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RESEARCH ARTICLE

PUSHOVER ANALYSIS OF SOFT STOREY BUILDING UNDER SEISMIC LOAD

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ABSTRACT

During an earthquake, the disaster is mainly caused due to the collapse of buildings. The main objective of the seismic analysis is to make the structure serviceable even after the minor intensity earthquake without causing any damage. It is essential to provide open ground stories also called "Soft stories" in commercial and residential buildings for parking. In this paper, a soft storey building having G+9 storey is analyzed using ETABS where the soft storey is provided on the ground floor. Static analysis is carried out by Response Spectrum method and non-linear analysis by Pushover analysis. The storey displacement, storey drift and base shear are obtained. Keeping storey drift as our main objective, the structure is analyzed by providing steel and RCC bracings in different patterns to reduce the soft storey damage due to the earthquake. It was seen that Steel X bracing shows minimum displacement and storey drift and Forward RCC bracing shows least soft storey effect.

INTRODUCTION

Earthquake is a natural disaster and the structures should have earthquake resistant features to safely resist the lateral forces. Since the structures are normally built only to carry its self-weight they are not able to resist even moderate intensity earthquakes. The lateral forces cause critical stresses and lateral sway of the structure. Urbanisation and increased demand for parking spaces have led to the provision of soft stories in the buildings. These soft stories are vulnerable to an earthquake because the stiffness of the load carrying members are reduced due to open storeys. Higher stresses are formed in the load carrying members due to increase in load and the plastic hinges are not formed in the predefined positions causing the ultimate failure of the columns. Therefore it is essential to think about the design of the soft storey buildings so as to make it safe during the earthquakes. According to IS 1893:2002 "Soft storey is one in which the lateral stiffness is less than 70 percent of that in the storey above or less than 80 percent of the average lateral stiffness of the three storeys above." Abhishek Arora (2015) found that the building with both columns and shear wall in the soft storey performed better during earthquake. Hieten.L. Kheni and Anuj.K. Chandiwala (2014) considered different models with different heights for the soft storey and the inter-storey drift of the soft storey was studied. The displacement was found lesser for the bottom stories and greater for the top stories. It was independent of the number of the stories. Raghavendra S Deshpande and Surekha A Bhalchandra (2014) studied the seismic analysis of a model with abare frame, asoft first storey with no walls, soft first storey with walls at the corners and soft first storey with stiff columns. Hefound that the lateral displacement of bare frame model was higher than that of other models. The storey displacement of thesecond model was maximum and model with walls at corners has least lateral drift. Spoorthi S K and Dr Jagadish kori G (2014) studied the soft storey effect of regular and irregular models.

All the models were analysed for 5, 10 and 15 stories. With the increase in mass, the number of stories and height of stories the base shear, storey displacement and drift also increases. These values obtained from the push over analysis were double the value obtained from thestatic analysis. It was also concluded that the lateral load carrying capacity does not increase with anincrease in the number of stories, but the storey displacement was increased.

MATERIALS AND METHODS

In this paper, a comparative study is done between a building with the soft storey and the same provided with bracings in different patterns using both linear and nonlinear analysis.

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A. ETABS Software

The software used in this study is ETABS. This is used for analysing the buildings, towers, bridges, dams, silos etc. It helps in the modelling and analysis of the complex structures easily. The analysis is carried out in accordance with IS 1893(part 1): 2002and FEMA 440 and FEMA 356 which are inbuilt in ETABS.

B. Pushover Analysis

In the pushover analysis, the structure is analysed by a set of incremental lateral loads provided over the height of the structure. The load is provided from zero to a value such that we get an ultimate displacement. Until a collapse mechanism is developed the structure will be pushed. Pushover analysis will give useful results that cannot be obtained by linear static and dynamic method. It helps to identify the critical members which is possible to reach the limit state during the earthquake by theformation of plastic hinges. Various models of the building are analysed and the storey drift is reduced within the permissible limit.

C. Modelling of the building

The analysis of the soft storey building is carried out using ETABS. The parameters such as storey drift, storey displacement and base shear using linear analysis is found. Static analysis is done by response spectrum method and non-linear seismic analysis is done by pushover analysis. In this the plastic hinges at various positions are identified. The type of building considered for the study is a regular building used for residential purpose. This building is provided with bracings in the soft storey to reduce the soft storey effect. The bracings are provided in different pattern at different locations.Fig.1 shows the plan of the building and Fig.2 shows the 3D view of the building and Fig.3 shows the plan of the Type A and Type B building.

