

Seismic Analysis of Vertically Regular building with and without Softstorey at different levels

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ABSTRACT: With urbanization and increasing unbalance of required area to availability, it is important to provide open ground storey in both type of buildings that is commercial and residential. These open storey's without brick infill reduce the stiffness of the load carrying member and progressive increase in load exhibit higher stresses in the load carrying member and these members i.e. columns fail as the plastic hinges are not formed on predefined positions. Therefore, the collapse of this soft storey during earthquake has caused structural engineer store think the design of a soft storey. This paper focus on performance and evaluation of 13 storey RC building with and without soft storey at different level . In this Paper 4 buildings out of which one is regular, in elevation, 3 regular buildings with Soft storey at different level and in elevation. Three methods of analysis namely Linear Static Analysis (equivalent Lateral load method), Response Spectrum analysis and Nonlinear Staic analysis (Pushover analysis) has been used. After the analysis results are evaluated for each model and results are compared. the Description of Geometry and procedure carried out in ETABS for each model

KEYWORDS: - Building Configuration, ETABS-2015, Linear Static Analysis, Pushover Analysis, Response Spectrum .

I. INTRODUCTION

For the purpose of recreational use, parking or for retail or commercial use, Many of multi-storey buildings in India do not have structural walls at ground floor level. The buildings that are called as soft storey building, has a discontinuity in the stiffness of the building,. The lateral stiffness of first storey in soft storey building is very less compared to other storeys which are infill with masonry, which results in concentration of large seismic forces, plastic hinges and consequently higher drift demand at that storey. Building with soft storey at diffrentlevel have at least one of the characteristics a) one storey is significantly more flexible than adjacent storeys, (b) have vertical discontinuity (e.g. posses fewer columns in one storey than that of storey above), (c) have a heavy superstructure

As per IS 1893 Soft storeyis defined as below:

a) Soft Story: A soft story is one in which the lateral stiffnesis less than 70 percent of that in the story aboveor less than 80 percent of the average lateral stiffnesof the three story above.

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b) Extreme Soft Story: An extreme soft story is one in which the lateral stiffness is less than 60 percent of that in the story above or less than 70 percent of the average stiffness of the three story above. For example, buildings on STILTS will fall under this category. A common soft storey example is Ground floor of building with greater height and no walls.

I.1 Objective

To study the effect of regular building having soft storey at different level using Finite element software. and To evaluate the response of building having soft storey in the form of lateral drift, base shear and time period.

II. METHODOLOGY

Following is the step by step procedure will be followed during work:

Step1: First 4 buildings as shown in figure.

Step2: For Regular building out of four building one is without soft storey and remaining three are with soft storey at different level.

Step3: Afterward carryout Linear static (Equivalent lateral load method), response spectrum method and nonlinear static analysis method.

Step4: Evaluate results in the form of Storey shear, Storey drift, Time period, member forces, Capacity curve and Performance point for all 3 models.

Step5: Results will be Compare in graphical form and final conclusion will be made.

II.1 STRUCTURAL MODELING:

Must In this chapter 4 buildings out of which one is regular in elevation and 3 regular buildings with Soft storey at different levels . The elevations are as shown in below figure 1.1 and 1.2. Three methods of analysis namely Linear Static Analysis (LSM) (equivalent Lateral load method), Response Spectrum analysis (RSM) and Nonlinear Static analysis (Pushover analysis) has been used. After the analysis results are evaluated for each model and results are compared. Following is the Description of Geometry and procedure carried out in ETABS for each model.

