International Journal of Advance Research and Innovation
Vol. 4(2), Apr-Jun 2016, pp. 52-65
Doi: 10.51976/ijari.421609
www.gla.ac.in/journals/ijari

Article Info
Received: 02 Apr 2016 | Revised Submission: 20 May 2016 | Accepted: 28 May 2016 | Available Online: 15 Jun 2016

Seismic Behavior of RC Frame Building and Its Analysis with Improving Measures

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ABSTRACT

The infill masonry walls are seldom included in analysis of reinforced concrete structural systems, since masonry panels are generally considered as non-structural components. However, these panels affect the structural response, although the complexity they introduce to analysis. The effects of masonry infill on the global seismic response of reinforced concrete structures arethe part of study. Recently, it becomes important to determine the earthquake behavior of structures with infill walls in earthquake engineering. Parametric analyses on a large variety of multi-storey infill reinforced concrete structures show that, due to the hysteretic energy dissipation in the infill, if the infilling is uniform in all storey, drifts and structural damage are dramatically reduced, without an increase in the seismic force demands. Presence Soft-storey effects due to the absence of infill in the bottom storey in building is a measure problem in earthquake, as soft storey is significantly less strong or more flexible, a large portion of the total building deflection tends to concentrate in that floor with consequent concentration of stress at the second floor connections and in that case collapse is unavoidable.

Open first storey is a typical feature in the modern multistory constructions in urban India. Such features are highly undesirable in buildings built in seismically active areas; this has been verified in numerous experiences of strong shaking during the past earthquakes. The present study highlights the seismic performance of RC frame building with soft stories at first as well as at different floor level. A parametric study is performed on an example building with soft storey and it is intended to describe the performance characteristics such as stiffness, shear force, bending moment, drift. The effects of masonry infill and cross bracing on above parameters have been studied for a building with soft storey. The modeling and post-processing is carried out using ANSYS software. The comparisons of different parameter of models have also been presented in the study.

Keywords: *Energy Balance; Land Surface Temperature; Radioactive Forcing; Urban Surface Albedo; White Roof.*

1.0 Introduction

Construction of multistoried building with open first storey is a common practice in India. This is an unavoidable feature and is generally adopted for parking of vehicles reception lobbies. Such a building in which the upper stories have brick infill wall panel and open ground storey is called stilt building and the open storey is called as stilt floor or soft storey [8].

A soft storey is also known as weak storey, is a storey in a building that has substantially less resistance or stiffness than the stories above or below. In essence, a soft storey has inadequate shear resistance or inadequate ductility to resist the earthquake induced stresses. Such features are highly undesirable in building built in seismically active areas.

The Indian seismic code IS 1893:2002 defines the soft storey as the one in which the lateral stiffness is less than 70% of that in the storey 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.

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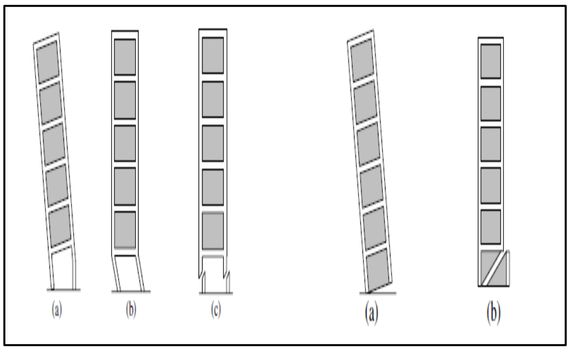
The essential characteristics of soft storey consist of discontinuity of strength or stiffness, which occurs at the second storey level. This discontinuity is caused because of lesser strength or increased flexibility in the first storey structure that results in extreme deflection in the first storey, which in turn results in the concentration of forces at the second storey connections. If all the floors are approximately equal in strength and stiffness, the entire building deflection under earthquake load is distributed approximately 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 storey 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.

Masonry infill walls are found in most existing concrete frame building systems [6]. These masonry infill walls which are constructed after completion of concrete frames are considered as non-structural elements. Although structural action. In addition to this infill walls have a considerable strength and stiffness and they have significant effect on the seismic response of the structural system. There is a general agreement among of the researchers that infill frames have greater strength as compared to frames without infill walls. The presence of the infill walls increases the lateral stiffness considerably. Due to the change in stiffness and mass of the structural system, the dynamic characteristics change as well. Infill walls have an important effect on the resistance and stiffness of buildings. However, the effects of the infill walls on the building response under seismic loading are very complex and math intensive.

In many countries situated in seismic regions, reinforced concrete frames are infill fully or partially by brick masonry panels with or without openings [12]. Although the infill panels significantly enhance both the stiffness and strength of the frame, their contribution is often not taken into account because of the lack of knowledge of the composite behavior of the frame and the infill.

Inspections of earthquake damage have shown that structural systems with a soft storey can lead to serious problems during severe earthquake ground shaking [13]. For instance, Figure 1 and 2 illustrate such damages. Figure 1 shows the failure mechanism of soft storey building. These are: a) Bending (tensile yielding of reinforcing bar), b) collapse of first storey (yield in column), and c) collapse of first storey (shear failure of column). As for a soft storey 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 storey (shear failure). The failure mechanism of the frame with wall is predominant and therefore controls the failure mechanism of the whole system (building).

Fig 1: Failure Types of Soft Storey Building **Fig 2: Failure Types of Soft Storey with Walls**



The objectives of the work is to focus on seismic performance of RC frame building with soft stories and to inspect the failure mechanism of soft storey building with analytical studies by using ANSYS software.

1. To describe the performance characteristics such as stiffness, axial force, shear force, bending moment, etc. at soft storey at different level.
2. Checking suitability of soft storey at different floor level.
3. Suggesting remedial measure to minimize the stress generated at soft storey in earthquake.

To have the insight into the subject, the resources like technical websites, research paper and national and international journal papers providing the appropriate information were explored. The following are the products of the search.

