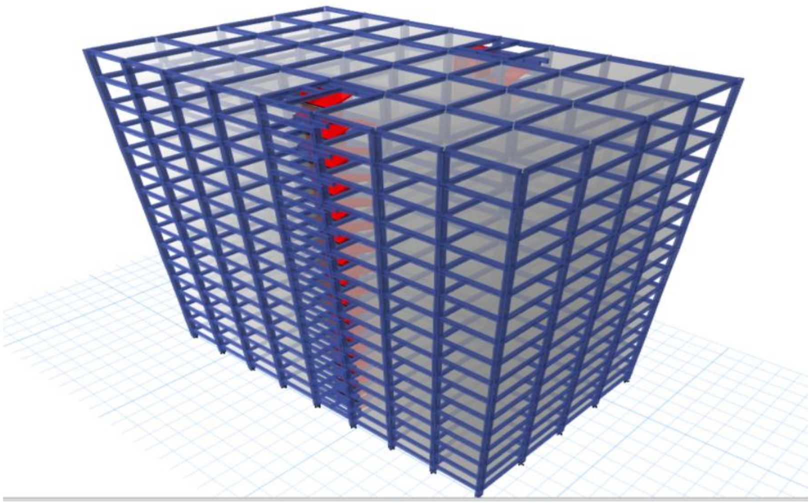

Fig No. 4 Rendered view

IV. RESULT AND DISCUSSION

A. Displacement

1) Displacement in x and y direction

Maximum displacements of different building models using equivalent static analysis are shown in following table:

Now we can compare the story displacement along the X-Direction & Y direction

Table No.1

Structural Model	**Maximum Displacement (mm)**	
	Transverse Direction	**Longitudinal Direction**
Model No.1	40.22	39.58
Model No.2	100.29	93.41
Model No.3	119.69	111.59
Model No.4	148.34	139.85
Model No.5	150.69	138.09
Model No.6	144.93	138.91
Model No.7	117.73	103.59