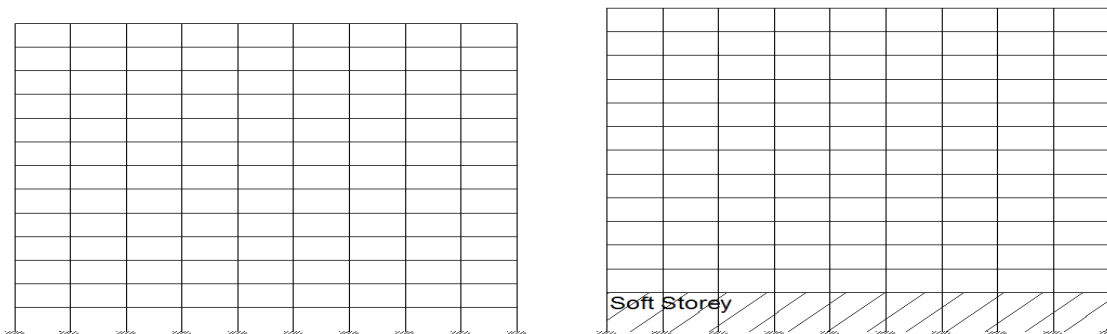


Fig 1.1 Model R and Model RS-1

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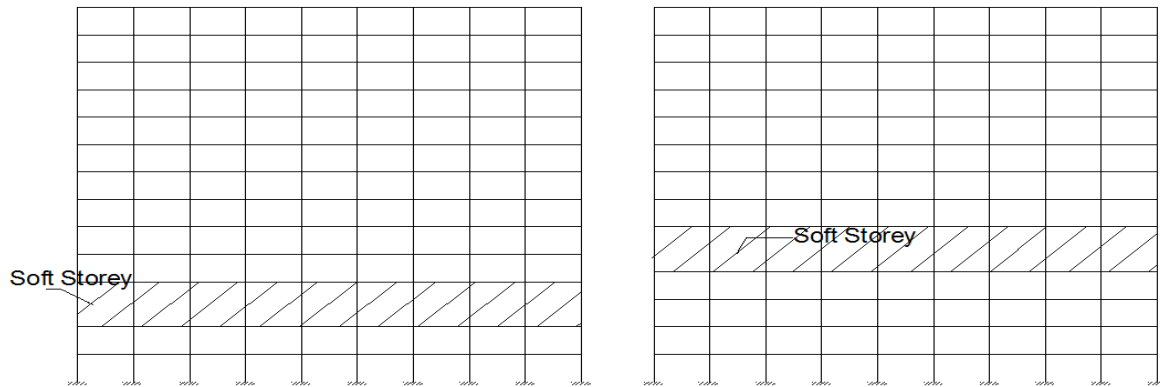


Fig 1.2 Model RS-3 and Model RS-5

Table 1.1: Geometric and Structural Detailing Of Model: R, RS-1, RS-3, RS-5

| Sr No. | Content | Description |
|--------|---------------------------------|--|
| 1. | Type of structure | Special moment resistant frame office building |
| 2. | Seismic Zone | ii |
| 3. | Zone factor | 0.24 |
| 4. | Number of storey | G + 12 |
| 5. | Floor height | 3.0 m |
| 6. | Load if wall on internal beam | 9kN/m |
| 7. | Load on Peripheral beams | 13kN/m |
| 8. | Live load | 2.5kN/m ² |
| 9. | Floor finish load | 1.5 kN/m ² |
| 10. | Concrete | M30 |
| 11. | Steel | Fe 500 |
| 12. | Base – storey 2 | 750x750 mm, bars 4 Nos. 20 mm, 20#20 size |
| 13. | Column 5th floor to 9th floor | 700X700 mm, bars 20 Nos. 16 mm size |
| 14. | Column 10th floor to 14th floor | 700X700 mm, bars 12 Nos. 16 mm size |
| 15. | All beam sizes | 230 X600 mm |
| 16. | Slab depth | 175 mm |
| 17. | Concrete density | 25 kN/m ³ |
| 18. | Damping | 5% |
| 19. | Soil type | Medium soil |

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III. RESULT & DISCUSSION

Results of Analysis: After modelling, load application and design 3 type of analysis namely Linear Static Analysis (LSM/EQX), Response Spectrum method (RSM/Spec X) and Nonlinear Static analysis (NSA/Pushover) has been done and result are represented in graphical manner

III.1 Model 01: R

III.1.1: Geometric Details of building

Building is having 9x9 bay of span 5 m in both direction with a story height of 3 m each having 13 stories. Frame is a special moment resisting frame, sizes of different section and loading considered in building are shown in table.1.1 Load consideration are as per residential building.