Arlekar J. N., Jain S. K. and Murty C.V.R.[11], studied the seismic response of exampled RC buildings with soft first storey in 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/√D given in IS: 1893-1984, wherein the height and Dis 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 modeled 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 storey stiffness of first and second storeys for different building models, Lateral Displacement Profile of storey drift to height for different building models by Equivalent Static Analysis and Multi-Modal Dynamic Analysis, Displacement at first floor, maximum forces in first storey columns and average of the maximum forces in the columns of the storeys above for different models is given in this research paper.

Fardis M. N. & Panagiotakos T. B.[4], studied the effects of masonry infill on the global seismic response of reinforced concrete structures through numerical analyses. In their paper they shows that, due to the hysteretic energy dissipation in the infill, if the infilling is uniform in all storey's, drifts and structural damage are dramatically reduced, without an increase in the seismic force demands. Soft-storey effects due to the absence of infill in the bottom storey are not so important for seismic motions at the design intensity, but may be very large at higher motion intensities, if the ultimate strength of the infill amounts to a large percentage of the building weight.

Asteris P. G. [12], developed a new Finite Element technique for the analysis of brickwork in filled plane frames under lateral loads. In present study he shows the influence of the masonry in filled panel opening in the reduction of the in filled frames stiffness has been investigated by using this technique. The basic characteristics of this analysis is that the infill/frames contact length (see figure 3) and the contact stresses are estimated taken as integral part of the solution and not assumed in adhoc way.

For the analysis, a four node iso-parametric rectangular finite element model with 8 degrees of freedom has been used. In case of plane stress the elasticity matrix is presented and defined by

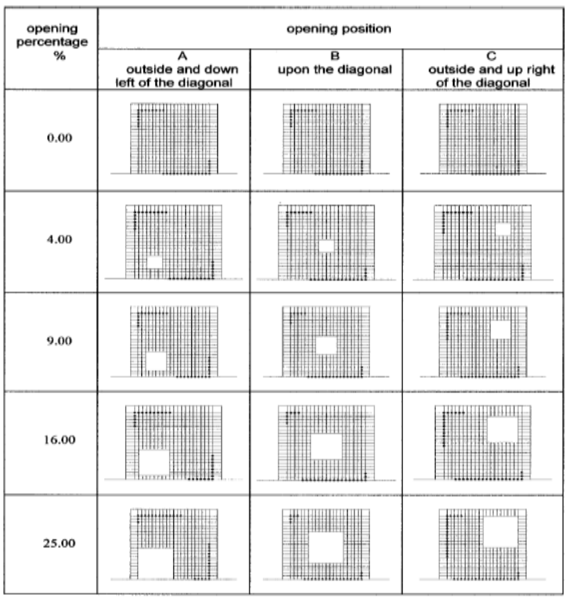
$$D=\begin{bmatrix} \frac{E_x}{1-\nu_{xy}\nu_{yx}} & \frac{E_x\nu_{yx}}{1-\nu_{xy}\nu_{yx}} & 0 \\ \frac{E_y\nu_{xy}}{1-\nu_{xy}\nu_{yx}} & \frac{E_y}{1-\nu_{xy}\nu_{yx}} & 0 \\ 0 & 0 & G_{xy} \end{bmatrix}$$

Where *Ex* and *Ey* = moduli of elasticity in the *x* and *y* direction respectively; v*xy*, v*yx* = Poisson's ratios in the xy and yxplane, respectively; and *Gxy*=shear modulus in the *xy* plane.

It is worth noticing that in the case of plane stress in an anisotropic material the following equation holds

$$E_x\nu_{yx}=E_y\nu_{xy}$$

Fig 3: Contact/Interaction Areas Between Infill Masonry Wall and Surrounding Frame for Different Opening Percentages



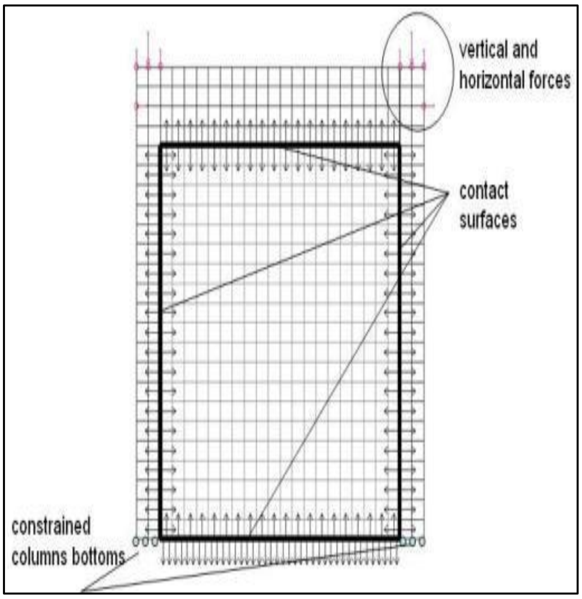
In order to model the surrounding frame he use the same constitutive relation that is used for the modeling of masonry material giving the same value for the modulus of elasticity (*Ex*) in the *x* direction and (*Ey*) in the *y* direction.

A parametric study has been carried out using as parameters the position and the percentage of the masonry infill panel opening for the case of one-storey one-bay in filled frame. The investigation has been extended to the case of multistory, fully or partially in filled frames. In particular, the redistribution of action effects of in filled frames under lateral loads has been studied. It is shown that the redistribution of shear force is critically influenced by the presence and continuity of infill panels. The presence of infill leads, in general, to decreased shear forces on the frame columns he shows. However, in the case of an in filled frame with a soft ground storey, the shear forces acting on columns are considerably higher than those obtained from the analysis of the bare frame that he investigated and shown in present paper.

Iwabuchi K., Fukuyama H. and Suwada H. **[7],** proposes a new technique for structural control of RC buildings with soft storey by 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 Cementitious 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-storey soft storey RC 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 storey 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.

