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Seismic Analysis of Vertically Irregular building with and without Soft storey at different levels

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Abstract: **-- With urbanization and increasing unbalance of the required area to availability, it is important to provide an open ground storey in both types of buildings that are 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 an earthquake has caused structural engineer store think the design of a soft storey. This paper focuses on performance and evaluation of 13 storey RC building with and without a soft storey at the different level. In this Paper 4 buildings out of which one is irregular, in elevation, 3irregular buildings with the Soft storey at the different level and in elevation. Three methods of analysis namely Linear Static Analysis (equivalent Lateral load method), Response Spectrum analysis and Nonlinear Static 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.**

Key words**: Building Configuration, ETABS-2015, Linear Static Analysis, Pushover Analysis, Response Spectrum.**

I. INTRODUCTION

Architects and Owner of buildings wants to build buildings which are not regular in shapes, e. g. Gulf countries. Now there is competition to build a building with new innovative shapes. These mentioned factors are responsible for affecting building regularity. These types of irregular buildings become popular due to its aesthetics and the functional purpose. Sometimes to get adequate day light, ventilation or to maintain building By-Laws step form (Setback) buildings are used Irregular building are characterized abrupt change in floor area along the height of building with consequently drop in mass, strength or stiffness. In building the point at which sudden change in regularity i.e. sudden change of Mass, Stiffness or Strength in vertical direction occurs that point is known as structurally weak point or weak point. In regular building at the time of earthquake smooth transfer of forces/stresses occurs due to its regular shape but in case of vertically irregular shape buildings due to sudden change in regularity forces/stresses transformation is not smooth. This abrupt transform of forces leads to stress concentration at weak points (Point at which vertical Geometry changes). Due to these high stresses at weak point material of structural components goes in plastic state and failure of component will occurs and this leads whole structure to fail. Therefore the Locations/points in building where Vertical Geometry changes abruptly or soft storey are known as weak points and these are locations where is maximum chance of failure at the time of earthquake is possible. Due to above mentioned reason it is necessary to study behavior of the vertical irregular building.

As per IS 1893 Soft storey is defined as below:

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

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

I.1OBJECTIVE

1) To study the different irregularities in building

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2) To study the combined effect of Vertical irregularity and Soft storey on RC building with the Help of Finite element software.
3) To study the effect of irregular building having soft storey at different level using Finite element software.
4) To evaluate the response of building having soft storey with and without vertical irregularity in the form of lateral drift, base shear and time period
5) Compare the responses of buildings having soft storey without vertical irregularity.

II. STRUCTUREAL MODELING

Mostly, in these chapter 4 buildings out of which one is Irregular in elevation and 3 Irregular buildings with Soft storey at different levels too. The elevations are as shown in below figure2.1 and 2.2. Three methods of analysis namely Linear Static Analysis (LSM) (equivalent Lateral load method), Response Spectrum analysis (RSM) and Nonlinear Staic 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.