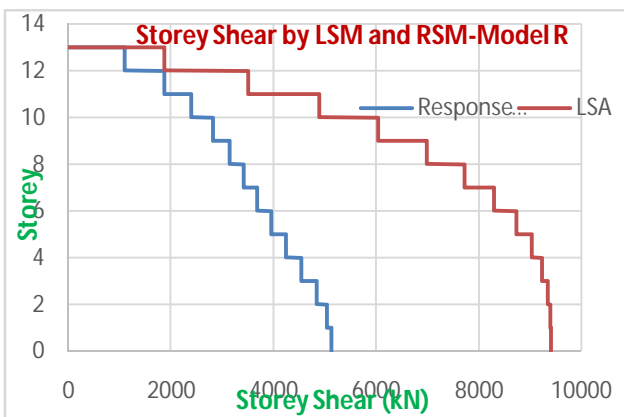


Fig 1.3 Storey Shear for Model -R

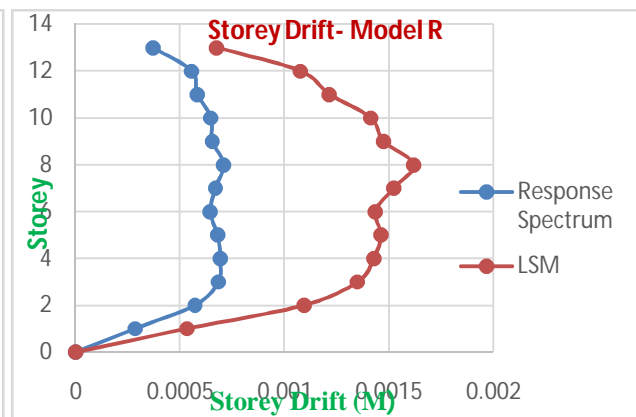


Fig 1.4 Storey Drift for Model -R

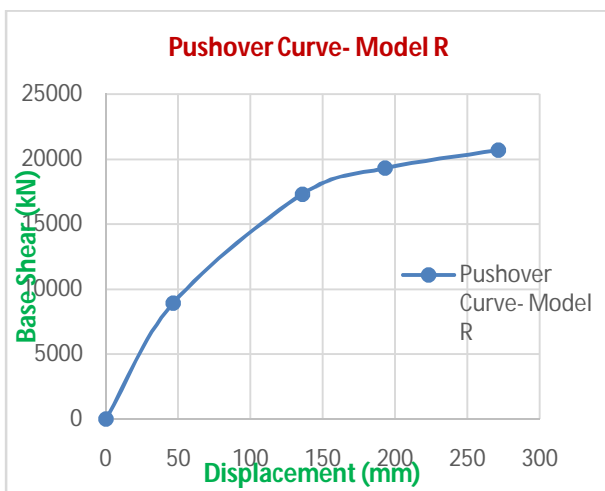


Fig 1.5 Pushover curve for model -R

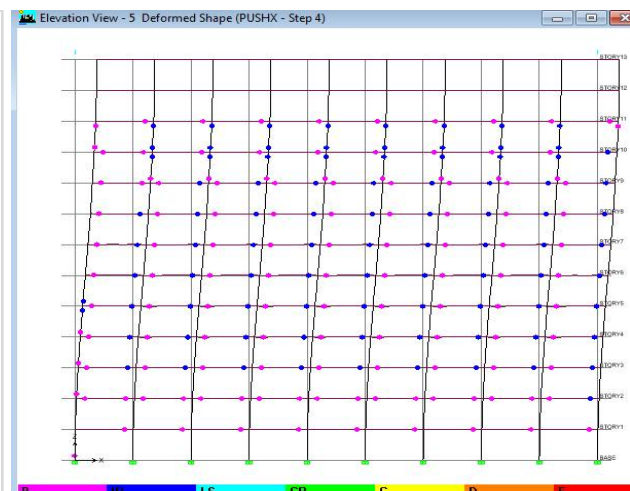


Fig 1.6 - Deformed shape and hinge Formation- Model -R

III.1.2: Discussion on results of Model R

Following are the observations from the result of analysis

Design Base shear obtained by LSM is 9411.29 kN which is almost 83 % greater than design Base shear by RSM (5129.77 kN). This large difference is due to Time period in both analysis considered is different. In LSM analysis time period calculated by Empirical formula (IS1893-1) has been used while in RSM analysis ETABS calculated time period has been used. Storey drift (Fig 1.4) obtained by LSM analysis (0.00162) is almost double of RSM analysis drift (0.00071) but it is less than allowable Storey drift limit of IS1893-1. (0.004). In pushover analysis maximum lateral

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displacement of top point of building is observed as 271.2 mm and building capacity for lateral load is 20701.71 kN.(Fig 1.5)By observing the deformed shape from (fig 1.6) it can be seen that no hinge is Crossing Life Safety limit (LS) and on only storey10 and 11 some hinges are formed in columns. There is no hinge formation in columns at bottom and top storey of building

III.2 Model 02: RS-1

III.2.1 Geometric Details of building

Building is having 9x9 bay of span 5 m in both direction with a story height of 3 m each (Except Storey 1-4.5 m height) having 13 stories. Frame is a special moment resisting frame, sizes of different section and loading considered in building are shown in table 1.1. Load consideration are as per residential building.

