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SEISMIC ANALYSIS OF SOFT STOREY BUILDINGS

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Abstract—Vehicle parking is a major concern in urban areas due to increased occupancy. Hence in most buildings, the lowermost storey is used for parking. RC framed buildings with open first storey (soft storey)are known as soft storey buildings. Earthquakes that occurred recently have shown that a large number of existing reinforced concrete buildings especially soft storey building are vulnerable to damage or even collapse during a strong earthquake. In this study, seismic behaviour of various models of soft storey framed buildings enhanced with shear walls, bracings and stiffer columns are compared with that of a soft storey framed model. Software ETABS is used to perform response spectrum analysis and parameters such as base shear, stiffness, interstorey drift and storey displacement are studied.

Index Terms— *ETABS, Inter Storey Drift, Linear Dynamic analysis, Seismic analysis, Shear Walls, Soft storey, Stiffness*.

1 INTRODUCTION

Parking floor has become an inevitable feature for most of the urban multi-storied buildings. First storey of a building is usually made open without any infill wall to facilitate vehicle parking. A soft storey building is a multi-story building with wide doors, commercial spaces, or the ground storey left open for the purpose of parking , i.e., columns in the ground storey do not have any partition walls (of either masonry or RC) between them. As per IS-1893:2002 (part I), a soft storey is the one 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 storeys above.

An extreme soft storey is the one in which the lateral stiffness is less than 60 % of that in the storey above or less than 70 % of the average stiffness of the three storeys above.

2 SOFT STOREY FAILURE

Earthquake produces low –high waves which vibrate the base of structure in various manners and directions, so that lateral force is developed on structure. In such buildings, the stiffness of the lateral load resisting systems at those stories is quite less than the stories above or below. Such building act as an Inverted Pendulum which swing back and forth producing high stresses in columns and if columns are incapable of taking these stresses or do not posses enough ductility, they could get severely damaged and which can also lead to collapse of the building.

Fig.1. Soft storey building failure during Gujarat Earthquke (2001) in India

The primary purpose of all kinds of structural systems used in the building 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 load such as earthquake load. Earthquake 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.

3 RESPONSE SPECTRUM ANALYSIS

In engineering purpose, the time variation of ground acceleration (motion) is the most useful way of defining the shaking of ground during an earthquake. It is expressed by time history graph. Response is the behaviour of single degree of freedom (SDOF) system against the existing ground motion which differs for the different building according to natural period of the system. Response is very useful tools for the designing of the structure according to the safety during an earthquake. Response spectrum is a graphical relationship of maximum values of acceleration, velocity and deformation response of an infinite series of elastic single degree of freedom (SDOF) systems subjected to time dependent dynamic excitation. Now days it is a central concept in earthquake engineering, the response spectrum gives a convenient means to understand the peak response of all possible linear SDOF systems to a particular component of ground motion. Response spectrum is discussed in the form of Deformation response spectrum; Pseudo-Velocity response spectrum and Pseudo- Acceleration response spectrum. In this work, response spectrum analysis is used.

3.1 DESIGN SPECTRUM

As per IS 1893 : 2002 (part 1), for the purpose of determining seismic forces, India is classified into four seismic zones. The design horizontal seismic coefficient A_h for a structure shall be determined by the following expression:

$$A_h = Z\ I\ S_a / 2\ R\ g \quad (1)$$

(Provided that for any structure with T ≤ 0.1 s, the value of A_h will not be taken less than Z/2 whatever be the value of I/R)

Where,

Z - Zone factor, is for the Maximum Considered Earthquake (MCE) and service life of structure in a zone. The factor 2 in the denominator of Z is used so as to reduce the Maximum Considered Earthquake (MCE) zone factor to the factor for Design Basis Earthquake (DBE). In the work Z is provided as 0.16 for moderate seismic intensity and seismic zone III.

I - Importance factor, depending upon the functional use of the structures, characterised by hazardous consequences of its failure, post-earthquake functional needs, historical value, or economic importance. In the work I value is given as 1 as per table 6 in the code.

R - Response reduction factor, depending on the perceived seismic damage performance of the structure, characterised by ductile or brittle deformations. However, the ratio (I/R) shall not be greater than 1.0. R is given as 3 as per code for Ordinary Moment Resisting Frame (OMRF).

