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RESEARCH ARTICLE

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STRENGTHENING OF SOFT–STOREY BUILDING

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ABSTRACT

Reinforced Concrete frame buildings with masonry infill panels are becoming increasingly common in urban and semi-urban areas all over India. Many such buildings constructed in recent times have a special feature of the ground storey being left open for the social purpose of parking, i.e., columns in the ground storey do not have any partition walls (of either masonry or reinforced concrete) between them. These buildings are immanently vulnerable to collapse or damage due to earthquake.

In this project, an attempt has been made to identify an efficient strengthening method for existing soft storey reinforced concrete frame buildings. Failure of several soft storey buildings in the past earthquakes underscores the need to strengthen existing soft storey buildings. A common cause for the collapse of multi-storey buildings is the occurrence of soft storey in the ground floor due to the presence of infill walls in the upper story. During the Bhuj (Gujarat) earthquake of 6thJanuary 2001 several soft storied building failed there by confirming the vulnerability of such buildings to earthquake loading. This underscores the need to strengthen existing soft story buildings to prevent their total collapse. The existing building structures, which were designed and constructed according to early codal provisions, do not satisfy requirements of current seismic code and design practices. The computer software ETABS is used for analysing the performance of a reinforced concrete buildings.

INTRODUCTION

Soft-story building: A soft story building is a multi-story building in which one or more floors have windows, wide doors, large unobstructed commercial spaces, or other openings. A typical soft story building is an apartment building of three or more storeys located over a ground level with large openings, such as a parking garage or series of retail businesses with large windows.

Effects on soft storey building due to earthquake: Once a general investigation of the results of the quakes that occurred so far is conducted, it can be seen that the biggest damage to human beings has always come from weakness buildings. Thus, the most effective way of protection against quakes is not to build resistant constructions. It is only possible to build a resistant construction if we take quakes into consideration at the stages of design, Project, construction, and occupancy. There are essential specifications which should be taken into consideration at these stages. These are short column, strong column-weak beam, and torsion. Soft storey irregularity is one of these. Short storey is an irregularity which should definitely be taken into consideration if the construction is to be a resistant one. It is only possible to build a quake resistant construction if all these irregularities are considered.

If structural irregularities are not taken into consideration, a construction cannot be said to be a resistant one no matter the highest quality concrete43is used. Just like an illness in one part of the body affects the whole body, so does an irregularity in a constructions. Because a construction is the whole with its ground and its super structure. Soft storey is the one of which the rigidity is lower than any other storeys due to the fact that it has not got the walls with the same properties the other ones have. If vertical load bearing structural elements and the partitioning wall continue in all the storeys, there is no soft storey in the construction. Softstoreys are generally present at the entrance floors of the buildings. This situation depends on the constructional properties of the cities and countries. If dwellings and trade centres are at the same building, soft storeys are more common, if not, soft storeys are rare.

Since dwellings and trade centre are in the same building in general in Turkey, most of the constructions have soft floors. Because entrance floors of the buildings are used as bank branches, stores, restaurants, offices and the upper storeys are used as dwellings. Since the business stores and the dwellings are not the two sections with the same properties, there exist soft storeys. This aspect of construction in Turkey was observed early when we investigate the Izmit-quake results of soft storeys. Nearly 85-90 % of the collapsed and damaged buildings had soft storeys in them.

During an earthquake, more moment and shear strength fall on the columns and walls in the entrance floors than the one in the upper storeys. If the walls that exist in other storeys do not exist in the entrance floor, these columns are forced more those in other storeys. Due to the fact that there is less rigidity in soft storeys, the structure is divided into two sections in terms of structural behaviour; the lower and the upper part of the soft storey. This can be called dangerous storey instead of soft storey.

It is not so easy for a country to say that no construction would be constructed having no store and offices in them. In order to do this, it would be better to investigate the precautions to be taken. The measure of the growth in construction technology is to build a construction according to the designated place and possibility of a quake. Since no nation would leave its country because of earthquake, it is necessary for that nation to build quake resistant buildings. Building quake resistant constructions is as important as other struggles. Since earthquakes do not respectful for country borders, it is a common menace for humanity. For this reason advances in the field of earthquake studies should be presented to every individual. This study covers the studies that were conducted in the quake area of Izmit (Mw=7.4 and August, 17,1999) and Duzce (Mw= 7.2 and November, 12, 1999). As a result of this investigation and according to the studies in literature, drawbacks of soft storeys and stages of preventing are covered.

