

Seismic Response of RC Building with Soft Stories

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Abstract— 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 fundamental design concept of earthquake resistance design of structures is to make strong column- weak beam construction to ensure safety of user means during earthquake beams yield before columns collapse.[2] Many buildings that collapsed during the past earthquake exhibited exactly the opposite strong beam weak column behaviour means columns failed before the beams yielded mainly due to soft storey effect. The buildings with soft storey are very susceptible under earthquake load which create disasters. For proper assessment of the storey stiffness of buildings with soft storey, different models were analysed using software.

Keywords— Seismic Analysis, Soft First Storey, Inter Storey Drift

I. INTRODUCTION

Stability of earth is always disturbed due to internal forces and as a result of such disturbance, vibrations or jerks in earth's crust takes place, which is known as an earthquake. The fundamental design concept of earthquake resistance design of structures is to make strong column- weak beam construction to ensure safety of user means during earthquake beams yield before columns collapse. Many buildings that collapsed during the past earthquake exhibited exactly the opposite strong beam weak column behaviour means columns failed before the beams yielded mainly due to soft storey effect.

A simple understanding of soft storey is sudden change of lateral storey stiffness within the structure. An irregularity in vertical configuration tends to create sudden changes in strength or stiffness that may concentrate earthquake forces or other 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.

The overall forces are concentrated at one or few points of the buildings such as a particular set of beams, columns, or walls. These few members may fail and, by chain reaction, bring down the whole building. The most serious condition of vertical irregularity is that of the soft storey.

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.

II. SOFT STOREY

The building in which the ground storey consists of open space for parking area is known as stilt building and the parking storey is called as stilt Floor or Soft-Storey. When sudden change of stiffness takes place along the building height, the storey of which the drastic reduction of stiffness is observed is known as 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) [6]

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 three storeys 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 three storeys above.

III. TYPES OF FAILURE

There are four major failure types for building structures.

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

A. Soft Storey Failure

Due to the shortage of land and for effective use of the sites for new constructions, multi-purpose buildings have been built. The most common structural system for the lower stories of these buildings has been the moment-resisting space frame because it can usually accommodate a parking area, commercial space, gardens, or open spaces for architectural reasons. Due to these provisions, the lateral displacement of the whole structure is governed mostly by the deformation at the lower stories. Therefore, it is essential to estimate the demand and supply in the force and deformation of the members at this part of the building to achieve a reasonable design of these structures.[3,4]

Figure 1 shows that if once the ground floor columns failed, the gravity load carrying capacity of the building was partially or completely lost, resulting in partial or fully collapse of the structures. Same figure shows that Collapse of apartment building due to open ground storey failure. 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.



Figure 1 Collapse of Multi-Storey Building Due To Soft Storey

B. Mass Irregularity Failure

Most multi-storey buildings have service water tanks on top of them. Usually, these tanks are only nominally connected to the building. Many such tanks have been separated from the building during this earthquake.

C. Plan Irregularity Failure

Due to irregular shape (T-shape, C-shape, L-shape etc.) of the building, torsional motions contributed to the damage. [EQ TIPS 6] Most of the damage was to walls of the structures on the outer face of the side that are basement storey for parking. Plan asymmetry, flexible ground storey, and weak infill's seem responsible for this collapse. Building structure with plan irregularity was collapsed due to improper connection at two wings as shown in figure 2.



Figure 2 L-Shaped Plan of Commercial Building with Collapse Part

D. Shear Failure

Detailing practice for transverse ties in columns in the affected area offers very light confinement to the core concrete against the large compressive stress generated by the extreme lateral deformation demands during strong seismic shaking. Many times, the mild steel ties were found to be 5 mm in diameter. Ground floor columns with such reinforcement detailing failed in brittle shear mode leading to failure of many open ground storey buildings, in some buildings, only a few ground storey columns sustained significant shear and flexural cracking, and these buildings were precariously standing.

IV. PARAMETRIC STUDY

Considering material non-linearity and height variation at soft first storey, following parametric study is performed to study inter drift relationship at soft storey.