Amato G., Cavaleri L., Fossetti M. and Papia M. **[5],** studied the influence of vertical load on the equivalent diagonal strut model. An equivalent diagonal pin-jointed strut model, able to represent the stiffening effect of the infill in presence of vertical loads, is given in this paper.

Fig 4: Finite Element Discretization of the Infill Frame Mesh

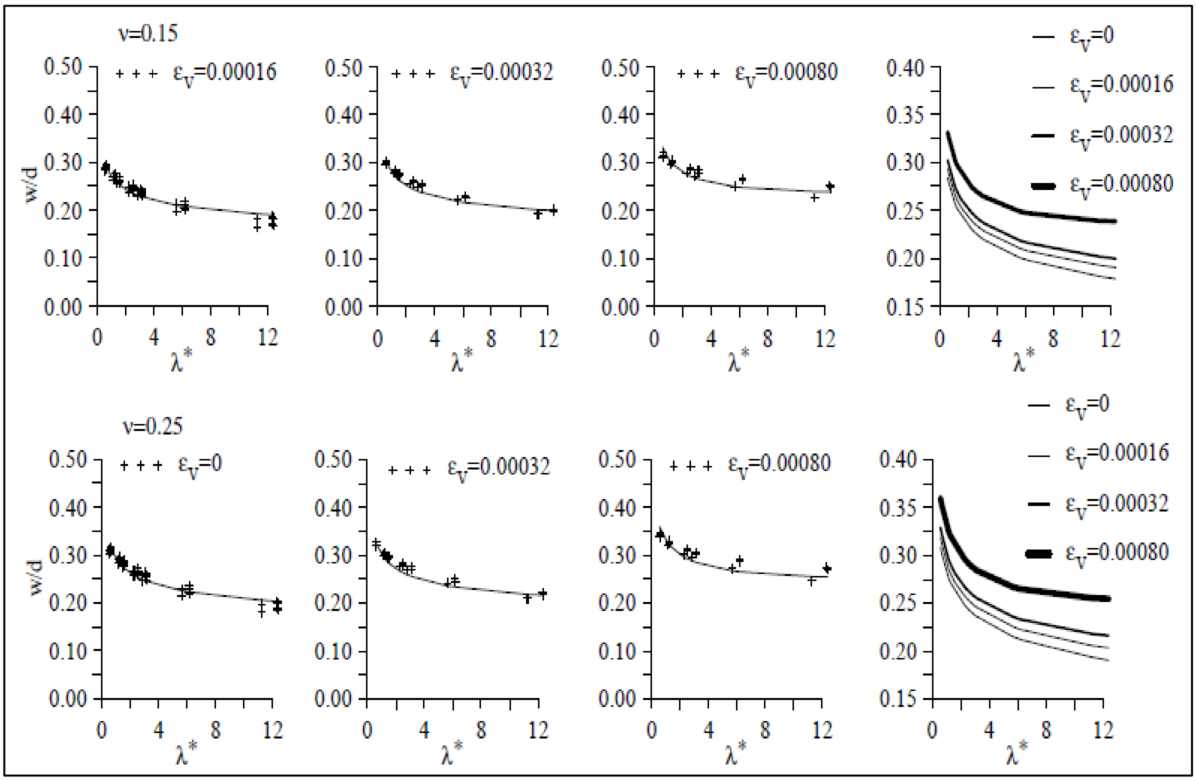


By a numerical experimentation based on a FEM discretization of the frame-infill system, the lateral stiffness of some infill frames is evaluated; then the ideal cross-section of the strut equivalent to the infill is obtained for different levels of vertical loads by imposing the equivalence between the frame containing the infill and the frame containing the diagonal strut. This way a correlation available in the literature between a parameter depending on the characteristics of the infill frame and the equivalent strut width is generalized here to consider the vertical load presence. This correlation is provided in an analytical approximated form of immediate use in the practical applications.

In this paper the mechanical behavior of single store-single bay infill meshes has been discussed and an analytical procedure available in the literature for the identification of a pin-jointed strut equivalent to the infill has been generalized to take the influence of vertical loads into account.

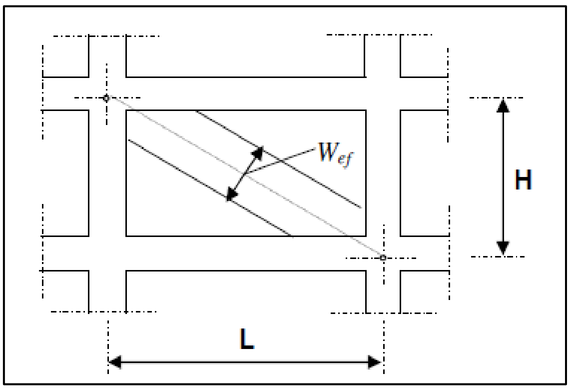
In details a numerical investigation on infill meshes has proved that also in the presence of vertical load it is possible a strong correlation between the dimension of the equivalent diagonal strut model and a single parameter which depends on the characteristics of the system.

Fig 5: Comparison Between Results Obtained by the Numerical Analysis and the Analytical Curves



Moreover the numerical results can be fitted by a law derived by the one proposed by Papia et al. (2003) using a multiplier which is a linear function of the vertical load acting on the system. A family of curves has so been obtained for different values of vertical load.

Fig 6: Compression Diagonal Model



Korkmaz K. A., Demir F. and Sivri M.[6], studied a 3-storey R/C frame structure with different amount of masonry infill walls is considered to investigate the affect of infill walls on earthquake response of these type of structures. The diagonal strut approach is adopted for modeling masonry infill walls. The elastic in-plane stiffness of a solid unreinforced masonry infill wall is represented with an equivalent diagonal compression strut of width Wef is given by

$$W_{ef} = 0.175 \left(\lambda_h H\right)^{-0.4} \sqrt{H^2 + L^2}$$

where

$$\lambda_h = \sqrt[4]{\frac{E_i \, t \sin 2\theta}{4 E_c \, I_c \, H_i}}$$

Where, H and L are the height and length of the frame, Ec, and Ei are the elastic moduli of the column and of the infill panel, t is the thickness of the infill panel, q is the angle defining diagonal strut, Ic is the modulus of inertia of the column and Hi is the height of the infill panel. In the present paper adopting diagonal strut model, the numerical analysis is carried out by considering specific frame to investigate its earthquake response. Pushover curves are obtained for the structures using nonlinear analyses option of commercial software SAP2000.

