"Seismic Response of High Rise Building with Ground Soft Storey"

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Abstract

Earthquake is the shaking of the surface of the Earth, resulting from the sudden release of energy in the Earth's lithosphere that creates seismic waves that are so weak that they cannot be felt to those violent enough to toss people around and destroy whole cities. After 26th January 2001, Gujarat Earthquake and other earthquakes in India, there is a nation-wide attention to the seismic vulnerability assessment of existing buildings. The buildings with soft storey are very susceptible under earthquake load which create disasters. Due to uses of vehicles and their movements at ground levels infill walls are generally avoided in parking plot, which creates soft storey effect. For proper assessment of the storey stiffness of buildings with soft storey, different models were analyzed using software.

Keyword- Seismic Analysis, Soft Ground Storey, Storey Drift

I. INTRODUCTION

Earth stability is always disturbed due to internal forces which results as vibrations or jerks in earth's crust generally known as an Earthquake. Under such condition, Behavior of building components are complex in nature. It depends on mainly horizontal as well as vertical configuration of structure and also on mass, time period, stiffness etc. Sudden change in strengths or/and stiffness tends to create due to irregularity in vertical configuration which may concentrate earthquake forces in an undesirable way.

These can be very difficult to deal with even in a modern structure although the size of the overall force that building must withstand is determined by the Newton's second law of motion, the way in which this is distributed and concentrated, is determined by the configuration of building in horizontal and vertical direction.[5]

A simple understanding of soft storey is sudden change of lateral storey stiffness within the structure. A high first storey is often architecturally desirable to accommodate larger rooms lobbies, banking floors, or hotel meeting rooms. Such design creates a major stress concentration at that location of discontinuity of lateral storey stiffness and, in extreme circumstance may lead to collapse unless adequate design is provided at such locations.

A common example of the soft storey occurs in apartment houses, which often allocate all or most of the ground floor as a parking, with widely spaced columns and a minimum of walls or no walls were provided.

II. WHAT IS SOFT STOREY?

A Soft story building is a multi-story building with wide doors, large unobstructed commercial spaces, or the ground storey is 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.[3]

As per IS-1893:2002 (part I) [7], An 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 3 storey's above.

Extreme Soft Storey: An extreme soft storey is one in which the lateral stiffness is less than 60 percent of that in the storey above or less than 70 percent of the average stiffness of the 3 storey's above.

III. TYPES STOREY FAILURE

There are four major failure types for building structures.

- Soft Storey Failure
- Mass Irregularity failure
- Plan Irregularity Failure
- Shear Failure

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Figure 1 shows partially or fully collapse occurs due to once the ground floor columns failed, the gravity load carrying capacity of the building was partially or completely lost. No structural damage is observed in the upper stories. The SOFT STOREY at the parking level is the major reason for such types of failure.

Most multi-storey buildings have service water tanks on top of them or bottom stories of building is used as commercial and other stories as residential. Usually, these tanks are only nominally connected to the building. Many such tanks or combined used building have been separated from the building during major earthquake. Fig 2 shows the mass irregularity in upper stories.

Fig. 1: Soft Storey Failure

Fig. 2: Mass Irregularity Failure

As per EQ Tips, Due to irregular shapes like T, C, L etc. of the building, torsional motions contributed to the damage in the structural elements. Most of the damage occurs in such type of buildings is due to improper connection (Fig 3).

Fig. 3: Plan Irregularity Failure

IV. LITERATURE REVIEWS

"Earthquake Analysis of High Rise Building with and Without Infilled Walls" by Wakchaure M.R, Ped S. P [1]

They worked on infill walls in G+9 storey building. The effect of masonry infill panel on the response of RC frames subjected to seismic action is widely recognized and has been subject of numerous experimental investigations, while several attempts to model it analytically have been reported by authors on software named ETABS.

They prepared two models for analysis work of R.C.C. G+9 High Rise building to know the realistic behaviour of building during earthquake. The length of the building was taken as 17.01m and width is 11.96m. Height of typical storey is 3m. Building is located in zone III. Shear wall is provided at the end of the building to resist the earthquake as well as wind forces.