Soft storeys in constructions came into being in two ways:

1. Columns, shears and walls showing difference between storeys
2. Rigidity between the storeys of the construction being different, resulting graters displacements at the stage of projecting a structure, certain solutions should be worked out as regards the quake region, importance and the function of the building, and irregularities should be eliminated. it cannot be said that storeys being constructed with the same physical properties are not soft storeys. For this two kinds of control should be carried out. The ratio of number of columns, shears, and walls on one storey of the building parallel to the quake to the ones on the other storeys (SS). The ideal ratio is 1 (But, as it

is not always possible to materialise this, this ratio can be taken less than 1. This ratio is taken as 0.80 in Code of Earthquake. When this ratio is lower, additional precautions should be taken or the design of the building should be reviewed. In case the soft storey irregularities are on the entrance floor, this ratio should be 0.8-0.9, according to the importance of the construction.

Earthquake behaviour in soft storey building: Symmetrical constructions in both plan and height show a better resistance during an earthquake than those that do not have this symmetry. Since the presence of a soft storey which has less rigidity than other storeys spoils the perpendicular symmetry of the construction, and if this fact was not taken into consideration, it causes the construction to be affected by the quake. Because the columns in this partare forced by the quake more than the ones in the other parts of the building. Studies conducted suggest that walls increase the rigidity at a certain degree in the construction (1).Code Earthquake accepted this ratio as 15 %. That is to say, there is 15 % difference of rigidity between a storey with walls and the one without any walls.

A construction is divided into two parts from the point where there is a soft storey. Of the constructions with equal rigidity between the storeys, the displacement of the peak points at the moment of a quake causes the other building with a soft storey to get damaged because the construction with a soft storey cannot shoe the same rigidity.

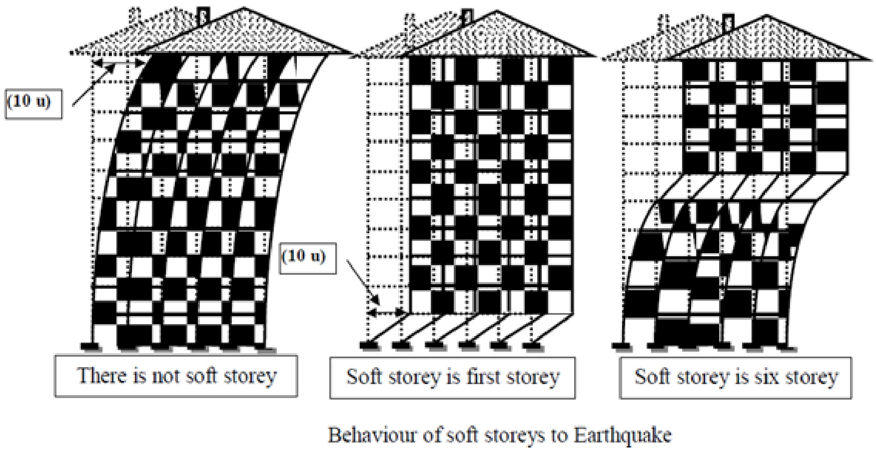

Figure 1: Behaviour of soft storey building during Earthquake

For example the top point of aten-storey building with no soft storey performs 3 cm displacement, another building with the same specification but having a soft storey at the entrance floor and with no necessary precaution can show the same displacement 3 cm at this floor. according to this result, a soft storey in upper storey's of the building is not so effective. Quake damages investigated verify this conclusion. U is displacements.

Soft storey is first storey Soft storey is six storey. Since soft storeys affect in great extend the behaviour of the buildings during a quake, this fact is given detailed place in Codes of Earthquakes Table1. Despite all this, still most of the constructions damaged suffer from this irregularity. As a result of investigation on this and other irregularities, it was observed that Codes of Earthquake are not sufficient, especially in Turkey. For this reason, it comes into forefront that it is necessary for these irregularities to be controlled at the stage of project and construction. It should be known that controlling is one stage in building quake-resistant constructions, and it should be applied.

Need of the project: Due to increasingly frequent number of earthquakes nowadays it is necessary to strengthen the soft storey buildings because soft storey buildings lack adequate strength or stiffness to prevent leaning or collapse in an earthquake.

Objective:

- To increase the strength of the soft storey building by providing an efficient and economical method.
- To analyse the building using ETABS.