Nonlinear analyses are realized to sketch pushover curves and results are presented in of masonry infill wall on the performance of the structure are studied. From the pushover curves, storey displacements, relative storey displacements, maximum plastic rotations are determined. Regarding with the analysis results, the effects of irregularities are determined in the structural behavior under earthquake.

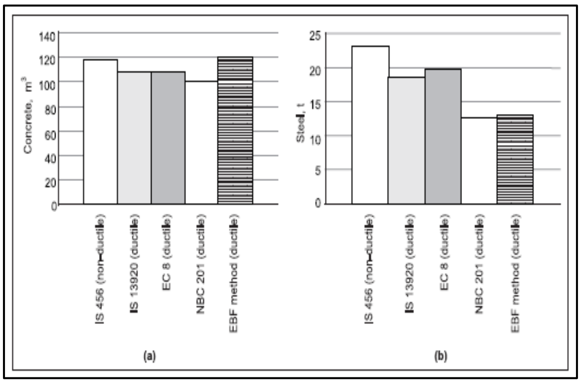
The results of the present study show that structural infill walls have very important effects on structural behavior under earthquake effects. Structural capacity under earthquake effect, displacement and relative storey displacement are affected by the structural irregularities. Regarding with the results of the pushover analyses, especially, infill walls have very important effects on structural behavior. In the present study, the infill walls are under investigation via nonlinear analyses. To determine the earthquake performance of the structural systems, nonlinear static pushover analyses are used instead of time history analyses. 3-storey R/C frame structure is used and this structure is designed according to Turkish Standard TS 500 and Turkish Design Code ABYYHY 1998. Five different Models of this structure with different wall application are taken into consideration for nonlinear static pushover analyses. The results of elastic analysis show that the presence of nonstructural masonry infill walls can modify the global seismic behavior of framed buildings to a large extent. The stability and integrity of reinforced concrete frames are enhanced with masonry infill walls. Presence of masonry infill wall also alters displacements and base shear of the frame. Irregular distributions of masonry infill walls in elevation can result in unacceptably elastic displacement in the soft storey frame. The behavior of structure with unfilled walls can be predicted by means of simplified diagonal models. Relatively simple and accurate approach can be obtained by using these models for including the effects of the infill walls.

Das D. and Murty C.V.R. [1], studied the comparative design of RC framed building with various codal provisions and with Equivalent braced Framed Method in the point of view of economy.

The design was worked with brick masonry infill in RC framed structure for the same seismic hazard in accordance with the applicable provisions given in Euro code 8, Nepal building Code 201 and comparison and the effects of irregular configuration

Indian Seismic Code and the Equivalent braced Framed Method. They designed the typical building in accordance with above codal provisions. They calculate the quantities of concrete and steel required for the design building according to above codal provisions and gives chart of respected quantities and they finally found that there is concrete quantities are comparable where as reinforcing steel required in building designed by Nepal Building Code 201 and Equivalent braced Framed method are about half of that in other three building. Therefore they conclude that the building designed by Nepal Building Code 201 and Equivalent braced Framed Method are economical.

Fig7: Quantity of Concrete and Steel in Building with Various Building Code Procedures.



Binici B. and Ozcebe G. **[14],** 2006 Turkey earthquake demonstrated the vulnerability of existing structures to large seismic demands that were not accounted in their design, hence there is an urgent need of development reliable and efficient upgrade method. In this study the author shown that, the use of fiber reinforced polymers (FRPs) was found to be an effective alternative with rapid retrofit time and providing substantial increases in strength with limited ductility. First of all they point out the observed behavior of analytical model of FRP strengthen reinforced concrete frames with infill wall on which the experiments was conducted with two dominant failure modes. First failure mode is mainly due to insufficient anchor depth and can be avoided by increasing the depth and number of anchor dowels. Second failure mode marks the limiting strength of the strengthened infill. The analytical model of strengthened frame proposed in this study is shown in figure 11.

Infill wall strengthened by using FRPs are modeled as compression strut and tension ties. The area of the composite tension ties is suggested as

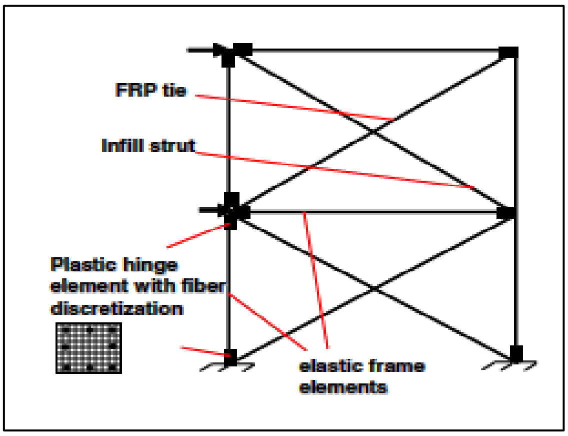
$$A_{tie} = w_f t_{tie}$$

And area of infill strut is by

$$A_{st} = w_s t_{st}$$

The experimental studies were carried out by Erduran in 2002-03 and Akguzel in 2003. Also Erdem tested two three-bay two-storey frames, one bare frame and one infill frame strengthened with FRPs. Akguzel tested four two-storey one bay frame, two of them are unstrengthened and two with FRP upgrade. They were given two charts, first showing material used, and their behavior in respect of compressive strength, tensile strength and modulus of elasticity. Second chart shows the details of sizes of