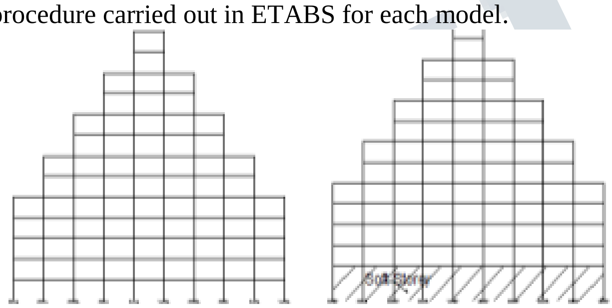

Fig 2.1 Model IR and Model IRS-1

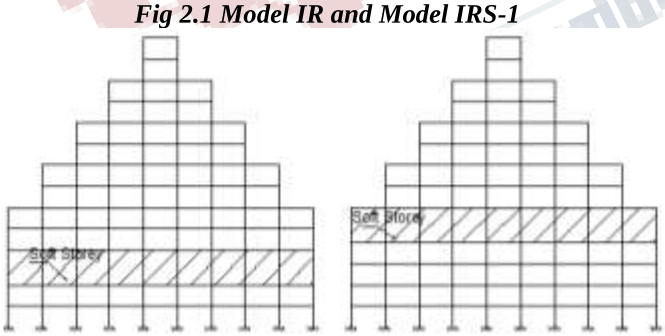

Fig 2.2 Model IRS-3 and Model IRS-5

Table 1.1 Geometric and Structural details of Model -IR

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(for softstorey lvl. Floor height - 4.5M)
6.	Load if wall on internal beam	9kN/m
7.	Load on Peripheral beams	13kN/m
8.	Live load	2.5kN/m2
9.	Floor finish load	1.5 kN/m2
10.	Concrete	M30
11.	Steel	Fe 500
12.	Base – storey 2	800 X 800 mm, bars 4#25+20#20
13.	Column 5th floor to 9th floor	700X700 mm, bars 4#25 + 18#20
14.	Column 10th floor to 14th floor	600X600 mm, bars 22 #16
15.	All beam sizes	230 X600 mm
16.	Slab depth	175 mm
17.	Concrete density	25 kN/m3
18.	Damping	5%
19.	Soil type	Medium soil

III. RESCULT & DISCUSSION

Model 01: Irregular building without softstorey -IR

3.1.1 Geometric Details of building

Building is having 9x9 bays of span 5 m in both directions 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 below table1.1. Load consideration is as per residential building.

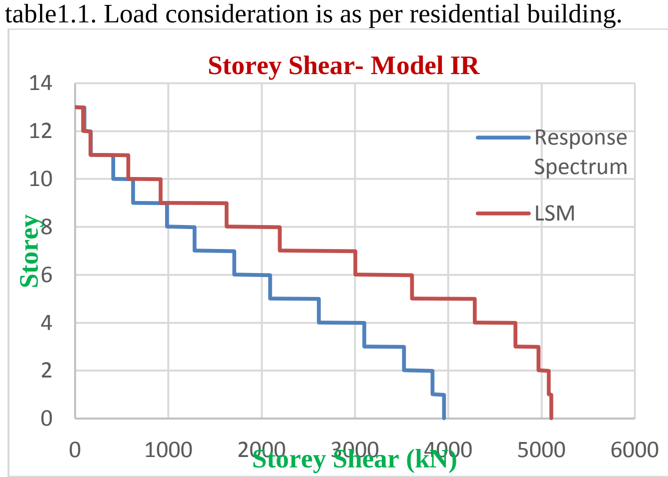

Fig 3.1 Storey Shear model IR

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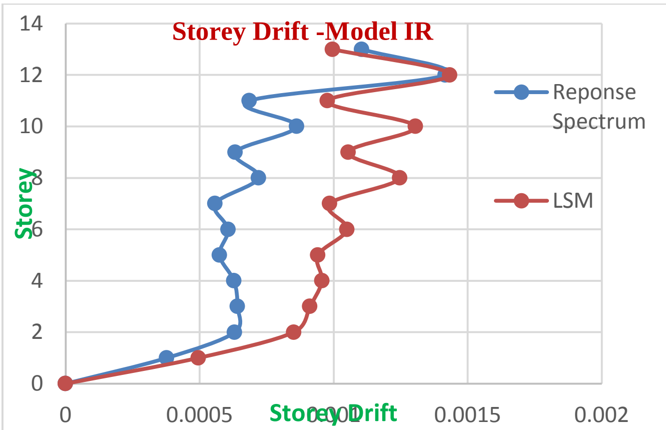