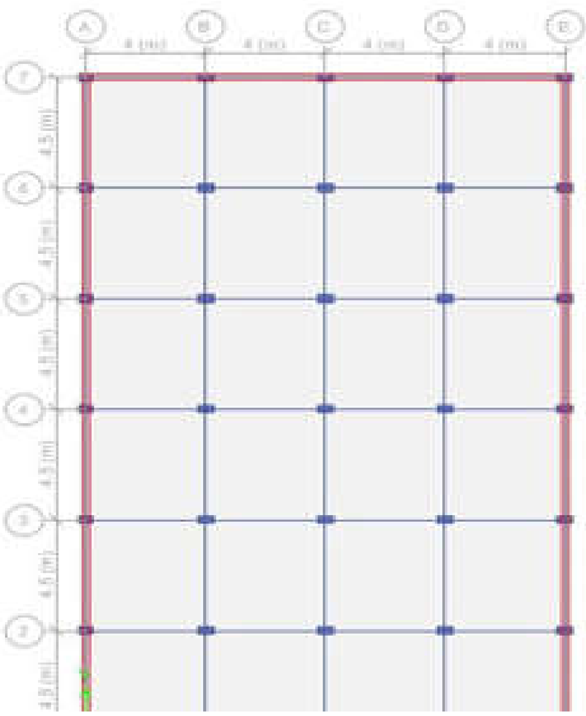

Fig.1. Plan of the building

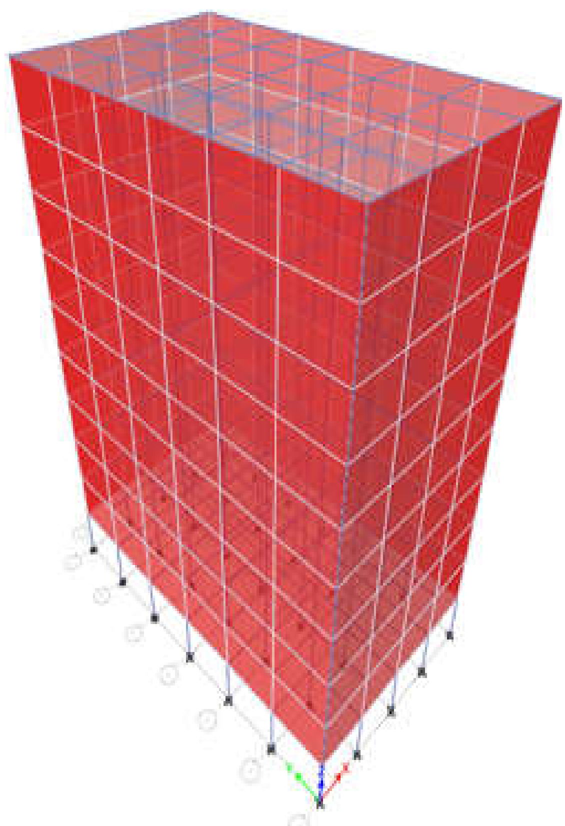

Fig.2. 3D view of building

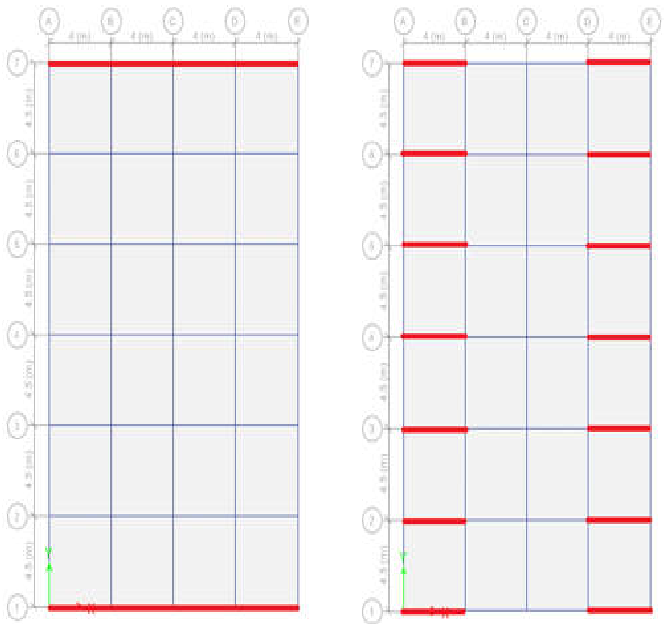

Fig. 3. Plan of Type A and Type B model

Model: With soft storey

TA1R: Backward RCC bracing in the outer frames parallel to x-axis

TA2R: Forward RCC bracing in the outer frames parallel to x-axis

TA3R: RCC X-bracing in the outer frames parallel to x-axis

TA1S: Backward steel bracing in the outer frames parallel to x-axis

TA2S: Forward steel bracing in the outer frames parallel to x-axis

TA3S: Steel X-bracing in the outer frames parallel to x-axis
TB1R: Backward RCC bracing in the frames at the edges parallel to x-axis
TB2R: Forward RCC bracing in the frames at the edges parallel to x-axis
TB3R: RCC X-bracing in the frames at the edges parallel to x axis
TB1S: Backward steel bracing in the frames at the edges parallel to x axis
TB2S: Forward steel bracing in theframes at the edges parallel to x axis
TB3S: Steel X-bracing in theframes at the edges parallel to x axis