Fig 8: Analytical Structural Model



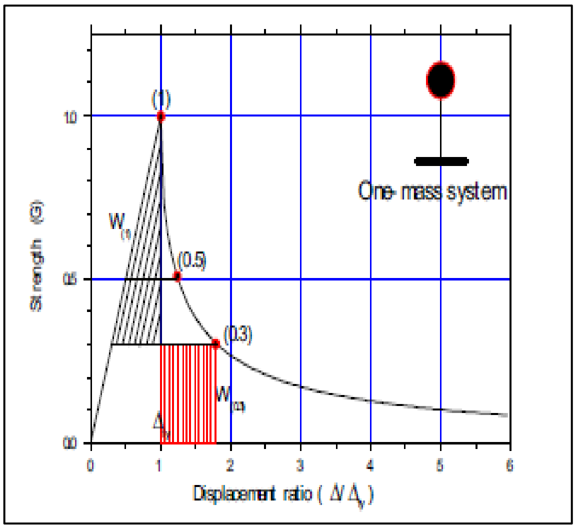
Columns, beams and anchors. They also gave the roof displacement behavior with applied load comparatively. The experimental verification was studied on the model. Finally they conclude that, with the FRP retrofit scheme, it is possible to achieve strength levels similar to those that can be obtained by addition of shear wall. Although not as ductile as the frame with a shear wall, the FRP retrofitted frame had a displacement ductility of about four. It can be concluded that in the presence of sufficient area of infill walls that can be strengthened with FRPs this retrofit alternative can provide rapid retrofits removing the need to relocate the occupants. In this way, it can be possible to retrofit regions with thousands of buildings within months.

Ramdane K., Kusunoki K., Teshigawara M. And Kato H.[13], proposeda new seismic design procedure in this paper that could secure the structural safety of soft first storey buildings during severe earthquake motions by allowing column sideway mechanism at the first storey. They conducted a non-linear numerical analysis on typical RC building of 6, 10 and 14 stories with soft first storey to evaluate the seismic capacity of building and to improve the seismic design method of 1995 Japanese Seismic Design Code. The expression of strength increasing factor αp is derived based on the energy constant law and it compared and verified with the results of the numerical analysis.

In this paper, a outline of the Seismic Design Code in Japan, failure mechanism of soft storey building, Model of the structure and method for deriving the factor αp to determine the failure modes of building with a soft storey from the failure modes of columns and walls at the soft storey are given.

Nagae T and Hayashi S.[2], In 1995 Hyougoken Nanbu Earthquake, the soft-first-storey buildings suffered significant damage because the buildings had to consume most of energy by the soft-first-storey 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

Fig 9: Energy Constant Law



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-storey buildings 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 storey 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 storey 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.[8], 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 a example building with soft first storey with the help of five different mathematical model. In their study they used a 3D analyticalmodel 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 storey stiffness. The first storey stiffness comes out to be 70% of second storey stiffness. The use of cross bracings reduces the moments by 50-60% as compared to soft storey model. Shear wall are found to be most effective in reducing the stiffness irregularity, storey drift and strength demand in the first storey. When shear wall introducing, the stiffness of first storey increased to 80% and moments are reduce by 50-60%.

Kazuhiro K. and Shinji K.[15], studied the earthquake resistant performance of plane RC frames strengthened by multi-storey steel brace. They were carried out the tests under cyclic loads reversals focusing on the base uplift rotation of the brace and the entire flexural failure at the bottom of brace caused by tensile yielding of all longitudinal bars in a RC edge column beside the brace. They were carrying the test on two specimens. The reinforcement details and section dimension are given by them. They tested three days to the structure with two stories providing the steel brace at central day.

They also gave the loading method and instrumentation in this paper. Each column axial load was kept constant. The specimen was controlled by the drift angle for one cycle and two cycles. The drift angle is defined as the horizontal displacement at the center of top floor beam divided by the height between the center of foundation beam and top floor beam. Lateral force and column axial load were measured by load cells.

They were given the graph which showing the relation between storey shear and drift angle for both specimen.

They were also given the graph showing relation between axial force acting on vertical steel rim and RC edge column and drift angle as well as for horizontal shear force resisted by steel brace and drift angle relation between tensile stresses and drift angle. Then the discussion shows measured strength and computed strength with respect to lateral strength.

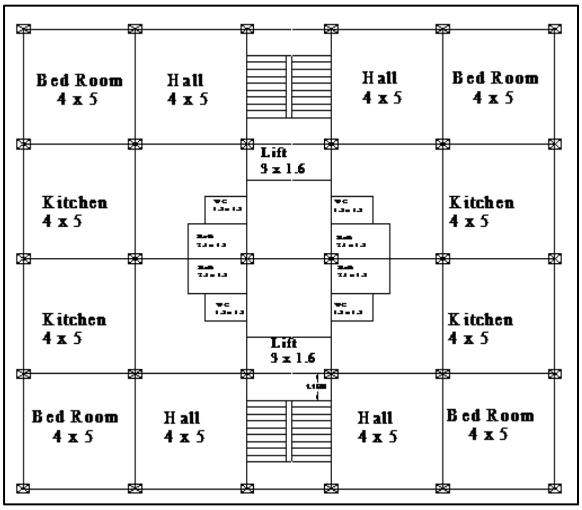
They show the contribution to lateral resistance for both specimen but specimen no. 1 was failed by uplift relation and specimen no. 2 was failed by entire flexure. Finally they conclude that earthquake resistant performance of strengthened R/C frames which suffer the entire flexural failure at the bottom of a multistory steel brace is superior to that in the brace uplift rotation failure within the range of the drift angle of 2%.

2.0 Building Description

To study the behavior of RC frame building with soft storey, an apartment building with simple symmetric plan is selected. Height of each storey is 3m. The building has plan dimensions 19m x 20m and is symmetric in both orthogonal directions as shown in figure 10. The building is assumed to be located in seismic zone III and it has 15 stories and total eleven plane frames in all directions. It is assume to be built on hard soil strata. In the analysis ordinary special RC moment-resisting frame (OMRF) of M 25 Grade concrete is considered.