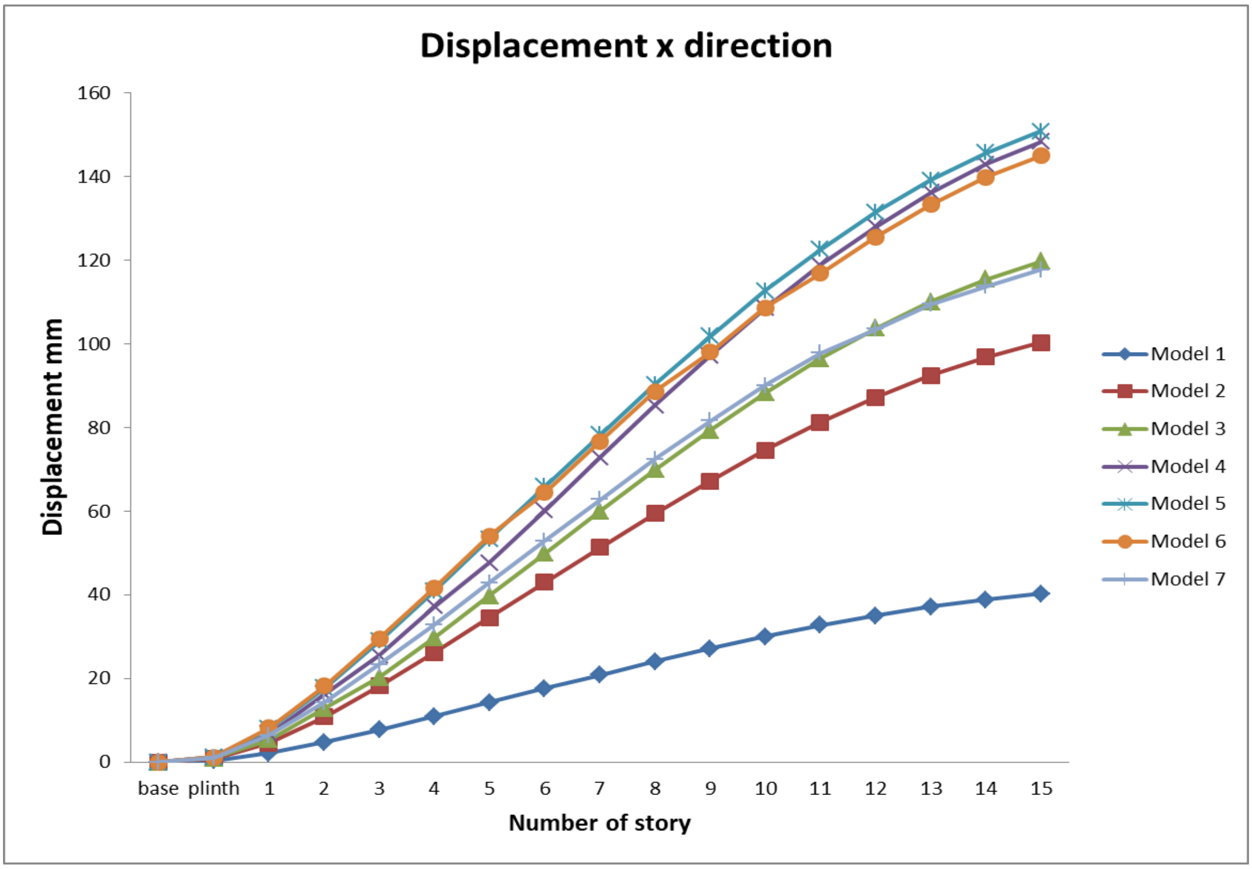

Fig No.5 Displacement in x direction

The unexpected change in displacement profile shows the story stiffness irregularity. As well as graph clearly shows that if soft story shifted above and above the displacement values increases. As comparison of maximum displacement of model No.2, No.3, No.4 it indicates that while increase in number of soft story in building displacement percentage increases upto15%. Model No.5 shows most severe and maximum value of story displacement as compared to other models. As comparison of result of model no.5 with other model it is clearly seen that if spacing between two soft stories increases story deflection of building increases. Hence the provision of side panel masonry in ground floor in model no.7 shows 8% to 10% reduction in displacement. The graph of transverse direction shows greater story displacement as compared to graph of longitudinal direction. Model No.5 shows greater value of displacement as compared to other model because of provision of soft story at higher level.

B. Bending Moment and Shear Force

Table No.2

Longitudinal Frame							
Parameter		Maximum Bending Moment (kN-m)		Maximum Shear Force(kN)			
				Along X Direction		Along Y Direction	
Model Name	Lower Floor	Soft story	Upper Story	Soft story	Upper Story	Soft story	Upper Story
Model No.1	Ground Floor	24503.09	22189.23	1605.73	1603.09	918.95	910.59
Model No.2	Ground Floor	22376.82	20152.03	1624.04	1621.78	920.81	900.71
Model No.3	Ground Floor	22360.77	20122.27	1648.16	1631.57	944.38	871.67
	3rd Floor	18282.97	16261.09	1645.73	1618.21	917.56	823.97
Model No.4	3rd Floor	18284.32	16246.34	1662.69	1618.25	888.80	790.15
	5th- Floor	14557.96	12681.80	1648.75	1583.81	838.92	749.02
Model No.5	6th- Floor	12428.14	10596.58	1580.69	1454.79	750.87	671.56
	8th- Floor	9064.74	7354.87	1529.50	1368.35	711.51	635.46
Model No.6	9th Floor	7056.46	5438.08	1346.74	1098.67	630.17	535.70
	11th Floor	4121.23	2713.38	1237.11	940.67	590.60	484.46
Model No.7	Ground Floor	22155.78	19936.07	1614.71	1605.51	929.18	900.90

C. Story Stiffness

In present analytical study, for calculation of story stiffness for building structure models no.1 to model no.6 in transverse as well as longitudinal direction, the soft lower story without infill and related upper story with infill are taken into account. The story stiffness is defined as the magnitude of the force couple required at the floor levels adjoin the story to produce a unit lateral translation within the story, letting all the other floors to move freely. For story stiffness calculation separate Modelling of building structural frame is done in Etabs software and from these result story stiffness is calculated. For different building frame models the stiffness of story without infill and related upper story as well as presence of soft story is shown in Table No.4

Table No.3

Model	**Lower Story**	**Story Stiffness**		**Ratio**	K_i	$0.7K_{i-1}$	**Is It Soft Story?** ($K_i < 0.7K_{i-1}$)
		Soft Story	**Upper Story**				
Model No.1	G-Floor	361109.8	361109.8	1	361109.8	252776.86	No
Model No.2	G-Floor	121786.9	355579.2	0.34	121786.9	241265.86	Yes
Model No.3	G-Floor	126987.8	344597.7	0.36	126987.8	241654.23	Yes
	2nd-Floor	126420.4	366520.3	0.34	126420.4	242365.25	Yes
Model No.4	2nd-Floor	126103.4	359997.7	0.35	126103.4	256579.25	Yes
	5th-Floor	126001.4	361257.3	0.34	126001.4	259987.25	Yes
Model No.5	5th-Floor	124589.8	343651.7	0.36	124589.8	240478.35	Yes
	7th-Floor	125147.4	362578.3	0.34	125147.4	245796.25	Yes

V. Conclusions

In multi-storeyed structure for parking of vehicles, ground floor is always used with open frames. As well as by adopting of new practices, now a day's parking of vehicles is also provided in above stories than ground floor. But it is important to check their response during earthquake excitation. So the present study as a dissertation part highlights the behaviour of reinforced concrete frame structure with soft story at ground floor as well as at above stories also. From results of analysis the following conclusions are found.

- Parametric analysis on multistoried infill reinforced concrete structures gives that, due to the hysteretic energy dissipation in the infill, if the infilling is uniform in all story, drifts and structural damage are dramatically reduced, without an increase in the seismic force demands. Presence of soft story effects due to the absence of infill wall in the bottom story in building is a measure problem in earthquake, as soft story is less strong or more flexible, a large part of the building deflection to concentrate in that floor with secondary concentration of stress at the second floor and in that case collapse is unavoidable.
- The stiffness irregularity in structural models with soft story is seen from the fact that the stiffness of soft story is less than that of corresponding above story stiffness.
- If soft story shifted above and above the displacement values increase.
- If spacing between two soft stories increases, the deflection of building increases.
- The provision of side masonry significantly increase stiffness and it considerably reduce the lateral deflection and show smooth displacement profile without affecting parking utility.
- In case of the soft story buildings the bending moments and shear forces value are severely higher for soft story columns as compare to upper story columns.

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