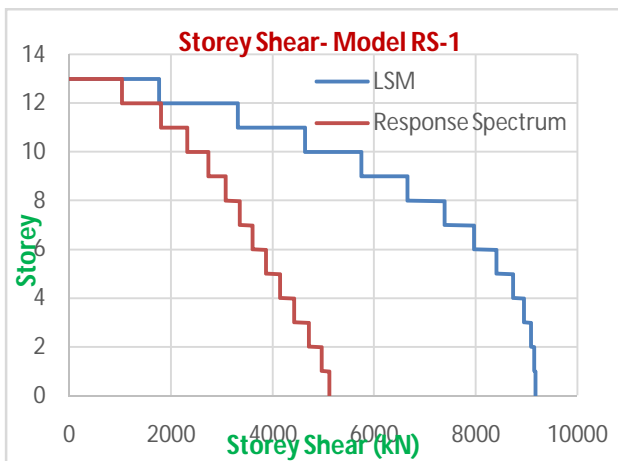


Fig 1.7 Storey Shear for Model –RS-1

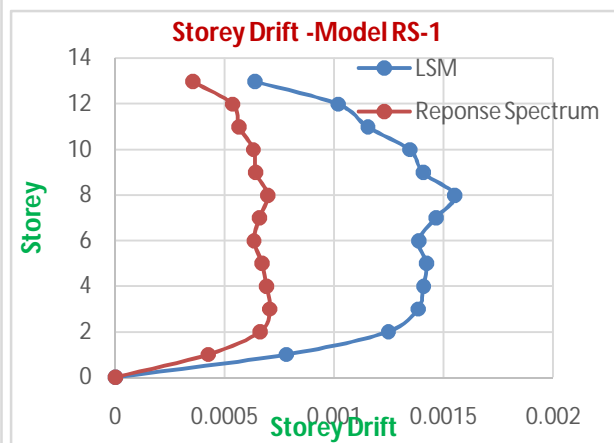


Fig 1.8 Storey Drift for Model –RS-1

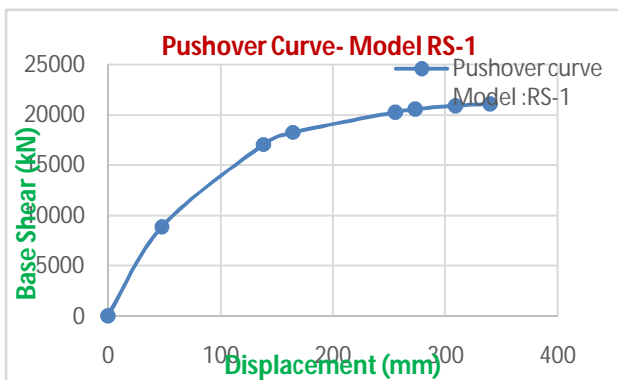


Fig 1.9 Pushover curve for Model –RS-1

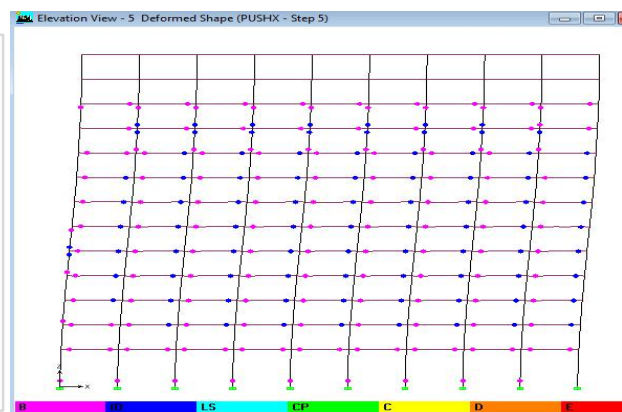


Fig 2.0: Deformed Shape and Hinge formation –Model RS-1

III.2.2 Discussion on results of Model RS-1

Following are the observations from the result of analysis

Design Base shear obtained by LSM is 9439.02kN which is almost 84 % greater than design Base shear by RSM (5109.03kN). This large difference is due to Time period in both analysis considered is different. In LSM analysis time period calculated by Empirical formula (IS1893-1) has been used while in RSM analysis ETABS calculated time period has been used. Storey drift (Fig 1.8) obtained by LSM analysis (0.00155) is almost double of RSM analysis drift (0.00070) but it is less than allowable Storey drift limit of IS1893-1. (0.004).In pushover analysis maximum lateral displacement of top point of building is observed as 340.2 mm and building capacity for lateral load is 21080.74kN. (Fig 1.9)By observing the deformed shape from (fig 2.0) it can be seen that no hinge is Crossing Collapse prevention

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state (CP) and on storey 1st, 10th and 11th hinges are formed in columns. There is no hinge formation in columns at bottom and top storey of building. As compare to regular model (Model-R) here extra hinges are there in first storey column due to Soft storey.

III.3 Model 03: RS-3

III.3.1 Geometric Details of building

Building is having 9x9 bay of span 5 m in both direction with a story height of 3 m each (Except Storey 3-4.5 m height) having 13 stories. Frame is a special moment resisting frame, sizes of different section and loading considered in building are shown in table 1.1. Load consideration are as per residential building.