Strengthening methods: In constructions where it is necessary to build a soft storey, lateral rigidity of this particular storeyshould be brought to the rigidity level of the other storeys. To be able to do this, the number of columns and shear walls should be increased. Because of this increase, longitudinal and lateral reinforcement should also be increased. These raise the cost of the construction. Soft storey is an irregularity which affects the behaviour of a construction during a quake and also increases the construction costs. For this reason, soft storeys should be avoided as much as possible. In case it is necessary, by the controls to be performed as a result of calculation made, irregularities can be eliminated as follows:

1. Building additional walls
2. Increasing the rigidity of the columns and the shear walls on the soft storey
3. Regulating the dimensions of the columns and shear walls by longitudinal and lateral reinforcement so that the soft floor would show a ductile behavior
4. Preventing cracking by placing the wall at a certain distance from columns and walls that are on the soft storey

Now that we cannot leave the already present buildings, we should turn them into resisting ones according to bring the present buildings into resistant state of being, proper one of the following method is applied:

1. Increasing the lateral rigidity of this storey by putting up shear walls between single structural elements on the soft storey.
2. Increasing the lateral rigidity of this storey by placing steel diagonals between the columns.

Shear wall: Basically, the structural wall is introduced in the open panel of the ground storey. A single layer of reinforcement was provided for theRC structural wall designed as per the Indian standard for ductile detailing [IS13920: 1993].

Steel bracing: The open ground storey column beam junction is steel braced by angle sections.

LITERATURE

M.R. Amin, etalstudied about Effect of soft storey on multistoried reinforced concrete building frame during December 22-24, 2011

In an attempt to investigate the effect of soft storey for multi-storeyed reinforced concrete building frame, four building models with identical building plan were analyzed. Equivalent diagonal struts were provided, as suggested in FEMA-273, in place of masonry to generate infill effect. Earthquake load was provided at each diaphragm's mass centre as a source of lateral load as set forth by the provision BNBC (1993). Soft storey level was altered from ground floor to top floor for each model and equivalent static analysis was carried away using ETABS 9.6.0 analysis package. Results show a general changing pattern in lateral drift irrespective to building height and location of soft storey. Inter-storey drift ratio was found increasing below the mid storey level and maximum ratio was obtained where the soft storeywas located. The rate of increase in drift ratio at any particular floor for different building height increases linearly from bottom to top floor. As the building height increases, location of soft storey goes downwards from mid storey level to produce maximum lateral drift.

Mizan, etal studied about Soft-storey behaviour in an earthquake(2002)

Due to the considerations of occupancy and architectural appearance, especially in the entrance floor and on one of the intermediate levels, inner sections between columns and outer walls are not constructed in the way they are done in other storeys or rigidity of the single structures in the storeys are different. These sections in the buildings are generally used for sales stores, restaurants, bank branches, installations and lightening. These are labelled as soft storeys in literature. Form the studies and investigation of the quake results, it is observed that partitioning walls and beam fillings enable buildings to gain great rigidity. Although irregularities of soft storey have taken place in many construction codes, it is observed that most of the damage constructions suffered result in this kind of irregularities. In the current study the focus, depending on the investigations on soft storeys conducted in quake regions of Izmit and Duzce, was on the investigation of the effect of a soft storey on the behaviour of a construction. Also solutions were investigated for making the soft storeys in the present constructions and in the ones to be built resistant to quake.

PravinB.Waghmare studied about A Comparative Study of Retrofitting Of R.C. Building Using Steel Bracing And Infill Walls.

The objective of this study is to identify an efficient retrofitting method for existing open ground story reinforced concrete frame buildings. Failure of several soft-stored buildings in the past earthquakes underscores the need to retrofit existing soft-story buildings. A common cause for the collapse of multi-storied buildings is the occurrence of soft story in the ground floor due to the presence of infill walls in the upper story. During the Bhuj (Gujarat) earthquake of 6thJanuary 2001 several soft storied building failed there by confirming the vulnerability of such buildings to earthquake loading. This underscores the need to retrofit existing soft story buildings to prevent their total collapse. The existing building structures, which were designed and constructed according to early codal provisions, do not satisfy requirements of current seismic code and design practices. A two dimensional R.C. frame designed with linear elastic dynamic analysis using response spectrum method. The computer software package STAAD Pro–2005 is used for dynamics analysis technique is used to assess the performance of a (G + 4) reinforced concrete buildings, of which the ground storey is a parking facility the ground storey is 3.5m high while the upper stories giving a total height of 15.5 m. the building is located in Seismic Zone IV.

METHODOLOGY

COLLECTION OF BUILDING DATA

Building 1

Location details: Silversky apartments is located at ramasamynagar in udumalpet, Tirupur District, Tamil Nadu. It is located 2 km from the udumalpet bus stand.