Table 1. Data used for modelling of building

PARAMETERS	VALUES
Building type	Residential
Seismic zone	V
Importance factor	1
Soil type	II (Medium)
Response reduction factor	5
Height of storey	3.5m
Thickness of the infill wall	230 mm
Plan dimension of building	16m x 27m
Beam size	250 mm x 350 mm
Column size	450 mm x 500 mm
Thickness of slab	100 mm
Live load	4 kN/m
Water proof	1 kN/m
Floor finish	1 kN/m
Material properties	M30 grade of concrete and Fe 415 steel

RESULTS AND DISCUSSION

In this study, the non-linear response of a building with soft story at the ground floor using ETABS has been carried out. The major objective of this study is to find the maximum storey drift, storey displacement and base shear in the soft storey building as well as the soft storey building provided with bracings. The following are the graphs drawn for the soft storey building by linear static analysis.

A. Base shear

As per IS 1893(Part1): 2002 "It is the total design lateral force at the base of a structure". Table 2 and Table 3 gives the maximum values of the base shear and storey displacement of the soft storey building with steel bracing and RCC bracing respectively. From Table 2, it is found that TB1S has the highest base shear, and from Table 3, TB1R has the highest value of base shear. It means that the building provided with steel and RCC bracings in the backward direction has greater base shear values. Fig.4 and Fig.5 is the bar graph showing the maximum value of base shear of the building provided with RCC bracing and steel bracing respectively.

Table 2. Maximum base shear and storey displacement with steel bracing

Model	Base shear ($x10^3$) (kN)	Storey Displacement (mm)
MODEL	11.8	85.1
TA1S	11.2	96.3
TA2S	13.34	65.3
TA3S	11.71	20.6
TB1S	10.78	42.3
TB2S	15.19	50
TB3S	14.38	33.91

Table 3. Maximum base shear and storey displacement with RCC bracing

Model	Base Shear($x10^3$)kN	Storey Displacement (mm)
MODEL	11.48	85.1
TAIR	20.48	74.1
TA2R	19.72	71
TA3R	16.25	32.4
TB1R	20.46	53.5
TB2R	14.81	34.5
TB3R	15.63	23.3

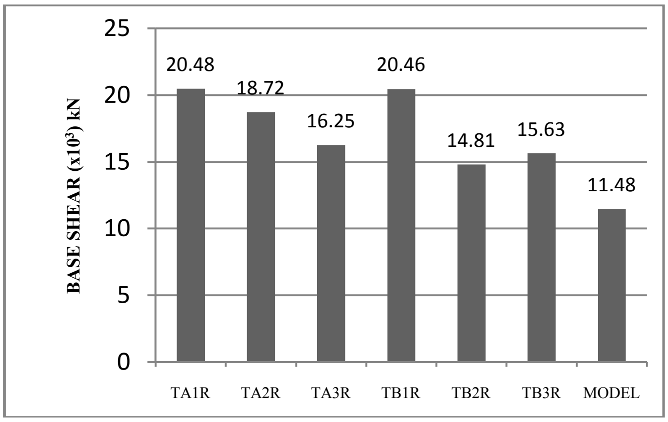

Fig. 4. Maximum Base Shear with RCC bracings

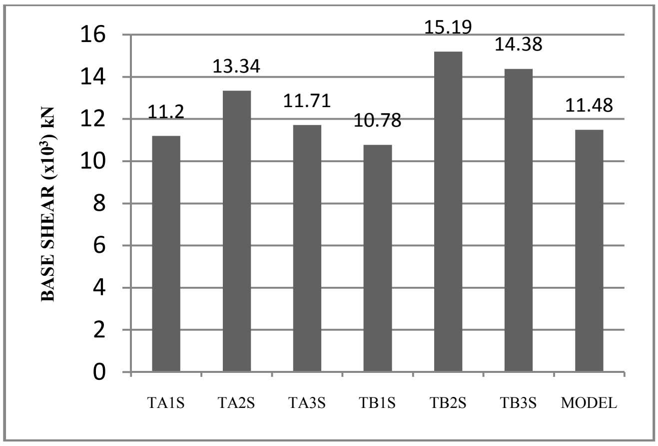

Fig. 5. Maximum Base shear with steel bracings

The least value of base shear in case of RCC bracing is for the model TB2R i.e. for the building provided with forward RCC bracing at the edges which is parallel to x axis. While considering the steel bracing the least value is for TB1S i.e. building with backward steel bracing provided in the outer frames parallel to the x axis