Fig 3.2 Storey Drift model -IR

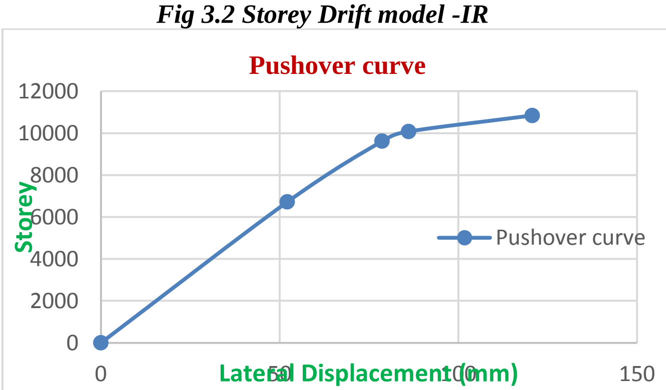

Fig 3.3 Pushover Curve for Model –IR

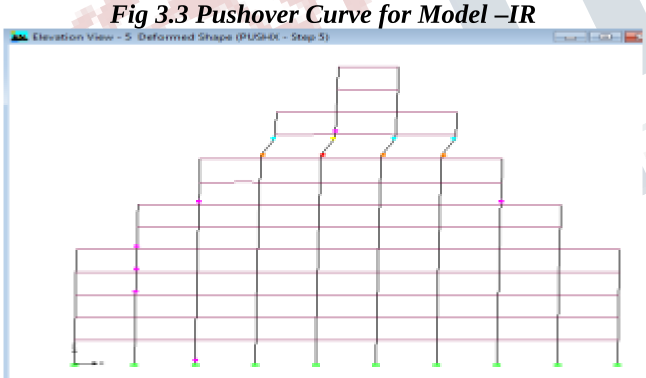

Fig 3.4 Deformed Shape and Hinge formation- model IR

3.1.2 Discussion on results of Model IR

Following are the observations from the result of analysis Design Base shear obtained by LSM is 5104.19kN which is almost 29 % greater than design Base shear by RSM (3954.73kN). This less difference in RSM and LSM analysis is due to less difference in time period obtained by Empirical formula of IS1893-1 and ETABS calculated.Maximum Storey drift (Fig 3.2) obtained by LSM analysis (0.00143) is almost equalto RSM analysis drift (0.001416) 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 120.7 mm and building capacity for lateral load is 10842kN, which is almost 52 % of base shear of Regular building. (Fig 3.3)By observing the deformed shape from fig 3.4 and 30 it can be seen that 4 hinges are crossed >E stateon storey 10th in columns. In lower storey no hinges has been formed in columns and beams.

Model 02: Irregular building with softstoreyat 1st storey – IR-1

3.2.1 Geometric Details of building

Building is having 9x9 bays of span 5 m in both directions with a story height of 3 m each (Except Storey 1st -4.5 m Height) having 13 stories. Frame is a special moment resisting frame, sizes of different section

Load consideration is as per residential building.