Specifications:

Table 1 : Specifications for building 1

S.No.	Parameters	Values
1.	Type of structure	soft-sotrey building
2.	No of storeys	G+2
3.	Storey height	3.7 m
4.	Zone	3
5.	Imposed load	2kN/m2 at roof & 5kN/m2 at floor
6.	Floor finish	0.5 kN/m^2
7.	Depth of slab	150mm
8.	Materials	M20 grade Fe415 steel
9.	Unit weight of R.C.C	25 kN/m^3
10.	Unit weight of masonry	20 kN/m^3
11.	Modulus of elasticity of concrete	2.23x107 N/mm2
12.	Hight of building	12 m
13.	Clear cover of beam and column	25mm &40mm
14.	Parapet height	1m
15.	Beam	230x350 mm
16.	Column	250x300 mm

Building 2

Location details: Muthoot financial corporation building is located nearudumalpet bus stand on the pollachi main road, udumalpet,Tirupur District, Tamil Nadu.

Specifications

Table 2: Specifications for building 2

S.No.	Parameters	Values
1.	Type of structure	soft-sotrey building
2.	No of storeys	G+1
3.	Storey height	4m
4.	Zone	3
5.	Imposed load	2kN/m2 at roof & 5kN/m2 at floor
6.	Floor finish	0.5 kN/m^2
7.	Depth of slab	150mm
8.	Materials	M20 grade Fe415 steel
9.	Unit weight of R.C.C	25 kN/m^3
10.	Unit weight of masonry	20 kN/m^3
11.	Modulus of elasticity of concrete	2.23x107 N/mm2
12.	Hight of building	9m
13.	Clear cover of beam and column	25mm &40mm
14.	Parapet height	1m
15.	Beam	230x350 mm & 230x300 mm
16.	Column	450x300 mm &400x400 mm

Introduction to ETABS: For nearly 30 years, ETABS has been recognized as the industry standard for Building Analysis and Design Software. Today, continuing in the same tradition, ETABS has evolved into a completely integrated building analysis and design environment.

ETABS can integrated models that include moment resisting frames, braced frames, staggered truss systems, frames with reduced beam sections or side plates, rigid and flexible floors, sloped roofs, ramps and parking structures, mezzanine floors, multiple tower buildings and stepped diaphragm systems with complex concrete, composite or steel joist floor framing systems. Solutions to complex problems such as panel zone deformations, diaphragm shear stresses, and construction sequence loading are now at your fingertips. ETABS is the solution, whether you are designing a simple 2D frame or performing a dynamic analysis of a complex high-rise that utilizes non-linear dampers for inter-story drift control.

ETABS is a programme for linear, nonlinear, static and dynamic analysis, and the design of building systems. From an analytical standpoint, multi-storey buildings constitute a very special class of structures and therefore deserve special treatment. The concept of special programmes for building type structures was introduced over 30 years ago and resulted in the development of the TABS series of computer programmes.

ETABS is very useful software in the field of civil engineering. It is the most used software in structural engineering for the design of buildings, bridges and more complex analytical models. It features a powerful graphical user interface. It is used for linear, non-linear, static and dynamic analysis and design of the building systems. Etabs is best for designing of simple 2D frames as well as performing a dynamic analysis of complex high-rise structures and shear walled buildings.

Using ETABS you can:

1. Create and modify a model
2. Execute the analysis
3. Design a model as well as optimize the design
4. It displays results in graphical forms and also display real time-history displacements and generates reports.

Features and Benefits of ETABS

1. Windows Drop Down Menu
2. Windows Tool Bar
3. Complete black screen of Graphical User Interface.
4. Command Tool Bar
5. ETABS gives you three views of your model (Plan, Elevation or 3D) and also the extruded view
6. Model can be rotated in 3D.
7. Different sides of the 3D model or the plan can be viewed one by one.
8. There are the too many zooming options. First one is for Rubber band zoom,second to restore full view, third to Restore Previous zoom, fourth to zoom in one step and last is to zoom out one step.
9. The input, output and numerical solution techniques of ETABS are specifically designed to take advantage of the unique physical and numerical characteristics associated with building type structures. As a result, this analysis and design tool expedites data preparation, output interpretation and execution.
10. The need for special purpose programmes has never been more evident as Structural Engineers put non-linear dynamic analysis into practice and use the greater computer power available today to create larger analytical models.
11. Over the past two decades, ETABS has numerous mega-projects to its credit and has established itself as the standard of the industry. ETABS software is clearly recognised as the most practical and efficient tool for the static and dynamic analysis of multi-storey frame and shear wall buildings.