B. Storey displacement

The displacement caused in different stories of the building due to the lateral forces acting on them. The maximum value of the displacement is observed on the top storey. Fig.6 gives the maximum storey displacement for the building provided with the RCC bracing. Fig.7 shows the maximum displacement value of the building provided with the steel bracing. The displacement value is found to be least for TB3R in case of RCC bracing and TA3S in case of steel bracing. Both in steel and RCC the displacement is least for the building with X bracing. It is because the X-bracings are more effective in reducing the storey displacement than the bracing provided only in any one direction. The value was much reduced in case of steel bracing than the RCC bracing.

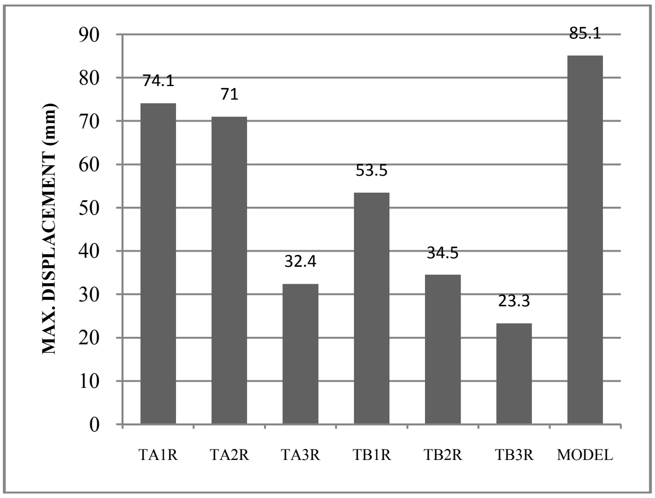

Fig. 6. Maximum displacement with RCC bracing

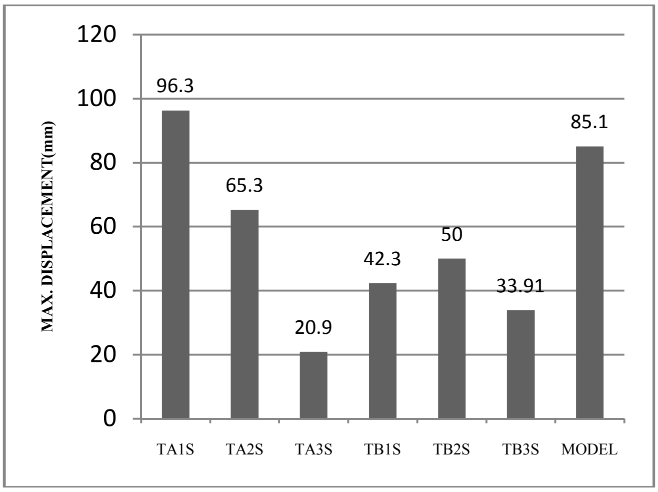

Fig. 7. Maximum displacement with steel bracing

C. Storey drift

As per IS 1893(Part 1):2002 "It is the displacement of one level relative to the other level above or below". The value of storey drift should not exceed 0.004 times the height of the storey. According to the code, the building considered for this study should not have a storey drift value more than 0.014 mm since the height of the storey considered is 3.5m. Table 4 gives the maximum drift values obtained in the different models considered. It is the most important parameter considered in the present study.

Table 4 and Table 5 gives the maximum storey drift values for the building with steel bracing and RCC bracing respectively.

Table 4. Building with steel bracing

Model	Maximum Storey Drift (mm)
MODEL	0.018277
TA1S	0.021172
TA2S	0.013121
TA3S	0.003828
TB1S	0.00884
TB2S	0.009257
TB3S	0.006106

Table 5. Building with RCC bracing

Model	Maximum Storey Drift (mm)
MODEL	0.018277
TA1R	0.013426
TA2R	0.012997
TA3R	0.005411
TB1R	0.009036
TB2R	0.006195
TB3R	0.003609