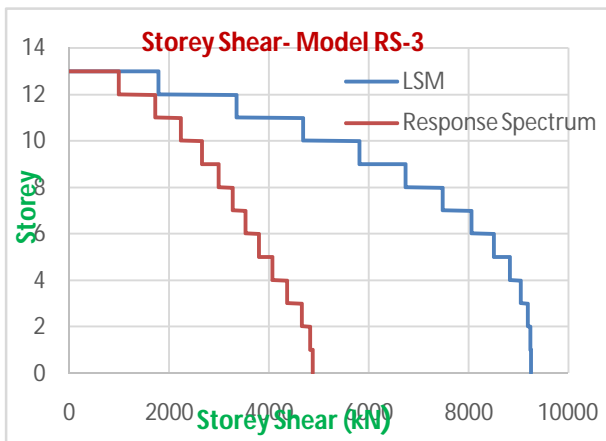


Fig 2.1 Storey Shear for Model -RS-3

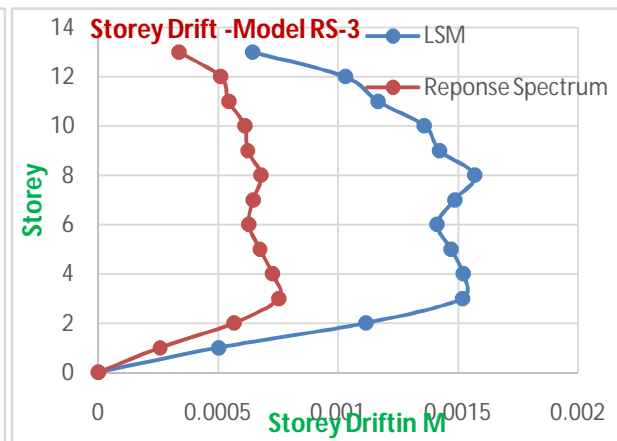


Fig 2.2 Storey Drift for Model -RS-3

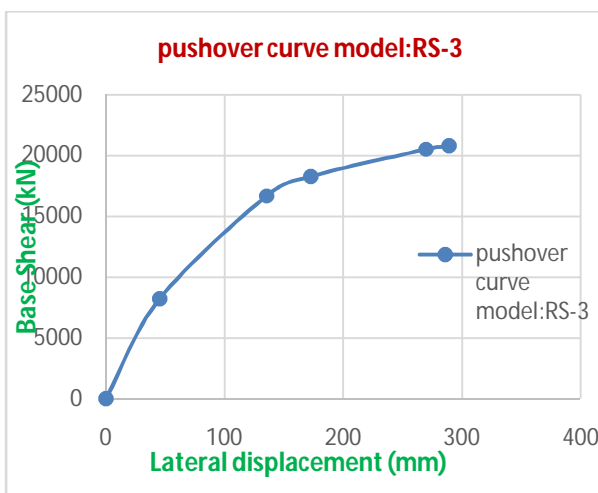


Fig 2.3 Pushover curve for Model -RS-3

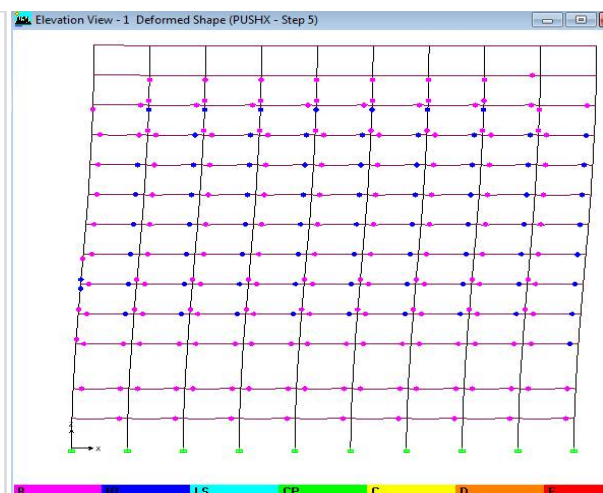


Fig 2.4 Deformed shape and Hinge formation Model RS-3

III.3.2 Discussion on results of Model RS-3

Following are the observations from the result of analysis. Design Base shear obtained by LSM is 9254.69kN which is almost 89 % greater than design Base shear by RSM (4873.24kN). This large difference is due to Time period in both analysis considered is different. In LSM analysis time period calculated by Empirical formula (IS1893-1) has been used while in RSM analysis ETABS calculated time period has been used. Storey drift (Fig 2.2) obtained by LSM analysis (0.00156) is almost double of RSM analysis drift (0.00075) but it is less than allowable Storey drift limit of IS1893-1. (0.004). In pushover analysis maximum lateral displacement of top point of building is observed as 289.1 mm and building capacity for lateral load is 20841.45kN.

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(Fig 2.3)By observing the deformed shape from(fig 2.4) it can be seen that no hinge is crossing life safety state (LS) and on storey 5th,6th,11th and 12th hinges are formed in columns. There is no hinge formation in columns at bottom and top storey of building.