RESULT AND DISCUSSION

Analysis using ETABS

Analysisof building 1: The building 1 is analysed as a framed structure using ETABS software. It is analysed under the following different cases:

a. Normal
b. Earthquake
c. Earthquake with shear walls
d. Earthquake with bracings

The main load cases considered for analysis is that as follows:

a. Dead load
b. Live load
c. Wind load
d. Earthquake load

Normal: For the normal building the live load is taken as 5kN/m and the wind speed is taken as 47m/s. The building is safe if the interaction value is below 1 for columns, according to the ETABS result the interaction value is below 1 for all the columns hence it shows that the building is safe in normal conditions.

Earthquake: For the earthquake loaded building the live load is taken as 5kN/m, the wind speed is taken as 47m/s and the seismic zone factor is taken as 0.16.The building is safe if the interaction value is below 1 for columns, according to the ETABS result the interaction value is above 1 for seven columns hence it shows that the building is not safe in earthquake conditions.

Earthquake with shear wall: The building is now strengthened using shear walls. The shear walls of 75 mm thickness are provided at all the four corners of the building and at the middle of the outer surface of the building. It is seen taken care that the shear walls are place symmetrically about both the axis. Now it is seen that all columns have an interaction value below 1 hence the building is safe.

Earthquake with steel bracing: The building is now strengthened using bracings. The bracings of double angle 70mmx70mmx10mm are provided at all the four corners of the building and at the middle of the outer surface of the building. It is seen taken care that the bracings are place symmetrically about both the axis. Now it is seen that all columns have an interaction value below 1 hence the building is safe.

Analysis of building 2: The building 1 is analysed as a framed structure using ETABS software. It is analysed under the following different cases:

a. Normal
b. Earthquake
c. Earthquake with shear walls
d. Earthquake with bracings

The main load cases considered for analysis is that as follows:

a. Dead load
b. Live load
c. Earthquake load

Normal: For the normal building the live load is taken as 5kN/m and the wind speed is taken as 47m/s.The building is safe if the interaction value is below 1 for columns, according to the ETABS result the interaction value is below 1 for all the columns hence it shows that the building is safe in normal conditions.

Earthquake: For the earthquake loaded building the live load is taken as 5kN/m, the wind speed is taken as 47m/s and the seismic zone factor is taken as 0.16.The building is safe if the interaction value is below 1 for columns, according to the ETABS result the interaction value is above 1 for ten columns hence it shows that the building is not safe in earthquake conditions.

Earthquake with shear wall: The building is now strengthened using shear walls. The shear walls of 100 mm thickness are provided at all the four corners of the building and at the middle of the outer surface of the building. It is seen taken care that the shear walls are place symmetrically about both the axis.

Now it is seen that all columns have an interaction value below 1 hence the building is safe.

Earthquake with steel bracing: The building is now strengthened using bracings. The bracings of double angle 80mmx80mmx12mm are provided at all the four corners of the building. It is seen taken care that the bracings are place symmetrically about both the axis.Now it is seen that all columns have an interaction value below 1 hence the building is safe.

Analysis Results

Result for building 1:

- The sway of building 1 for the different conditions of loading and strengthening is measured using ETABS.
- The maximum sway for building 1 with normal loading condition is 9.05mm.
- The maximum sway for building 1 with earthquake loading condition is 18.55mm.
- The maximum sway for building 1 with earthquake loading and restrained using shear walls condition is 13.1mm.
- The maximum sway for building 1 with earthquake loading and restrained using steel bracings condition is 13.36mm.

Result for building 2:

- The sway of building 2 for the different conditions of loading and strengthening is measured using ETABS.
- The maximum sway for building 2 with normal loading condition is -0.009mm.
- The maximum sway for building 2 with earthquake loading condition is 21.39mm.
- The maximum sway for building 2 with earthquake loading and restrained using shear walls condition is 12.92mm.
- The maximum sway for building 1 with earthquake loading and restrained using steel bracings condition is 8.60mm.

CONCLUSION

- In this project two soft storey buildings were analyzedfor earthquake loads based on the codal provisions (IS456-2000, IS875-1987(part 1, 2,3 and 4), IS1893-2002).
- The structure has been analysed for earthquake using ETABSfor all the structural components.
- Form the result of building 1 the shear walls are suitable for soft storey buildings which include wind load because shear walls resist the sway better than steel bracings.
- For the result of building 2 the steel bracings are suitable for soft storey buildings which do not include wind load

because steel bracings resist the sway better than shear wall.

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