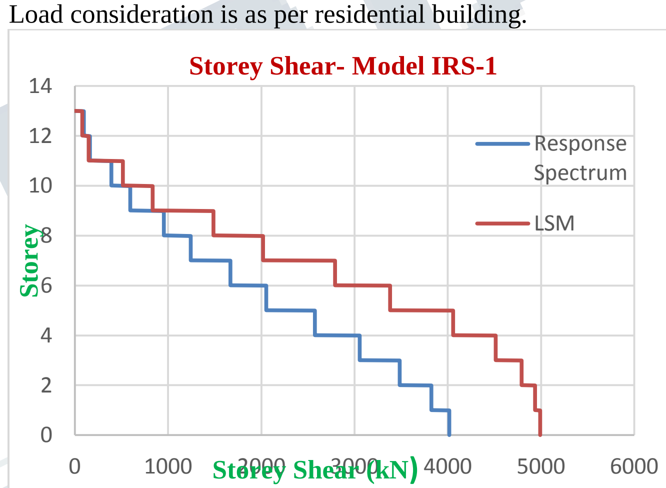

Fig 3.5:Storey Shear plot for Model IRS-1

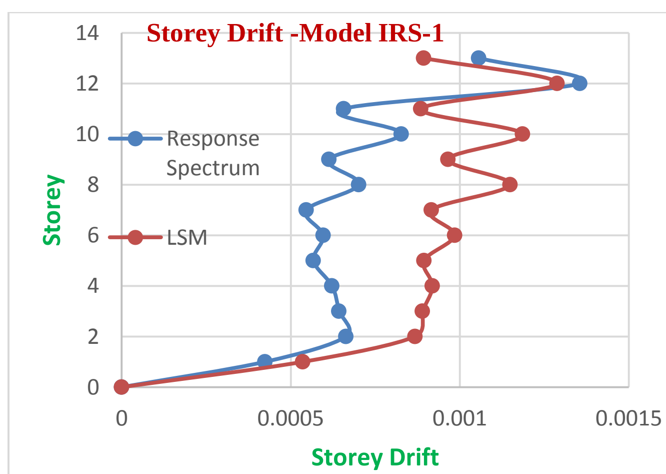

Fig 3.6:Storey Drift plot for Model IRS-1

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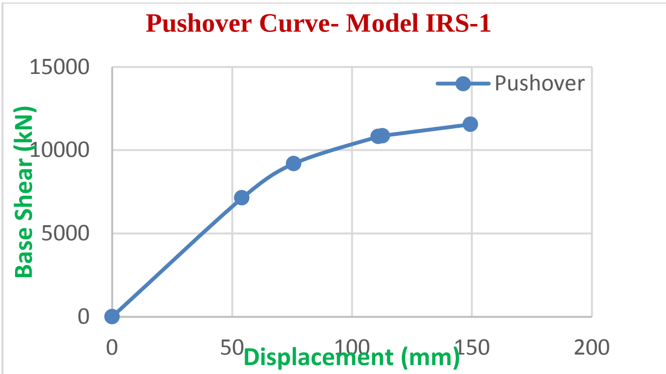

Fig 3.7 Pushover Curve for Model IRS-1

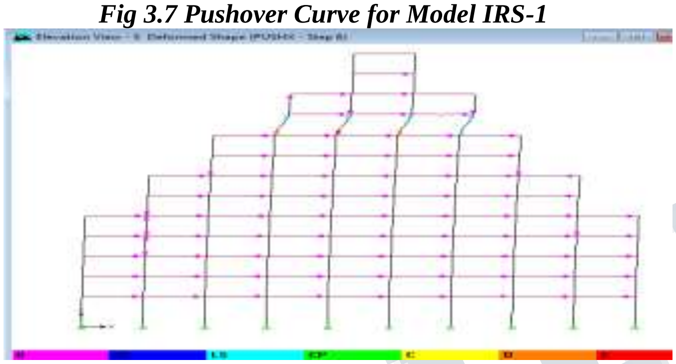

Fig 3.8: Deformed Shape and Hinge formation IRS-1

3.2.2 Discussion on results of Model IRS-1;

Following are the observations from the result of analysis; Design Base shear obtained by LSM is 4990.4kN which is almost 24 % greater than design Base shear by RSM (4017.07kN). This less difference in RSM and LSM analysis is due to less difference in time period obtained by Empirical formula of IS1893-1 and ETABS calculated.Maximum Storey drift (Fig 3.6) obtained by LSM analysis (0.00128) is less than RSM analysis drift (0.001355) but it is less than allowable Storey drift limit of IS1893-1. (0.004). in this case RSM maximum drift is greater than LSM drift In pushover analysis maximum lateral displacement of top point of building is observed as 149.5 mm and building capacity for lateral load is 11547.1 kN (Fig 3.7).By observing the deformed shape from fig 3.8 and 36 it can be seen that 2 hinges are crossed >Estate on storey 10th in columns. Inlower storey hinges has been formed in beams only and are in B State

Model 03: Irregular building with softstoreyat 3rd storey – IR-3

3.3.1 Geometric Details of building

Building is having 9x9 bays of span 5 m in both directions with a story height of 3 m each (Except Storey 3rd -4.5 m Height) having 13 stories. Frame is a special moment resisting frame, sizes of different section