General data considered is:

- Height of ground storey – 3.2m, 4.2m and 6.0m
- Numbers of bays – 5 @ 4.5m both way
- Height of other storey – 3.2m (constant for all models)
- Column size – 600mm*600mm (Footing), 500mm*500mm (up to 3 stories), 450mm*450mm (others)
- Beam size – 300mm*600mm
- Slab thickness – 125mm thick
- Wall thickness – 230mm thick

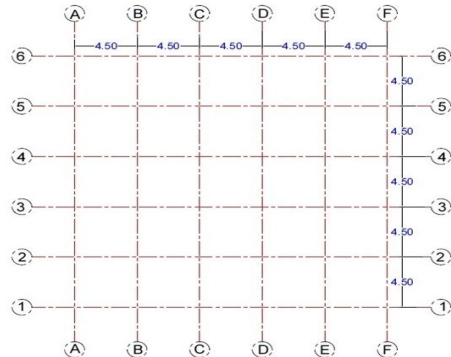


Figure 3 Plan of the Model Consider for the Study

- Live load – 4 KN/m² at typical and 1.5 KN/m² at terrace floor
- Floor finish – 1.0 KN/m²
- Water proofing – 2.0 KN/m²
- Zone of building- Surat (III)
- Wind load – as per IS 875
- Earthquake load – as per IS 13920
- Type of soil – Medium
- Average thickness of footing – 900mm (assuming isolated footings)
- Grade of steel and concrete- Fe 415 and M25 respectively

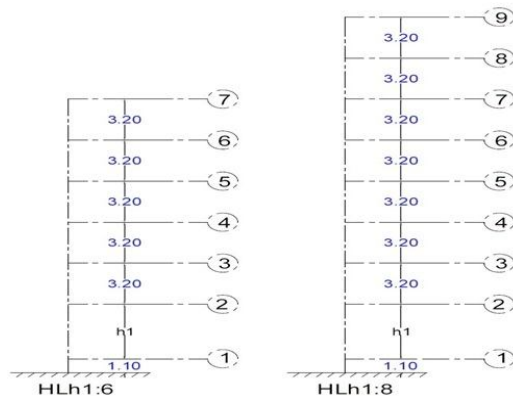


Figure 4 Sectional Elevation of Different Models Consider for the Study

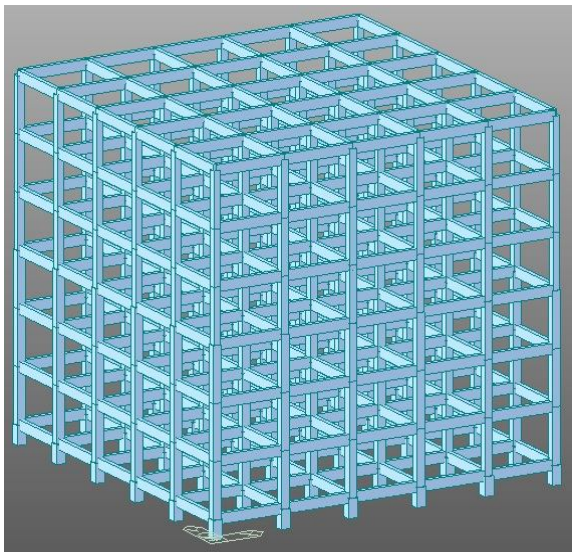


Figure 5 3-D View of Model HL3.2:6

In order to examine the soft storey behaviour of the building structures, several two-dimensional analytical models are considered in this study. During the development of the analytical models, several issues are taken into consideration. An important topic at this stage is to evaluate easily the existence of the soft story behaviour in the structure. For this reason, two dimensional frame models for which the soft story behaviour can easily be accepted are selected for investigation.

Each model in this study is named according to the total number of stories and first story height of it. For example model name “**HL3.2:6**” 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 6 storey. All these analytical models are analysed according to the requirement of Indian Standard Codes.

V. RESULTS AND DISCUSSIONS

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 analysed separately and then it compared with other models results. For comparative purpose inter story drift for different models with different frequencies are considered.

Using the analytical procedure, typical soft storied infilled frame with variable first soft storey is analysed using the software MIDAS GEN (validated before study) considering all the parameters stated above. The results are compared with different models with different mode shapes and charts were prepared for comparison between different heighted storeys.

Lateral deformation or inter storey drift is one of the most important result in the design and analysis of a building. Therefore lateral deformations due to equivalent lateral loads

of seismic zones have been studied and comparisons are also made.