S_a/g - Average response acceleration coefficient. The value depends uponthe soil type and the selected soil type is type III soft soil.

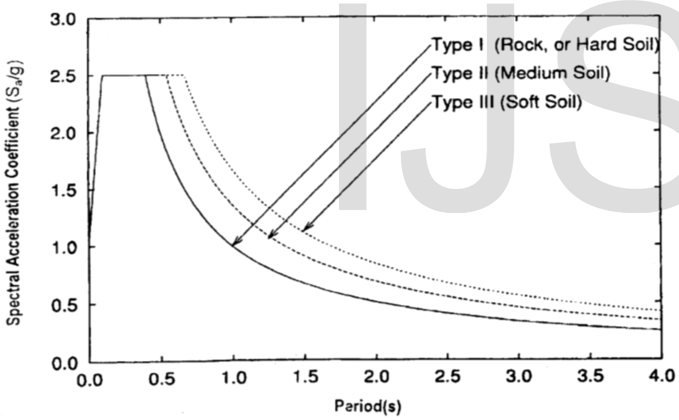


Fig.2. Design Response Spectra with 5% damping given in IS 1893: 2002 (part 1)

4 MODEL SPECIFICATIONS

Four different models were considered for the analysis and they are:

Model 1: Building with ground storey as soft storey.

Model 2: Building with cross bracings at the corner bays of the soft storey.

Model 3 : Building with shearwalls at corner bays.

Model 4 : Building with thicker columns in the soft storey.

For this study, a 5-storey building model with a 3.5-meters length for each bay, regular in plan was chosen.The buildings were assumed to be fixed at the base. The buildings were modeled using software ETABS. Models were studied by comparing storey displacement, storey stiffnes and inter storey drift in X and Y direction for all structural models under consideration.

The dimensions and loads were selected according to IS 456 : 2000 and IS 875 : 1987 codes.

Storey height	3.5m
Ground Storey height	4m
Column Size	0.40m X 0.40m
Beam Size	0.30m X 0.30m
Slab thickness	0.15m
Grade of Concrete	M30
Grade of Steel	Fe 415
Live load on floors	2 kN/m²
Live load on roof	0.75 kN/m²
Shear wall thickness	0.23 m
Floor finish	1 kN/m²

In model 2, size of concrete bracing is taken as 0.23m x 0.23m and in model 4, thickness of columns in ground storey is taken as 0.50m x 0.50m. In model 3 shearwall thickness is kept as 230mm. Figure 3 and figure 4 shows the basic plan and 3D views of the models.