ANSYS finite element software is used for analysis of different plane frames, frames with soft storey at different levels. For better understanding of pure seismic response of RC frames with soft stories at different levels, only seismic forces are considered on frames at different floor level.Size of all beams are 250mm x 400mm, Size of all columns are 400mm x 500mm, Slab thickness is 150mm, Wall thickness is 230mm and Storey Height is 3000mm used for analysis.

Fig 9:. Proposed Line Plan of RCC Apartment Building



Unit weight of concrete and brick masonry is 25kN/m3 and 19kN/m3respectively taken. Modulus of Elasticity of concrete [17] =5000√*fck* = 25000N/mm2, Modulus of Elasticity of brick masonry [1] = 6300 N/mm2, Poisons Ratio of concrete = 0.3, Poisons Ratio of masonry = 0.25 are used.

The modeling is done using the ANSYS finite element software. Beams and columns are modeled as two nodes beam element with six DOF at each node in preprocessor. Walls are modeled by Equivalent Strut Approach. The diagonal length of the strut is same as the brick wall diagonal length with the same thickness of strut as brick wall, only width of strut is derived manually. The strut is assumed to be pinned at both the ends to the confining frame. In the modeling material is considered as an isotropic material.

The following models have been studied and performance analysis is done in general post-processing of ANSYS software.

Model I: Building having brick infill masonry wall at all stories.

Model II: Building having no wall in the ground storey and brick infill masonry at remaining upper stories.

Model III: Building having no wall in the ground floor and second floor, brick infill masonry at remaining stories.

Model IV: Building having no wall in the second floor and fifth floor, brick infill masonry at remaining stories.

Model V:Building having no wall in the fifth floor and seventh floor, brick infill masonry at remaining stories.

Model VI: Steel bracing in stair case portion in longitudinal direction frame with infill remaining portion.

Model VII: Building having brick wall in side panel at ground floor and no wall in middle portion of ground floor in transverse direction.

Model VIII: Building having Steel Bracing in side panel at ground floor and no wall in middle portion of ground floor in transverse direction.

3.0 Structural Analysis

Self weight of beams, columns; slabs, infill wall panels, Stair case weight and weight of RCC lift duct and is calculate from assumed dimensions.Intensity of live load is taken as 2 kN/m2 at each storey, except roof floor.According to IS 1893 (part 1): 2002, for Zone III, seismic coefficient method is used to calculate the seismic forces and base shear. Seismic forces at each storey level are calculated by distribution formula.Vertical distribution of base shear to different floor along the height of building is given by formula,

$$Qi = \frac{V_B \times Wi \times Hi^2}{\sum Wi \times Hi^2}$$

Where, Qi is lateral forces at roof of floor i in kN and Hi is Height floor measured from the base of building in m.

Equivalent Diagonal Strut Width (Wef) is calculated by using

Formula

$$W_{ef} = 0.175\,(\lambda_h\, H)^{-0.4}\,\sqrt{H^2 + L^2}$$

where

$$\lambda_h = \sqrt[4]{\frac{E_i\, t \sin 2\theta}{4 E_c\, I_c\, H_i}}$$

Where, H and L are the height and length of the frame, Ec, and Ei are the elastic moduli of the column and of the infill panel, t is the thickness of the infill panel, q is the angle defining diagonal strut, Ic is the modulus of inertia of the column and Hi is the height of the infill panel.

3.0 Results and Discussion

The present study highlights the seismic performance of RC frame building with soft stories at first as well as at different floor level. The performance characteristics such as stiffness, deflection, shear force and bending moment are studied.The analysis results of different models are discussed. The modeling and post-processing is carried out using ANSYS software. The comparisons of different parameter of models have also been presented in this study.The present study highlights the seismic performance of RC frame building with soft stories at first as well as at different floor level. A parametric study is performed on an example building with soft storey and it is intended to describe the performance characteristics such as stiffness, deflection, shear force and bending moment.In this chapter the analysis result of different models are discussed. The modeling and post-processing is carried out using ANSYS software. The comparisons of different parameter of models have also been presented in this study.

Storey Stiffness: In present analysis, for calculation of storey stiffness for building models Ito Vin transverse as well as longitudinal direction, the blank lower storey without infill and corresponding upper storey with infill are considered. The storey stiffness is defined as the magnitude of the force couple required at the floor levels adjoin the storey to produce a unit lateral translation within the storey, letting all the other floors to move freely. For stiffness calculation separate modeling of building frame is done in ANSYS software and from result of deflection storey stiffness is worked out.

For different building frame models the stiffness of storey without infill and corresponding upper storey as well as presence of soft storey is shown in table no. 1

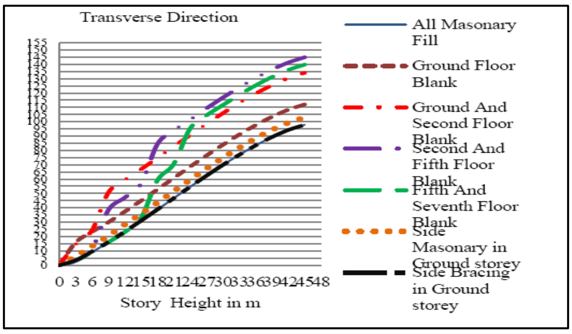
Table 1: Storey Stiffness

Model Name1	Lower Storey	Storey Stiffness		Ki	$0.7K_i$-1	Is It Soft Sotrey? (Ki< 0.7Ki-1)
		Blank Storey	Upper Storey			
Model 1st	G-Floor	361010.8	361010.83	361010.8	252707	No
Model 2nd	G-Floor	121876.9	354484.23	121876.9	248139	Yes
Model 3rd	G-Floor	125580.8	343760.74	125580.8	240632	Yes
Model 4th	2nd-Floor	126103.4	359841.67	126103.4	251889	Yes
Model 5th	2nd-Floor	125580.8	343760.74	125580.8	240632	Yes
	5th-Floor	126103.4	360620.27	126103.4	252434	Yes
	5th-Floor	125580.8	343760.74	125580.8	240632	Yes
	7th-Floor	126103.4	360620.27	126103.4	252434	Yes