III.4 Model 04: RS-5

III.4.1 Geometric Details of building

Building is having 9x9 bay of span 5 m in both direction with a story height of 3 m each (Except Storey 5th - 4.5 m height) having 13 stories. Frame is a special moment resisting frame, sizes of different section and loading considered in building are shown in table 1.1. Load consideration are as per residential building.

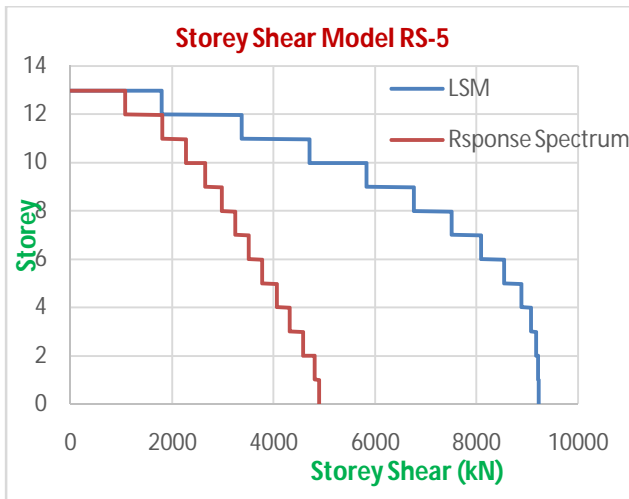


Fig 2.5 Storey Shear for Model -RS-5

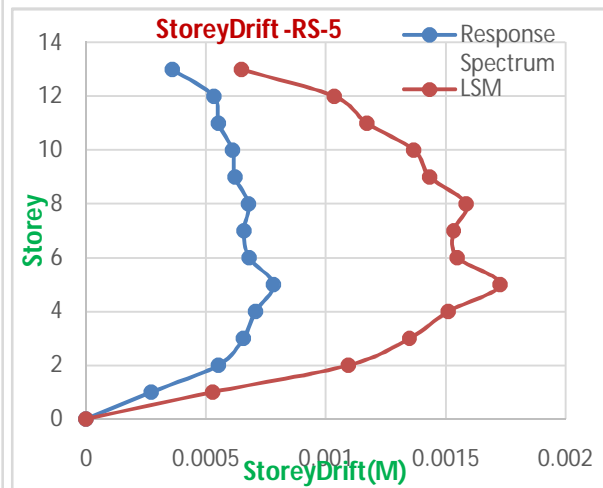


Fig 2.6 Pushover curve for Model -RS-5

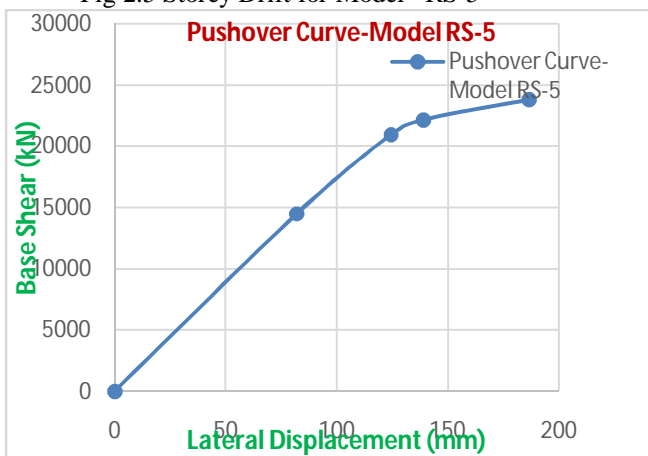


Fig 2.7 Storey Drift for Model -RS-5

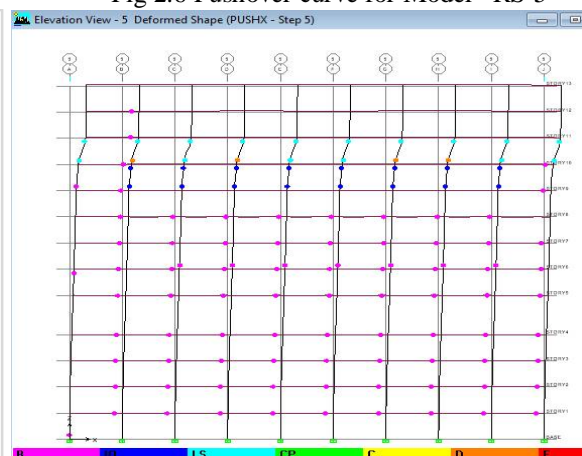


Fig 2.8 Pushover curve for Model -RS-5

III.4.2 Discussion on results of Model RS-5

Following are the observations from the result of analysis

Design Base shear obtained by LSM is 9230.4kN which is almost 88 % greater than design Base shear by RSM (4891.5kN). This large difference is due to Time period in both analysis considered is different. In LSM analysis time period calculated by Empirical formula (IS1893-1) has been used while in RSM analysis ETABS calculated time period has been used. Storey drift (Fig 2.6) obtained by LSM analysis (0.0017) is almost double of RSM analysis drift (0.00078) but it is less than allowable Storey drift limit of IS1893-1. (0.004). In pushover analysis maximum lateral displacement of top point of building is observed as 186.7 mm and building capacity for lateral load is 23820.28kN.