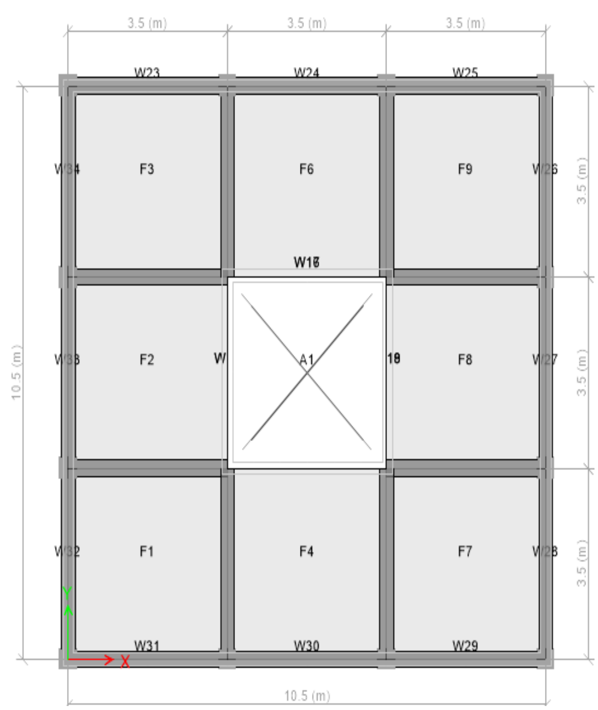
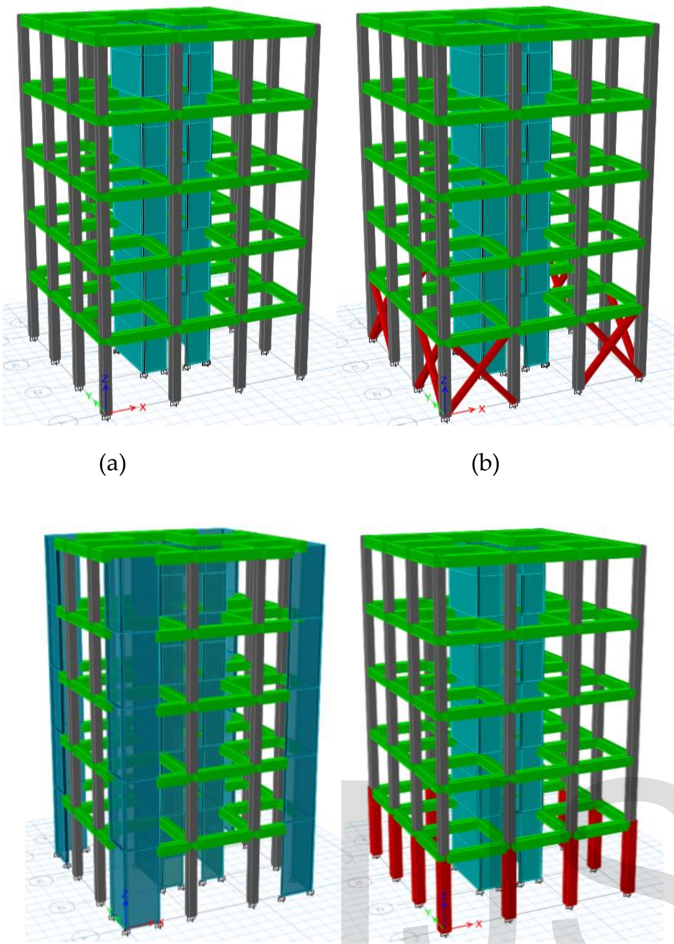


Fig.3. Plan view



(a) (b)

(c) (d)

Fig.4. (a) building with softstorey (b) building with cross bracing (c) building with shearwall (d) building with thicker columns

5 RESULTS AND DISCUSSION

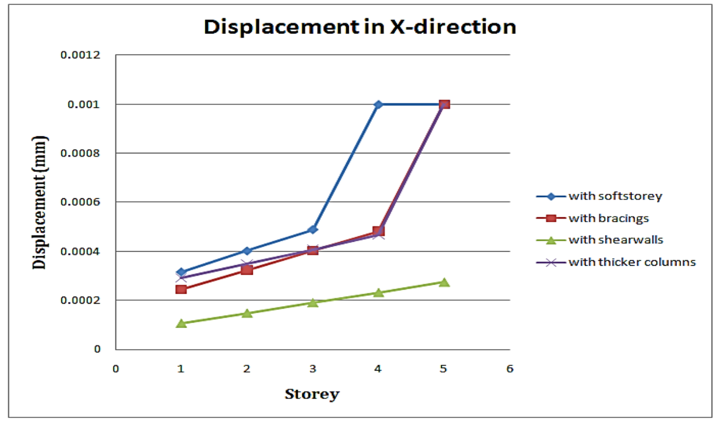
From the response spectrum analysis of the structural models the results for maximum stiffness, maximum displacement, maximum inter-storey drift, maximum base shear, etc for each storeys are tabulated and based on the values graphs are ploted.

Storey displacement : For seismic design it is important to estimate, maximum lateral displacement of the structures due to sever earthquake for several reasons.storey displacement is the absolute value of displacement of a storey with respect to ground, under the action of lateral forces. The results obtained for storey displacement is shown in figure 5.

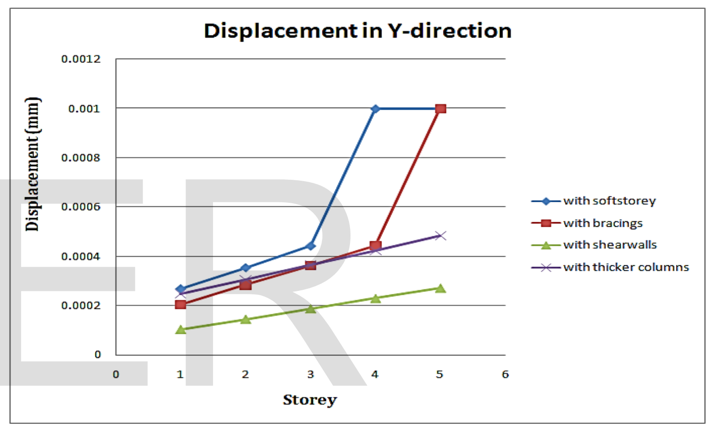
Inter storey drift: It is the difference between the roof and floor displacements of any given storey as the building sways during the earthquake, normalized by the storey height. The results are shown in figure 6.