Load considerations are as per residential building

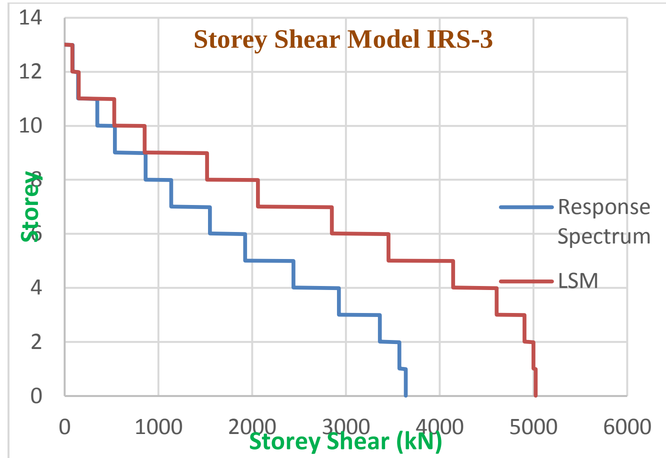

Fig 3.6:Storey Shear plot for Model IRS-3

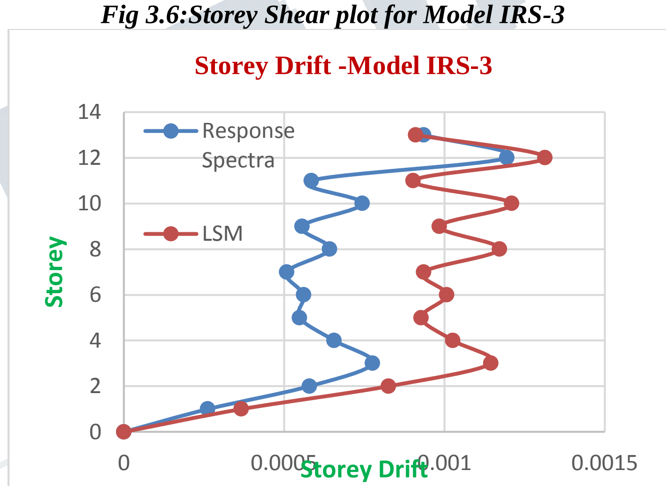

Fig 3.7:Storey Drift plot for Model IRS-3

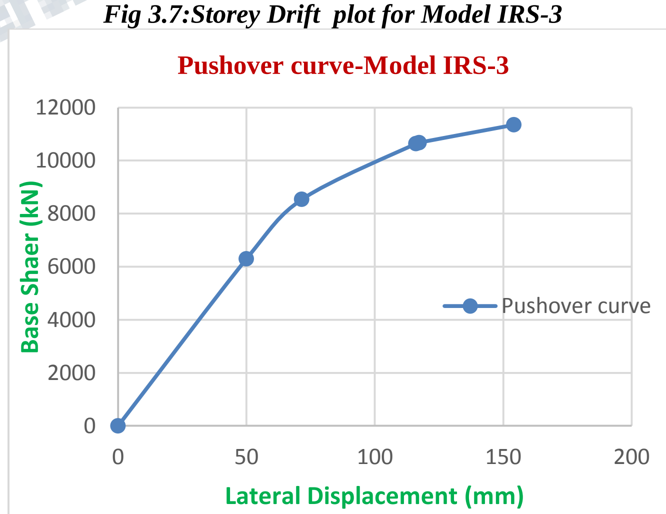

Fig 3.8 Pushover Curve for Model –IRS-3

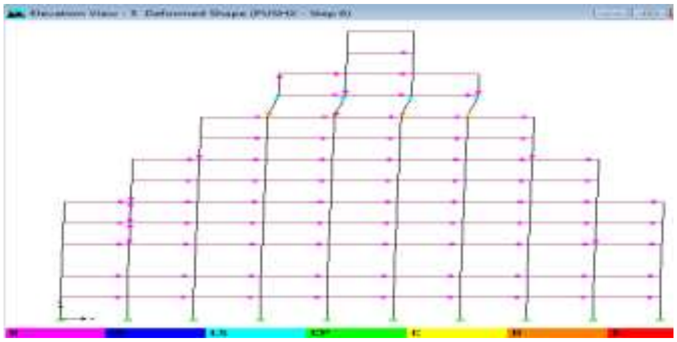

Fig 3.9 Deformed Shape and Hinge formation- model IRS-3

5.7.3 Discussion on results of Model IRS-3

Following are the observations from the result of analysis Design Base shear obtained by LSM is 5023.19kN which is almost 38 % greater than design Base shear by RSM (3638.41kN). Maximum Storey drift (Fig 3.7) obtained by LSM analysis (0.00131) is less than RSM analysis drift (0.001195) 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 154.2 mm and building capacity for lateral load is 11347.07.1 kN (Fig 3.8).By observing the deformed shape from fig 3.9 and 42 it can be seen that 2 hinges are crossed >Estate on storey 10th in columns. In lower storey hinges has been formed in beams only and are in B State.