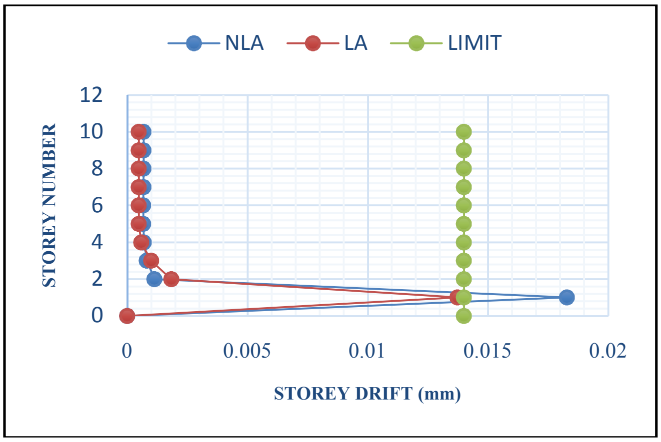

Fig. 8. Storey drift with linear and non-linear analysis

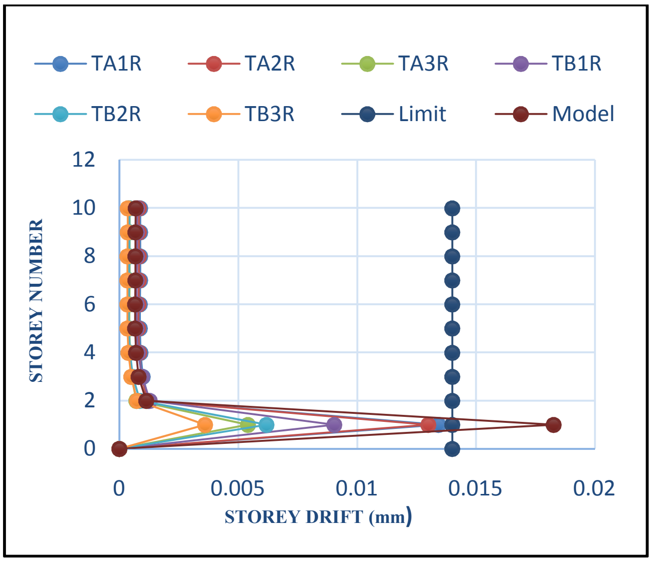

Fig. 9. Storey drift with RCC bracing

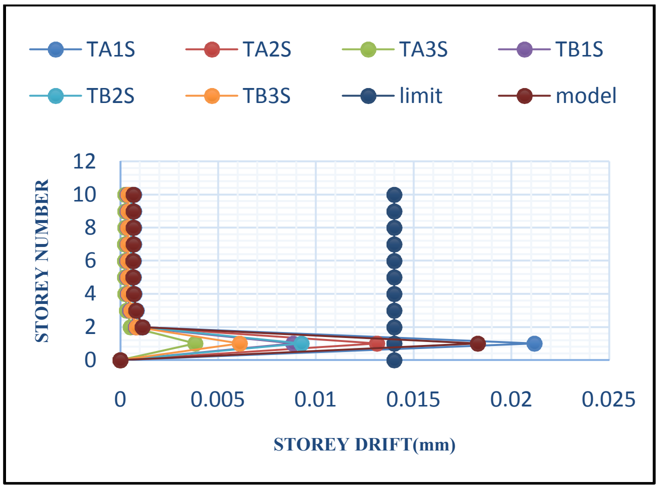

Fig.10. Storey drift with steel bracing

The safest model is TB3R in case of RCC bracing and TA3S in case of steel bracing. In both the cases, the soft drift is greatly reduced while using X bracing in the frames at the edges parallel to x axis. Fig.8 gives the storey drift values using linear and nonlinear analysis. Fig.9 gives storey drift when RCC bracing is used and Fig.10 shows the storey drift when steel bracing is used. The safest model is the one which is provided with steel X bracing. Although it is the safest it is not necessary to adopt the same because it is costlier. The other models are also safe and the value of the storey drift comes within the permissible limit.

Conclusion

Considering all the models provided with steel bracing it is found that TA3S is having minimum displacement and storey drift with comparatively lesser base shear. Therefore the model with X bracing is considered the safest in steel. From the graph of storey drift, it is observed that the model TA1S is more unsafe than the base model even though it is provided with backward bracing. Therefore it is not recommended to use this type of bracing. Comparing the models with RCC bracing, TA2R and TA3R are safe considering all the parameters like storey drift, base shear and storey displacement. But for economic reasons we shall go with TA2R instead of TA3R. Since our main objective is only storey drift we can consider the model TA2R as the best alternative to reduce the soft storey effect. In this model, the building is provided with forward RCC bracing in the outer frames along the x-axis. Although there are sections which are safer than this, we adopt this model considering economy because our main objective is only restricting the storey drift within the permissible limit.

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