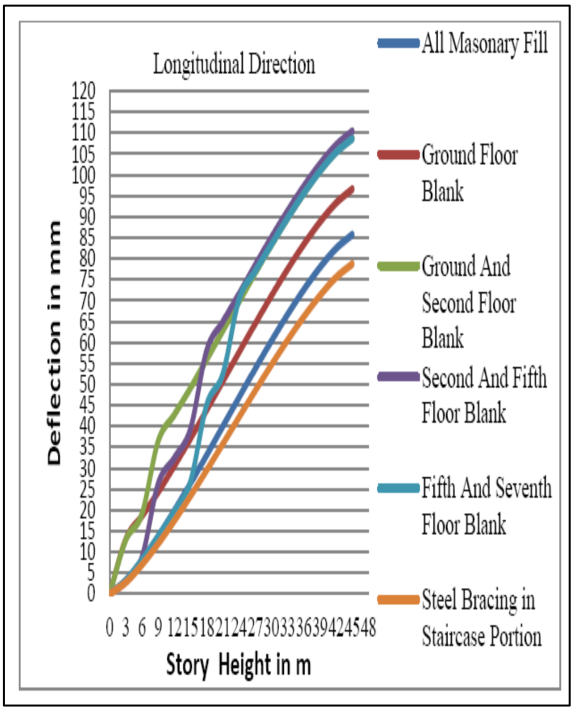
Table 2: Maximum Displacement

Building Models	Maximum Displacement (mm)	
	Transverse Direction	Longitudinal Direction
Model I	98.76	87.84
Model II	112.81	98.73
Model III	134.70	110.89
Model IV	145.49	112.71
Model V	140.39	111.15
Model VI	-	81.78
Model VII	103.82	-
Model VIII	98.75	-

Graph 1 Lateral Deflection of Different Models of Building Frame in Transverse Direction



Graph 2: Lateral Deflection of Different Models of Building Frame in Longitudinal Direction



Graph 3: Bending Moments of Different Models of Building Frame in Transverse Direction

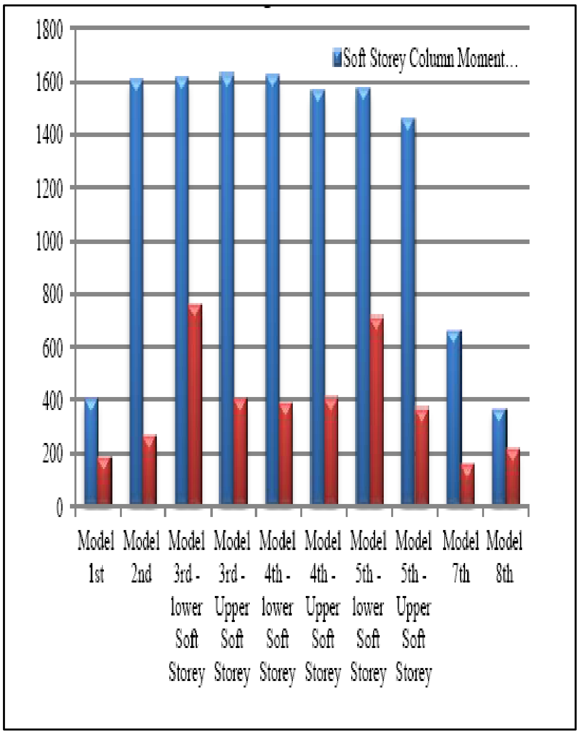


Table 3: Transverse Frames Bending Moment and Shear Force

Transverse Frame							
Parameter		Maximum Moment (kN-m)		Maximum Shear Force(kN)			
				Along X Direction		Along Y Direction	
Model Name	Lower Floor	Blank Storey	Upper Storey	Blank Storey	Upper Storey	Blank Storey	Upper Storey
Model 1^{st}	G-Floor	404.61	183.39	3249.3	3069.8	134.87	61.13
Model 2^{nd}	G-Floor	1608.0	262.80	3242.3	3134.3	536.01	90.919
Model 3^{rd}	G-Floor	1611.0	758.53	3259	3205.7	537.01	252.84
	2^{nd} - Floor	1627.4	403.20	2639.3	2562.6	536.84	134.40
Model 4^{th}	2^{nd} - Floor	1622.2	388.51	2681	2602.3	540.74	129.50
	5^{th} - Floor	1562.0	407.49	1770.6	1697.0	520.66	135.83
Model 5^{th}	5^{th} - Floor	1574.6	712.94	1814.2	1749.1	524.86	237.65
	7^{th} - Floor	1455.8	367.74	1210.3	1145.0	485.26	122.58
Model 7^{th}	G-Floor	656.88	154.35	3491.8	3112.9	218.96	51.451
Model 8^{th}	G-Floor	365.72	213.08	3367.6	3006.3	121.87	71.027

From results of stiffness, it is clear that all models except first one show soft storey. The stiffness irregularity in building models with soft storey is evident from the fact that the stiffness of blank storey for models II to V is about 35% less than that of corresponding upper storey stiffness, as the clause no. 4.20 of IS 1893 (Part I): 2002 says if storey in which the lateral stiffness is less than 70 % of that in the storey above or less than 80 % of the average lateral stiffness of the three storey above. While model I shows no stiffness irregularity as because stiffness of all floor are same as they are fully infill storey.

Lateral Displacement: Maximum displacements of different building models using equivalent static analysis are shown in following table no. 2

The Abrupt change in displacement profile indicates the stiffness irregularity. As well as graph shows that if soft storey shifted above and above the displacement values increases. As comparison of maximum displacement of model II with III and V, it concludes that while increase in number of soft storey in building displacement percentage increases upto15% to 20%. Model IV shows most severe and maximum value of displacement as compared to other models. As comparison of result of model IV with other model it is clear that if spacing between two soft stories increases deflection of building increases.