Storey stiffness: It refers to the rigidity of a structural element.this means the extent to which the element is able to resist deformation or deflection under the action of applied force. The results are shown in figure 7.

Base shear: It is an estimate of the maximum expected lateral forces that will occur due to seismic ground motion at the baseof-structure. Obtained results are shown in figure 8.

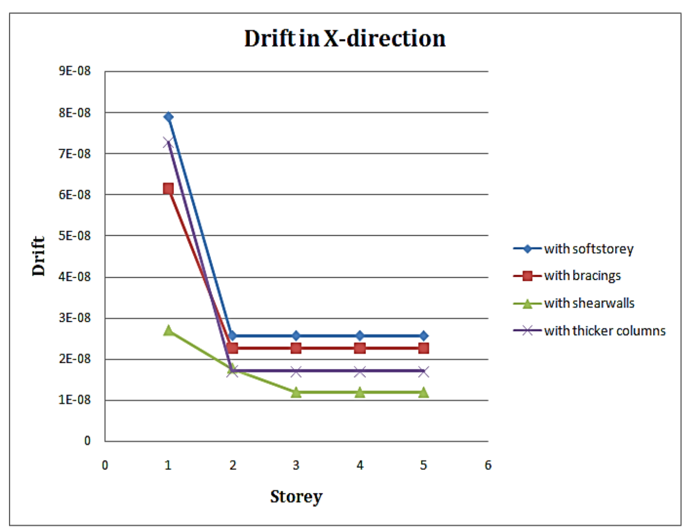


(a)



(b)

Fig.5. (a) Storey Vs Displacement in X-direction. (b) Storey Vs Displacement in Y-direction



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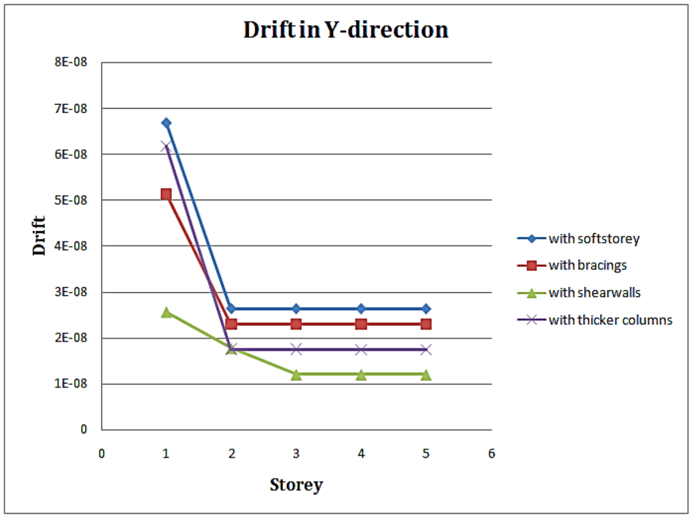
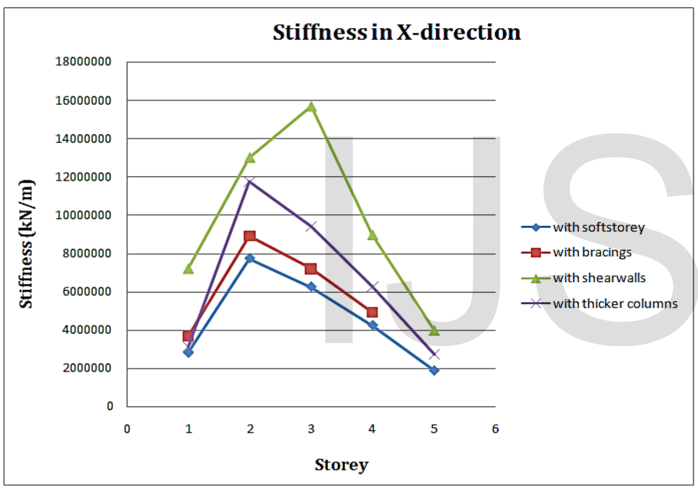
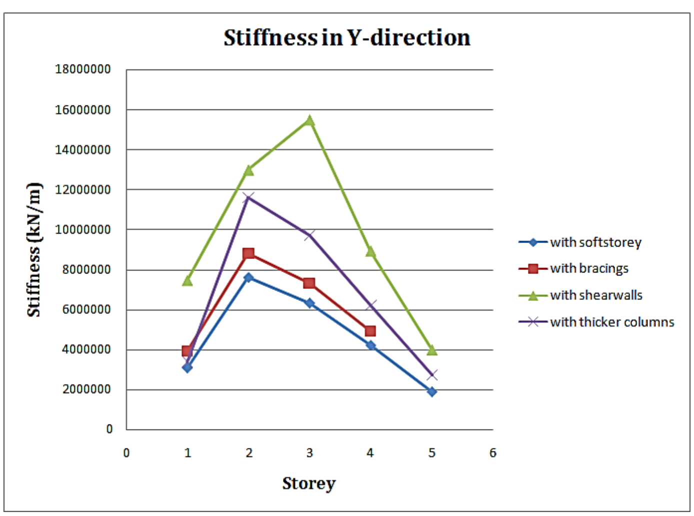