Model 04: Irregular building with softstorey at 5th storey – IR-5

3.4.1 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 1-4.5 m height) having 13 stories. Frame is a special moment resisting frame, sizes of different section

Load consideration are as per residential building

Fig 3.10: Storey Shear plot for Model IRS-5

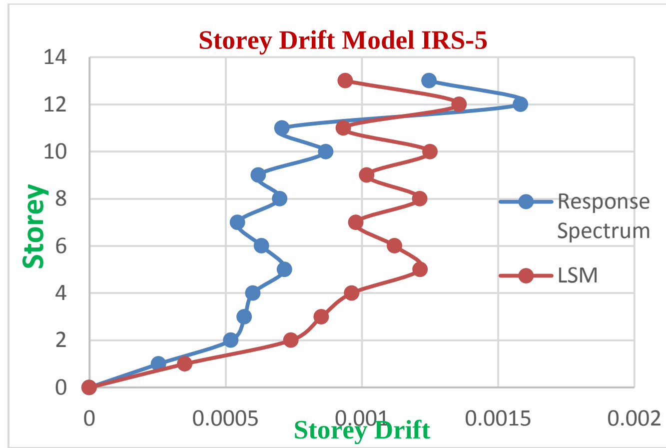

Fig 3.11:Storey Drift plot for Model IRS-5

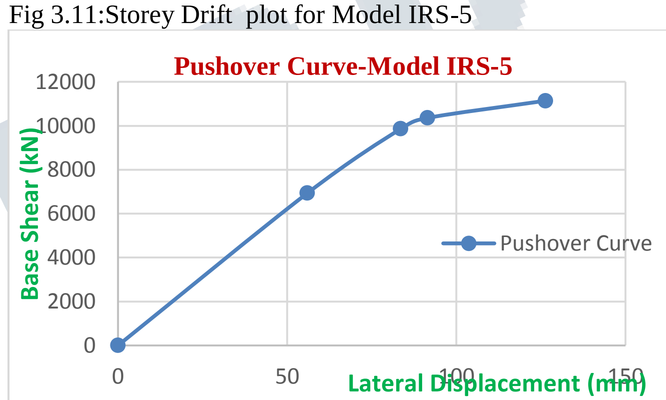

Fig 3.12 Pushover Curve for Model –IRS-5

3.4.2 Discussion on results of Model IRS-5

Following are the observations from the result of analysis;Design Base shear obtained by LSM is 5030.49 kN which is almost 35 % greater than design Base shear by RSM (3724.64kN). Maximum Storey drift (Fig 3.11) obtained by LSM analysis (0.001357) is less than RSM analysis drift (0.001582) 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 126.4 mm and building capacity for lateral load is 11144.56.1 kN (Fig 3.12).