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(Fig 2.7)By observing the deformed shape from (fig 2.8) it can be seen that some hinges are in D-E state and on storey 7th, 10th, and 11th hinges are formed in columns. The all critical hinges D-E are formed in columns at 11th storey.

III.5 Result Compression of regular Buildings

III.5.1 Storey Shear Comparison:

Linear Static method/EQX: results of all models obtained by linear static method has been plotted on one graph. Fig.2.9 shows the combined graph of Storey shear of all 4 models by LSM method

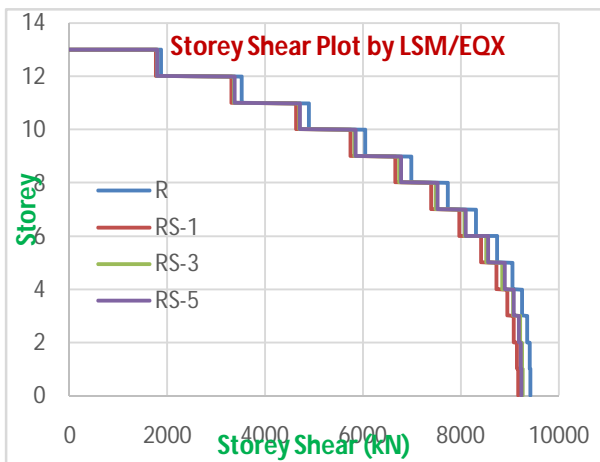


Fig 2.9: Combined plot of Storey shear by LSM

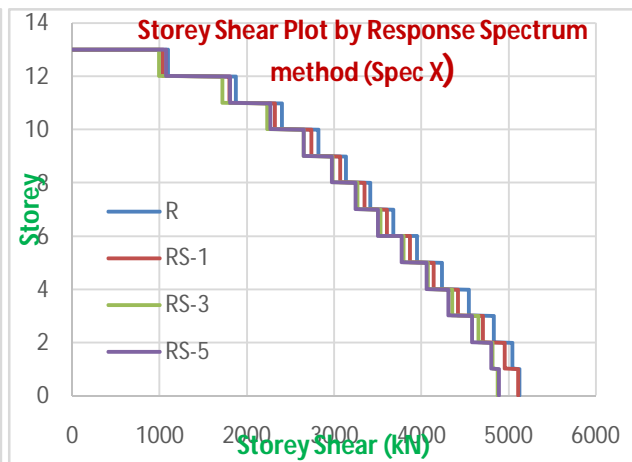


Fig 3.0: Combined plot of Storey shear by RSM

Following are the observations from the plot of storey shear for all models by linear static method.

For regular building maximum design shear force obtained is 9411 kN which is slightly greater than regular building with soft storey. As the soft storey is moving from bottom to top of building design base shear is reducing as per LSM.

Response Spectrum method/Spec X: results of all models obtained by response method has been plotted on one graph. Fig.3.0 shows the combined graph of Storey shear of all 4 models by RSM method

The obtained Storey shear results by RSM for regular building are close as compare to LSM due to ETABS calculated time period. For regular building etabs calculated time period is less that's why Spectral acceleration value is higher

III.5.2: Storey Drift Comparison:

Drift by Linear Static method/EQX: Storey Drift of all models obtained linear static method has been plotted on one graph. Fig.3.1 shows the combined graph of Storey drift of all 4 models by LSM method