The provision of side masonry in ground floor in model VII shows 8% to 10% reduction in displacement value as compared to model II in transverse direction. As well as the provision of side steel bracing in ground floor in model VIII shows near about same value of displacement of model I and also shows smooth displacement curve. The graph of transverse direction shows grater displacement as compared to graph of longitudinal direction. Model VI shows less value of displacement as compared to other model because of provision of steel bracing in staircase portion. It shows 25% of reduction in displacement in longitudinal frame. Graph no. 1 and 2 are plotted taking storey height as the ordinate and the storey displacement as the abscissa for different models in the transverse and longitudinal direction.

Bending Moment and Shear Force: Maximum moment and maximum shear forces in soft storey columns and maximum forces in the columns of the storey above for different models for transverse frame are shown in following table no. 3

Graph no. 3 is plotted taking different models as the ordinate and the results of bending moments are as the abscissa for different models in the transverse direction.

Maximum moment and maximum shear forces in soft storey columns and maximum forces in the columns of the storey above for different models for longitudinal frame are shown in following table no. 5

Graph no. 4 is plotted taking different models as the ordinate and the results of bending moments are as the abscissa for different models in the longitudinal direction.

Graph 4: Bending Moments of Different Models of Building Frame in Longitudinal Direction

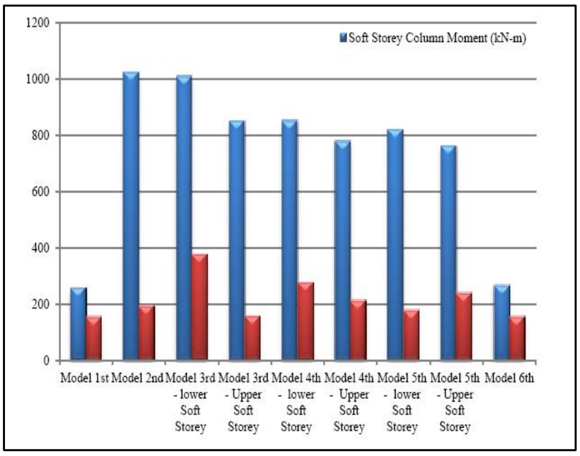


Table 4: Longitudinal Frame Bending Moment and Shear Force

Longitudinal Frame							
Parameter		Maximum Moment (kN-m)		Maximum Shear Force(kN)			
				Along X Direction		Along Y Direction	
Model Name	Lower Floor	Blank Storey	Upper Storey	Blank Storey	Upper Storey	Blank Storey	Upper Storey
Model 1st	G-Floor	256.34	155.26	3110.4	2921.2	170.89	116.97
Model 2nd	G-Floor	1022.2	194.37	3096.6	2973.9	681.46	129.58
Model 3rd	G-Floor	1008.7	375.70	2991.6	2932.9	660.09	125.23
	2st-Floor	848.34	157.55	2530.5	2464.6	419.25	155.87
Model 4th	2st-Floor	850.54	275.84	2483.1	2416.6	443.23	183.89
	5th-Floor	778.37	213.71	1750.6	1687.2	412.43	134.64
Model 5th	5th-Floor	818.91	178.73	1676.6	1619.9	418.92	119.15
	7th-Floor	760.75	239.64	1240.9	1181.2	394.99	159.76
Model 6th	G-Floor	266.64	155.90	2938.4	2786.8	177.76	103.93

The results show that the bending moment and shear force (strength) demands are severely higher for soft storey columns, in case of the soft storey buildings. As the force is distributed in proportion to the stiffness of the members, the force in the columns of the upper storey above soft storey, for all the models are significantly reduced due to the presence of brick infill walls.

From comparison of results of bending moment of full infill model (Model I) with soft storey model (Model II to V), it is clear that presence of soft storey in building increases bending moments by 75% in soft storey columns. In model II, the bending moments are 85% higher in soft storey columns as compared with upper infill storey columns. In model III, the bending moments are 53% higher in ground soft storey are 75% higher in 2nd floor soft storey columns as compared with upper infill storey columns respectively.

The provision of side masonry in ground floor in model VII shows 60% reduction in bending moment value as compared to model II in transverse direction. As well as the provision of side steel bracing in ground floor in model VIII shows near about same value of bending moment of model I in transverse direction. The provision of steel bracing in staircase portion in model VI does not affect much more the results of bending moment with comparison of model I results in longitudinal frame.

5.0 Conclusions

In multistoried building for parking of vehicles, ground storey is always used with open spaces. As well as by adoption of new practices, now a day's parking area is also provided in upper stories. But it is necessary to check their behavior during earthquake. So the present study as a dissertation part highlights the behavior of RC frame with soft storey at ground floor as well as at upper stories also. From results of analysis the following conclusions are found.

Parametric analysis on multistoried infill reinforced concrete structures show that, due to the hysteretic energy dissipation in the infill, if the infilling is uniform in all storey, drifts and structural damage are dramatically reduced, without an increase in the seismic force demands.

Presence of soft storey effects due to the absence of infill wall in the bottom storey in building is a measure problem in earthquake, as soft storey is significantly less strong or more flexible, a large portion of the total building deflection tends to concentrate in that floor with consequent concentration of stress at the second floor connections and in that case collapse is unavoidable. The stiffness irregularity in building models with soft storey is evident from the fact that the stiffness of blank storey is less than that of corresponding upper storey stiffness. If soft storey 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 and side steel bracing significantly increase stiffness and it considerably reduce the lateral deflection and show smooth drift profile without affecting parking utility. Steel bracings are found to be most effective in reducing stiffness irregularity, storey drift and strength demand in building with soft storey without affecting utility. In case of the soft storey buildings the bending moments and shear forces value are severely higher for soft storey columns as compare to upper storey columns.

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