III.5 Result Compression of regular Buildings

3.5.1Storey Shear Comparison: Linear Static method/EQX: a result of all models obtained by linear static method has been plotted on one graph. Following is the combined graph of Storey shear of all 4 models by LSM method

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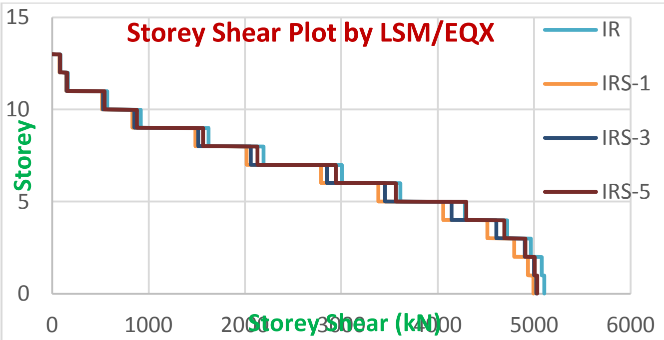

Fig 1.5 Combined plot of Storey shearby LSM

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

Though the respective time period for irregular building is same (by IS1893-1) the difference in design base shear is due to difference in seismic mass. As the irregular building is having less mass the design shear is less. For irrregular building maximum design shear force obtained is 5104.19 kN which is slightly greater than irrregular building with softstorey. As the soft storey is moving from bottom to top of building design base shear is reducing as per LSM.For irregular building also design base shear is more in irregular building without soft storey than irregular building with soft storey

3.5.2Response Spectrum method/Spec X:results of all models obtained by response method has been plotted on one graph. Following is the combined graph of Storey shear of all 4 models by RSM method

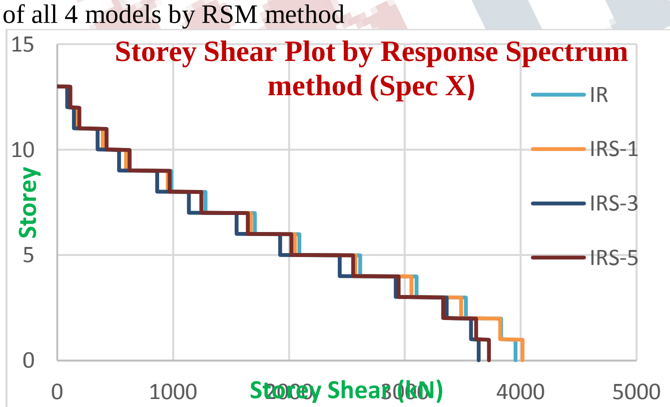

Fig 1.6 Combined plot of Storey shear by RSM

For irrregular building maximum design shear force obtained is 3954.1 kN The obtained Storey shear results by RSM for irregular building are close as compare to LSM due to ETABS calculated time period. For irrregular building etabs calculated time period is more that's why Spectral acceleration value is higher

3.5.3StoreyDrift Comparison:

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

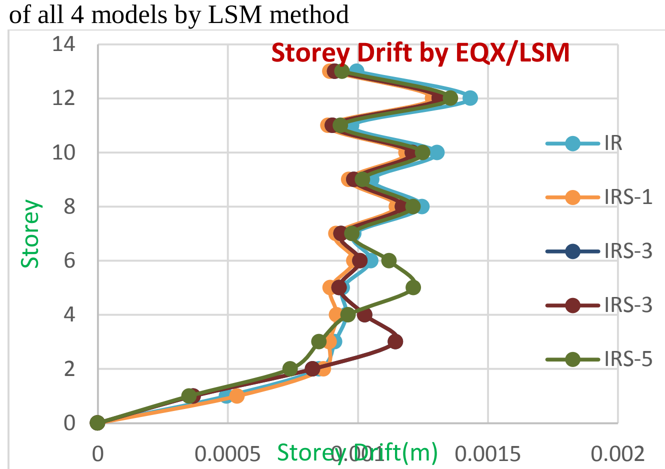

Fig 1.7 Combined plot of Storey Drift by LSM

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

For irrregular building without softstorey drift plot is having very less kinks while irrregular building with soft storey is having Kinks in Storey drift plot at Soft storey level..StoreyDrift of irregular building with Soft story is higher at Soft storey level as compare to Irregular building without soft storey.For irregular building drift of top storey is higher, this due to fact that irregular building is having very less Lateral stiffness.