Building was designed as per code IS 456-2000. Grade of concrete and grade of steel was taken as M20 and M25 while Fe415 and Fe500 respectively. Density of Masonry brick was taken as 19 KN/m3. 5% Damping is considered. The columns are assumed to be fixed at the ground level. Size of beams and columns were taken as 230mm x 450mm and 230mm x 600mm respectively.

They gave a result on storey drift that as per clause no 7.11.1 of IS-1893 (Part-1):2002 the storey drift in any storey due to specified design lateral force with partial load factor of 1 shall not exceed 0.004 times the storey height. They also observed that the difference of base shear in G+9 storey building with infill walls and without infill walls was about 4.86%.

"Earthquake Response of Reinforced Concrete Frame with Open Ground Storey" by J. Prakashvel, C. UmaRani, K. Muthumani, N. Gopalakrishnan [2]

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They analyzed the seismic performance of the soft storey reinforced concrete building with the help of the test named SHAKING TABLE TEST. They used 4m X 4m shake table to test the reinforced concrete frame model and required earthquake time history is given to the shake table in the form of displacement values through the multi directional actuators in the test setup.

Specifications of shake table which they used are:

- Size of the table: 4m x 4m
- Maximum pay load: 30 tons
- Frequency of operation: 0.1Hz – 50Hz
- Acceleration (Maximum): 1.0g (H&V)
- Velocity (Maximum): 0.8 m/sec
- Wave form: Sine wave, Sine sweep, Random

High speed data units with necessary sensor or amplifier or recording devices are used to measure the strain, displacement and acceleration.

- Shake table
- Accelerometer
- LVDTs (Linear Variable Displacement Transducer)
- NCDTs (Non-Contact Displacement Transducer)
- Strain Gauge

After completion of shake table test, they observed that the inter storey drift is higher in ground storey compared to other stories.

Due to infill wall panel in other model considered, the cracks formed in sliding cracks instead of "X" cracks means that the maximum base shear value is higher than the strength of that infill panel which was provided. It was also found that the ratio of ground storey stiffness to second storey stiffness is 35% with compare to the stage before testing. They observed that the stiffness of the column reduced to 3.32% due to strengthening of the soft storey effect.

V. SOFTWARE IMPLEMENTATION

Three types of analysis are available for present study named as Linear Static Analysis, Modal Analysis and Non Linear Analysis. Analysis of the models regarding present study was performed in Midas Gen Software.

Modelling of any structure in software is very important for performing any type of analysis using software. A small mistake in modelling can change the final analysis results significantly.

Modelling of the structure in the software includes, creating grid system, adding the structural elements as per the drawing, defining the structural properties and assigning those structural properties to the respective structural elements.

The various steps involved in modelling are as follows:

- Units are set for the suitability
- Define the properties of various material used in the models
- Define the section properties of various structural element of the model
- Model making
- Define and Assign the different loads
- Assign section properties to the model
- Assign the various loads on the structure
- After creating full model, static analysis is performed
- From result tables, material properties and sections are checked
- If required then process of material change or section changes is done
- After that again static analysis is performed
- From result tables, required results and modes or graphs are taken
- From design part, design of structural member is taken along with sketch and reinforcement details

VI. WORK METHODOLOGY

If irregularities in the building are not taken in account while preparing the designing then Good quality of construction will never be enough. Even if an irregular building structure satisfies the requirements of a code, it might never show the performance of a regular building designed by the same code. Concentration of plastic hinges may be formed in definite locations during an earthquake if a structural system contains irregularities.

In general, the vertical irregularities of building structures may be categorized as weak storey, soft storey, discontinuity of vertical elements and mass irregularity. Depending on the soft storey criteria in the recent codes, it is advisable that the mass irregularity is also taken into account within the soft storey irregularity definition.

A weak storey is defined by comparing the effective shear areas of the lateral force resisting systems of adjacent stories; on the other hand, the soft storey irregularity is defined by comparing the stiffness's of the lateral force resisting systems of adjacent stories.

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During an earthquake, if irregular inter-storey drifts between adjacent stories occur, the lateral forces cannot be well distributed along the height of the structure.