(b)

Fig.6. (a) Storey Vs Inter storey Drift in X-direction (b) Storey Vs Inter storey Drift in Y-direction



(a)



(b)

Fig.7. (a) Storey Vs Stiffness in X-direction (b) Storey Vs Stiffness in Y-direction

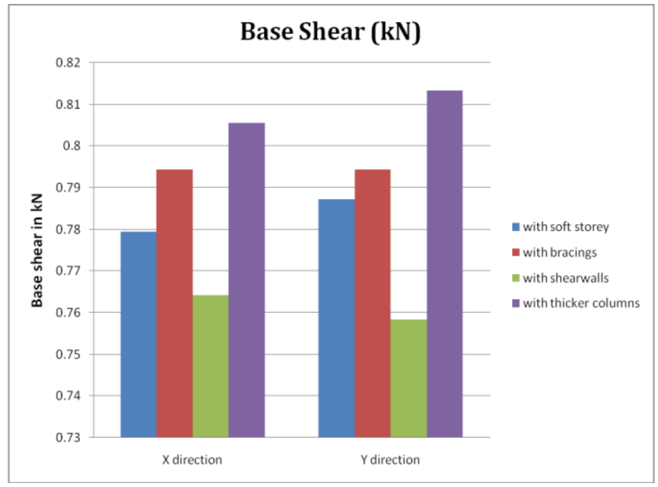


Fig.8. Base shear of models in X and Y directions.

Model 1 ie., basic soft storey structure shows high values for storey displacement & drift and low value for stiffness compared to the other models. When compared with model 1, building with cross bracing (Model 2) shows a maximum of 30.79 % increase in its stiffness and inter storey drift and storey displacement is decreased by 22.18%.The stiffness of structure with shear walls at corner is increased by 156.05% compared with model 1. Also the inter storey drift and displacement is decreased by 65% in comparison with basic model. softstorey building with stiffer ground floor columns (model 4) have 52% increase in stiffness and 53% and 33% decrease in displacement and drift respectively compared to basic model.

6 CONCLUSION

Design Response spectrum analysis was carried out on 5 storey building models as per IS 1893: 2002 (part 1). 4 different models were selected and analysis was done using ETABs 2015. Storey displacement, Inter storey drift, Storey stiffness and Base shear of each models are obtained as results and comparitive study was carried out for finding model with better performance.

- When building with shearwall is compared with building with bracings it has 95% increase in stiffness and there is 56% decrease in drift and displacement
- When the shear wall model is compared with model with thicker ground floor columns, it is found that that the shearwall model has 131% increase in stiffness and about 62% decrease in displacement and drift.
- Base shear of shearwall model is found minimum compared to other modes.

From the comparitive study it is clear that building with shearwalls at corner has better performance when seismic forces are considered.

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