Drift by Response Spectrum method/Specx: Storey Drift of all models obtained Response Spectrum method has been plotted on one graph. Following is the combined graph of Storey drift of all 4 models by RSM method.

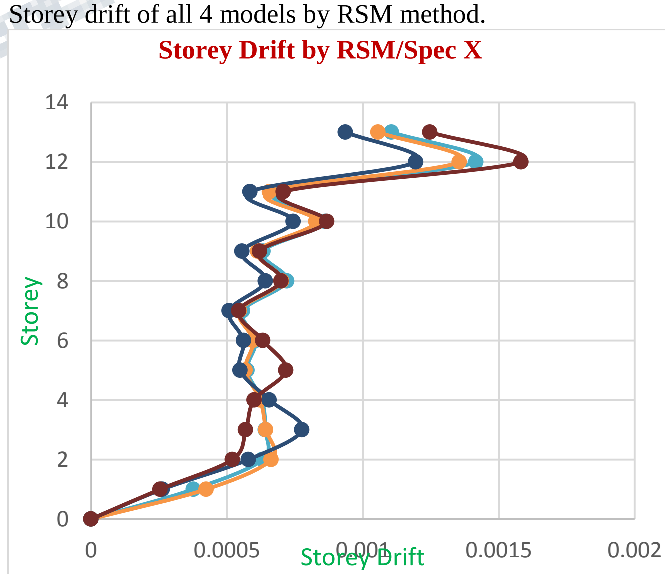

Fig 1.8:Combined plot of Storey Drift by RSM

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Following are the observations from the plot of storeyDrift for all models by linear static method. For irregular building with and without soft storey, drift plot is having very high kinks.this is due to sudden change is Stiffness and mass.There is very high difference in top storey drift in between irregular building.

3.5.4 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.

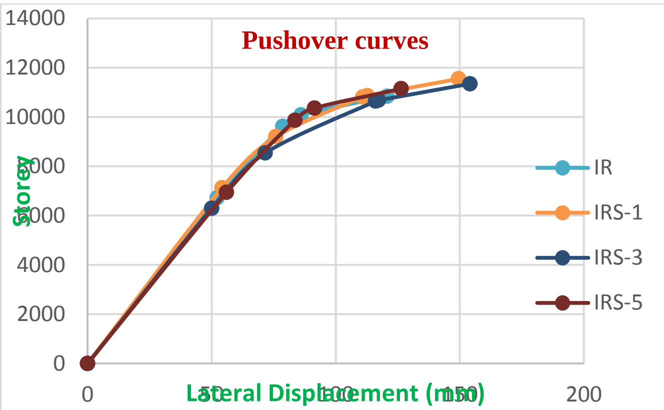

Fig 1.9 Combined plot of Pushover curve

Following are the observations from the combined plot of Pushover curve

For all irregular building with and without soft storey the pushover curve is almost overlapped, this means that all four model IR, IRS-1, IRS-3 and IRS-5 are having nearby same equal lateral load carrying capacity. Lateral load carrying capacity of irregular building is almost 50 % of regular building lateral load capacity

IV. CONCLUSION

A total 4 building models having vertical irregularity with and without Soft storey has been modeled in ETABS. Softstorey has been considered at storey 1, Storey 3 and Storey 5. All the loads have been applied and nonlinear hinges has been assigned as per ATC-40. After modelling 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 has been represented and compared. From the study following conclusion can be made. Linear Static method (LSM) over estimates the Storey shear and Storey drift as compare to Response Spectrum method. Storey shear plot of irregular building are close by Response spectrum method (35 % difference) as compare to Linear static method storey shear plot of regular and irregular building (82- 88 % difference). Program (ETABS) calculated time 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 irregular or 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 irregularity of building. Top Storey drift of irregular building is higher storey drift this is due to less lateral stiffness at the top storey Storey drift plot for all building is within allowable limit. While for irregular building the storey drift plot is having almost zig zag curve due to sudden change in Stiffness and mass at different level. Lateral displacement capacity of irregular building is almost 150 mm.

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