This situation causes the lateral forces to concentrate on the storey having large displacement. In addition, if the local ductility demands are not met in the design of such a building structure for that storey and the inter-storey drifts are not limited, local failure mechanism or, even worse, a storey failure mechanism, which may lead to the collapse of the structural system.
Lateral displacement of a storey is a function of stiffness, mass and lateral force distributed on that storey. It is also known that the lateral force distribution along the height of a building is directly related to mass and stiffness of each storey.

VII. DESCRIPTION OF ANALYTICAL MODEL

In order to take above into account 8 and 10 storey frames with 5*5 bays are modelled since most of the framed structures in Surat have number of stories ranging between five to twelve with minimum 3*3 to maximum 6*6 bays.

The span length for the bays is chosen as 4.5m in all the models considered. The story height in the models is chosen as 3.2m for all the floors except the first floors. In order to carry out a parametric study to examine the soft story irregularity, the height of the first story of the models is kept as the selected variable.

Three different heights that are considered for the first floor are: 3.2m, 4.2m and 6m. With these three different heights for the first floor the total number of analyzed models reaches to 12.

Each model in this study is named according to the total number of stories and first story height of it. For example model name "HL3.2:8" indicate six storey models with 3.2m heighted soft storey at ground level.

The expression "HL" used for the height of the lower or first story, after that two digits (as 3.2) indicate height taken in related model as 3.2m and the digit after colon ":" indicates the numbers of stories taken in related model as 8 storey.

A. *General Data's of Analytical Model*

- Height of ground storey 3.2m, 4.2m, 6m (variable)
- Height of typical storey 3.2m (for all models)
- Column sizes:
  1) 600mm*600mm(ground)
  2) 500mm*500mm(up to 3stories)
  3) 450mm*450mm(after 3 stories)
- Beam as 300mm * 600mm & Slab thickness 125mm thick
- Live load
  1) 4KN/m2 at typical floor
  2) 1.5KN/m2 at terrace
- Floor finish 1.0 KN/m2 & Water proofing 2.0 KN/m2
- Location Surat (Zone III)
- Wind load As per IS 875 & Earthquake load As per IS 13920 (Part-1)
- Type of soil Medium
- Thickness of wall 230mm thick

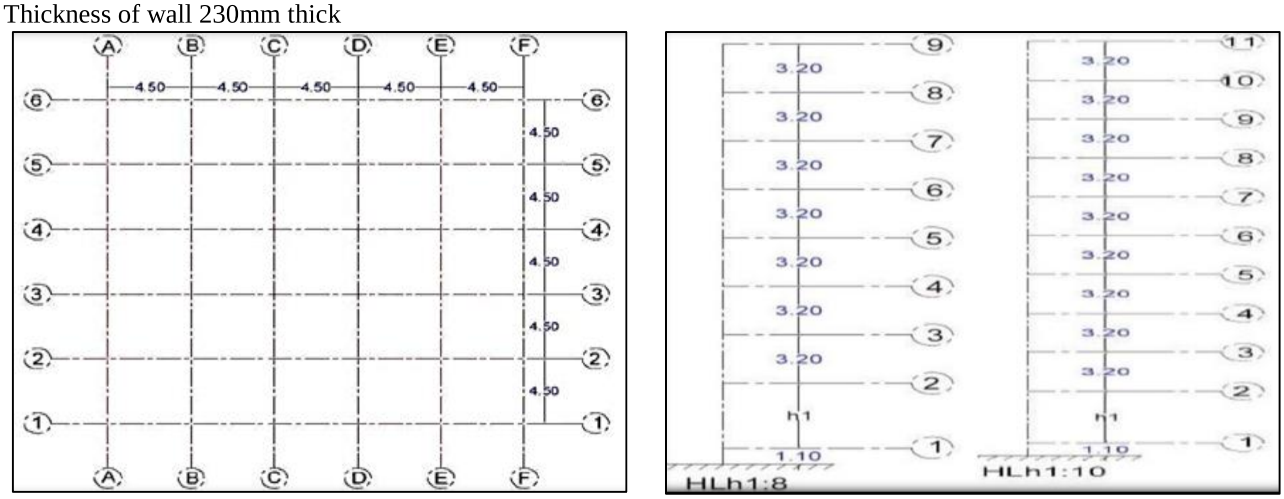

Fig. 4: Plan and Sectional Elevation of the Model Considered

VIII. RESULTS AND DISCUSSION

Main objective of this exercise to find out inter story drift for soft storey by considering stiff column and height variable of soft first storey at first storey level. First the different models are analyzed separately and then it compared with other models results.