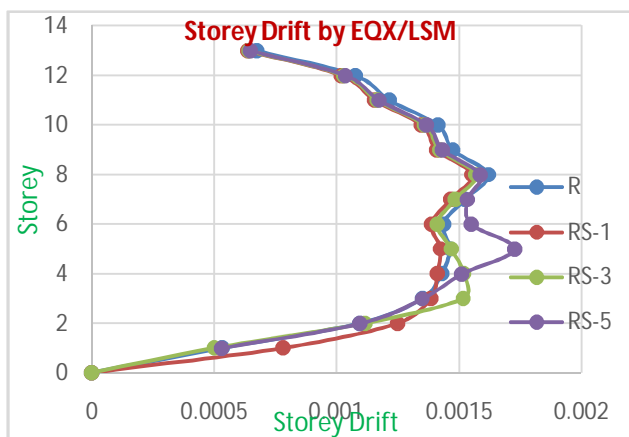


Fig 3.1: Combined plot of Storey Drift by LSM

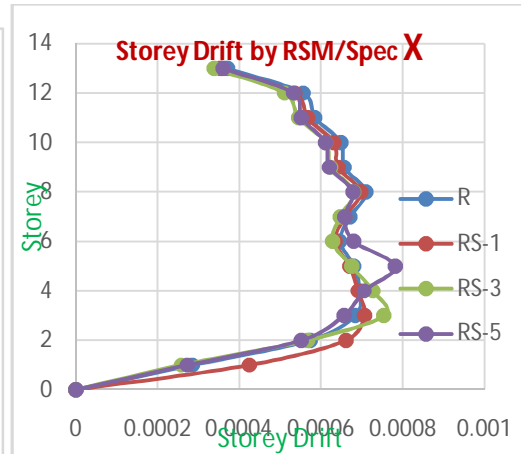


Fig 3.2: Combined plot of Storey Drift by RSM

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Following are the observations from the plot of storey Drift for all models by linear static method.

For regular building with storey drift is maximum on soft storey level as compare regular building without soft storey. For regular building without soft storey drift plot is having very less kinks while regular building with soft storey is having kinks in storey drift plot at soft storey level. Storey drift of regular building with soft storey is higher at soft storey level as compare regular building without soft storey.

Drift by Response Spectrum method/Specx: Storey Drift of all models obtained Response Spectrum method has been plotted on one graph. Fig.3.2 shows the combined graph of Storey drift of all 4 models by RSM method. Following are the observations from the plot of storey drift for all models by linear static method. Storey drift curve for regular building without soft storey is smooth but for regular building with soft storey shear plot is having kinks at soft storey level.

III.5.3 Pushover curve Comparison: Pushover curve obtained by Nonlinear Static analysis has been plotted on one graph. On horizontal axis lateral displacement of top point has been taken and Base shear has been plotted on on Y axis. Before carrying analysis nonlinear hinges has been assigned to beams and columns.

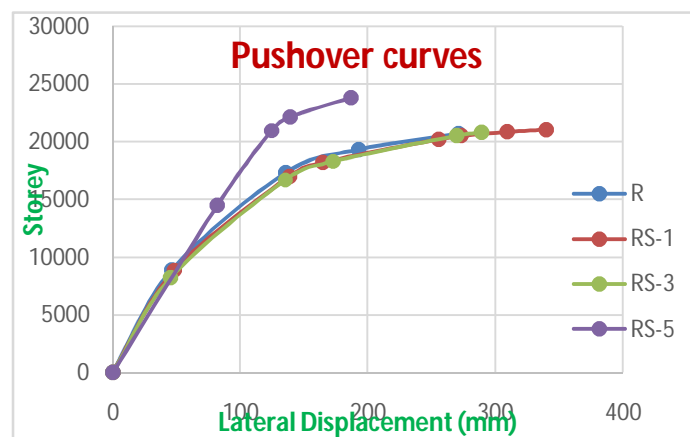


Fig 3.3: Combined plot of Pushover curve

Following are the observations from the combined plot of Pushover curve. Pushover curve for Model R, RS-1 and RS-3 are almost overlapped, which means that these three models are having almost equal lateral load carrying capacity. As the model RS-1 has the maximum lateral deflection, RS-1 is more flexible than RS-3 and R building. Model RS-5 (Regular building with 5th storey as soft storey) is having the highest lateral load carrying capacity as compared to all models. This is due to the fact that the columns of these models are stronger than other models. But the lateral deflection of the model is very less as compared to other regular models. This means that this model is less flexible than other regular buildings.

IV. CONCLUSION

A total of 4 building models having vertical regularity with and without soft storey have been modeled in ETABS. Soft storey has been considered at storey 1, storey 3 and storey 5. All loads have been applied and nonlinear hinges have been assigned as per ATC-40. After modeling and load application analysis has been done by Linear Static method (LSM), Response Spectrum method (RSM) and Nonlinear Static method (NSA). The results in the form of Storey shear, Storey drift, Pushover curve and time period have been represented and compared. From the study, the following conclusion can be made.

Linear Static method (LSM) overestimates the Storey shear and Storey drift as compared to Response Spectrum method. Storey shear plot of regular building is close to Response Spectrum method (35% difference) as compared to Linear Static method storey shear plot of regular (82-88% difference). Program (ETABS) calculated time

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period gives the more accurate value as it based on actual Mass matrix and Stiffness matrix of building. Code based time period is only depends on the height of structure and it's not considering any Mass changes and stiffness changes in building with soft storey. it's better to use software time period for analysis or some different formula has to be developed which should berelated to mass and stiffness of building. Storey drift plot for all building is within allowable limit. Storey drift plot of regular building is smooth curve and for regular building with soft storey there is kink at soft storey level. Lateral displacement capacity of regular building can go higher deformation upto 325 mm

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