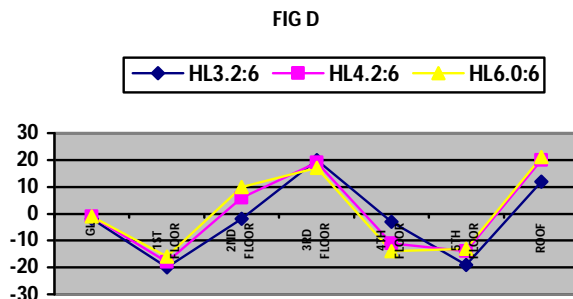
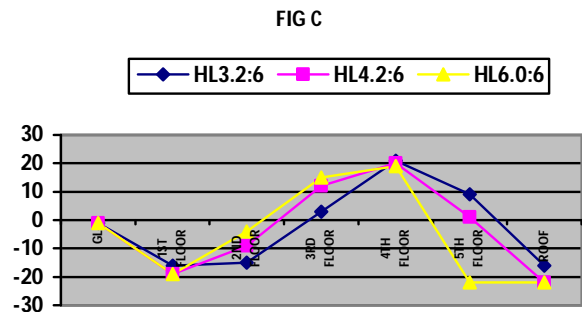
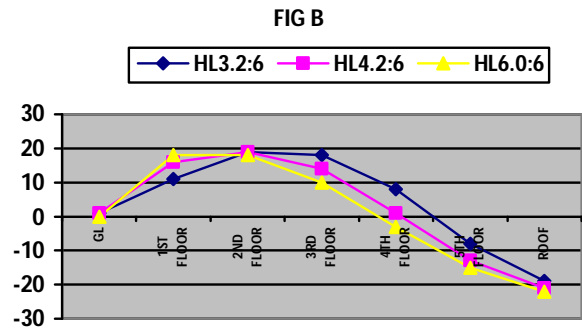
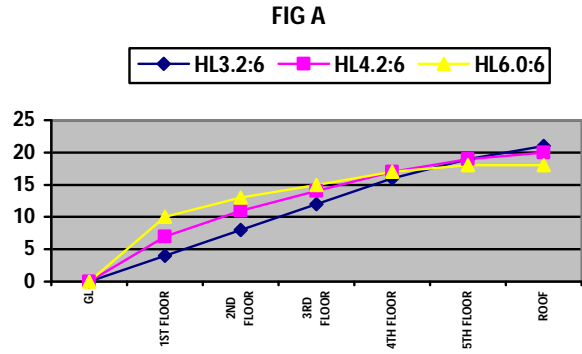


Figure 6 Storey Drift vs Floor Level for Six Storied Building for (A) Mode I, (B) Mode IV, (C) Mode VII and (D) Mode X

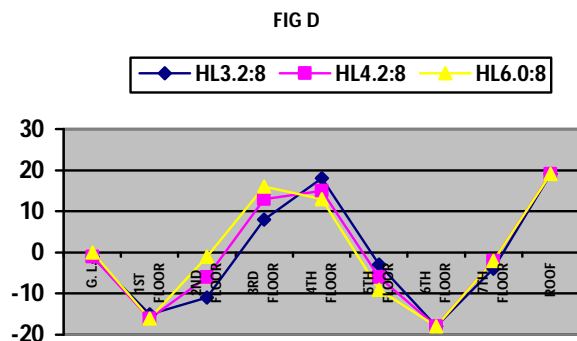
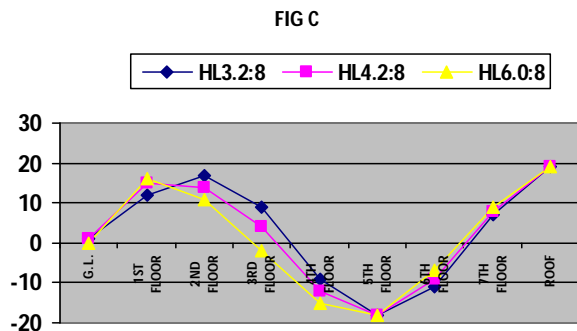
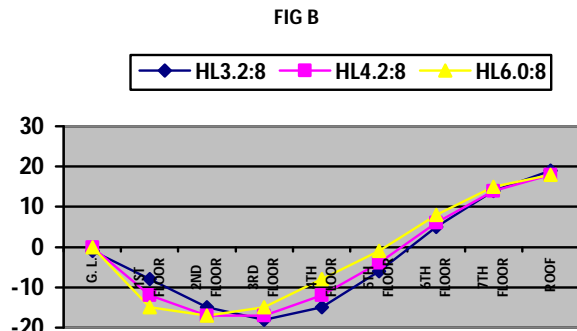
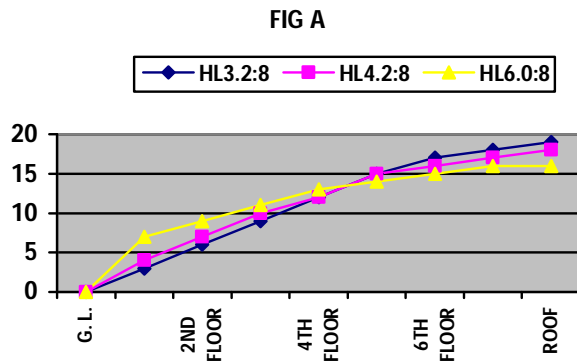


Figure 7 Storey Drift vs Floor Level for Eight Storied Building for (A) Mode I, (B) Mode IV, (C) Mode VII and (D) Mode X

VI. CONCLUSIONS

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

- 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.

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