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For comparative purpose inter storey drift for different models with different frequencies are considered. The graphical views of all models are shown in below figures.

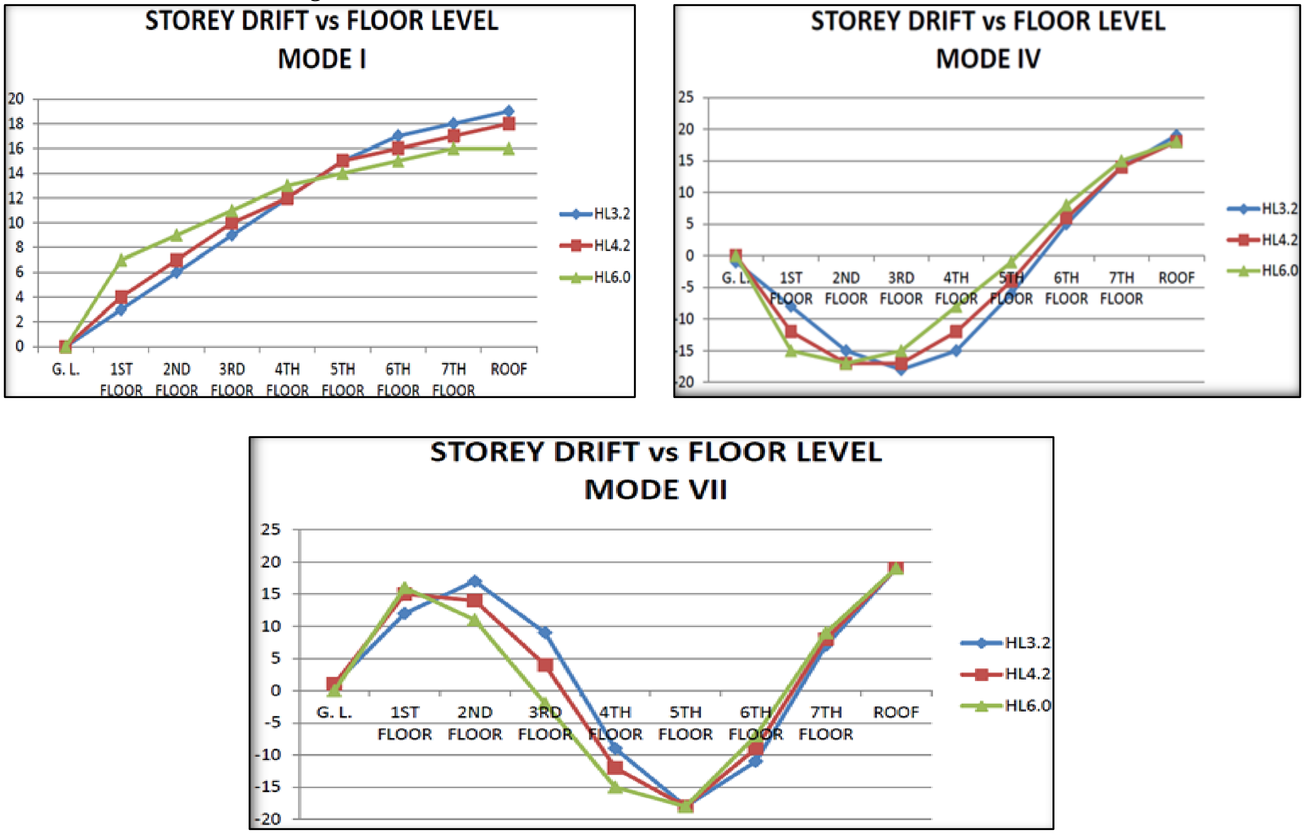

Fig. 5: Storey Drift for Eight Storied Building for Mode I, IV & VII

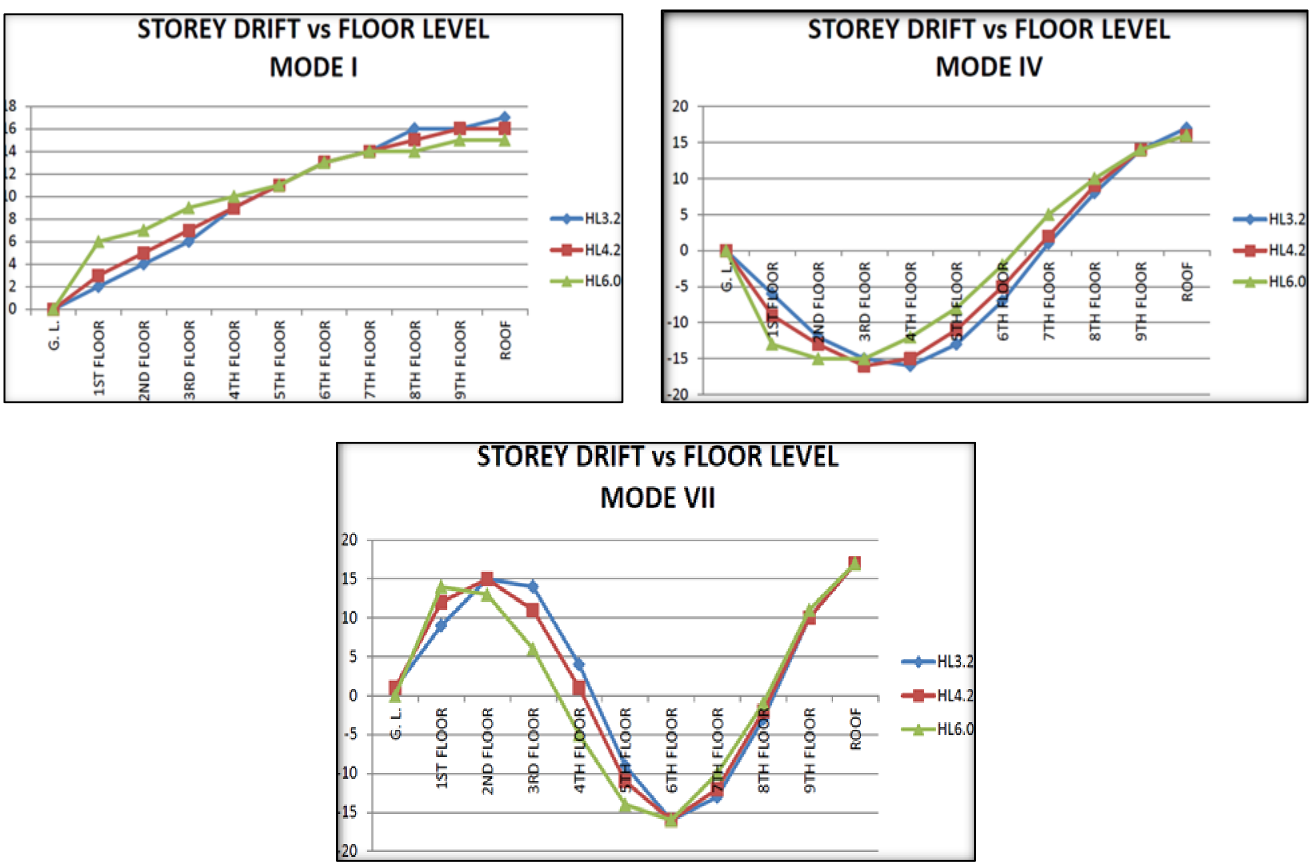

Fig. 6: Storey Drift for Ten Storied Building for Mode I, IV & VII

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IX. Conclusions

In view of the results obtained by the seismic analysis of the considered building structures, following primary conclusions on the observations of behavior of the models are obtained as:

The displacement estimates of the codal lateral load patterns are observed to be smaller for the lower stories and larger for the upper stories and are independent of the total number stories of the models.

The uniform lateral load pattern leads to overestimations of displacements for all of the models and deformation levels.

The estimations of the first mode lateral load pattern leads to more accurate displacement, the deviations on the results of this lateral load pattern decreases due to the existence of the soft stories as the number of stories and number of spans increase.

Depending on the increase in the height of soft story irregularity level of the models, the results of the first mode, code and uniform lateral load patterns approach to the results of nonlinear time history analyses.

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