INTERNATIONAL JOURNAL OF PURE AND APPLIED RESEARCH IN ENGINEERING AND TECHNOLOGY

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SPECIAL ISSUE FOR
INTERNATIONAL LEVEL CONFERENCE
"ADVANCES IN SCIENCE, TECHNOLOGY & MANAGEMENT"
(IC-ASTM)

SEISMIC BEHAVIOR OF RCC STRUCTURE WITH SOFT STOREY AT EARTHQUAKE FORCES

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Accepted Date: 05/09/2017; Published Date: 10/10/2017

Abstract: The concept of Soft storey has taken its place in the Indian urban environment due to the fact that it provides the parking facility in the soft storey of the building. The cost of construction of this type of building is much less than that of a building with basement parking. Surveys of buildings failed in the past earthquakes show that this types of buildings are found to be one of the most vulnerable. The majority of buildings that failed during the Bhuj earthquake (2001) and Gujraat earthquake were of the soft storey type. The collapse mechanism of such type of building is predominantly due to the formation of soft-storey behavior in the ground storey of this type of building. The sudden reduction in lateral stiffness and mass in the ground storey results in higher stresses in the columns of soft storey under seismic loading. Buildings are classified as having a "soft story" if that level is less than 70% as stiff as the floor immediately above it, or less than 80% as stiff as the average stiffness of the three floors above it. The static analysis of this given structure with soft storey at different level subjected to the earthquake forces. Seismic performance of 3D building structure with intermediately infill frame was studied. Performance of R.C. structure was evaluated considering different models for the soft storey by using the STAAD Pro software.

Keywords: Soft Storey, Earthquake, Seismic Analysis.

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Access Online On:

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How to Cite This Article:

A. R. Gupta, IJPRET, 2017; Volume 6 (2): 39-44

PAPER-QR CODE

INTRODUCTION

Soft story (also known as open ground story) buildings are commonly used in the urban environment nowadays since they provide parking area which is most required. This type of building shows comparatively a higher tendency to collapse during earthquake because of the soft storey effect. Large lateral displacements get induced at the first floor level of such buildings yielding large curvatures in the ground storey columns. Again when a sudden change in stiffness takes place along the building height, the story at which this drastic change of stiffness occurs is called a soft story. The Indian code (clause no. 4.20) classifies a soft storey as, It 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 storey's above(IS 1893:2002). Soft storey can form at any level of a high rise building to fulfill required functional necessity and serve various purposes.

1. DETAILED STUDY –

2.1 SOFT STOREY BUILDINGS –

A soft storey is characterized by vertical discontinuity in stiffness. When an individual storey in a building (often the ground level storey) is made taller and more open in construction, it is called a soft storey The presence of infill walls in the upper storeys of the soft storey building increases the stiffness of the building, as seen in a typical infilled framed building. Due to increase in the stiffness, the base shear demand on the building increases while in the case of typical infilled frame building, the increased base shear is shared by both the frames and infill walls in all the storeys. In soft storey buildings, where the infill walls are not present in the soft storey, the increased base shear is resisted entirely by the columns of the ground storey, without the possibility of any load sharing by the adjoining infill walls. The increased shear forces in the soft storey columns will induce increase in the bending moments and curvatures, causing relatively larger drifts at the first floor level.

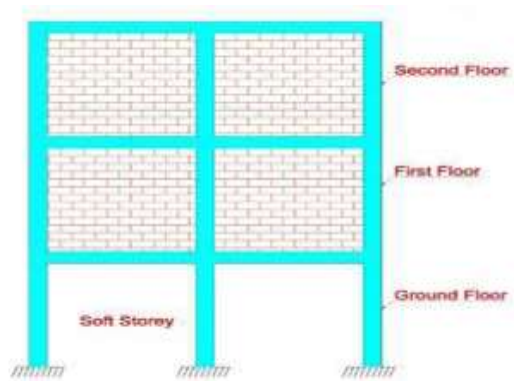

Figure 1.1: Soft storey structure

2.2 SOFT STOREY AND WEAK STOREY –

Soft storey- Definition- It is the one 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.

Weak storey- Definition- It is one in which the storey lateral strength is less than 80 percent of that in the storey above. The storey lateral strength is the total strength of all seismic forces resisting elements sharing the storey shear in the considered direction.

2.3 SOFT STOREY FAILURE-

The shortage of land in the urbanized area has made the engineers to build the first storey of the building with open space for parking, etc. The strength demand on the column in the first storey for these building is also large, but however in the upper stories the forces in the columns are effectively reduced due to presence of brick infill walls which share the forces. If the stiffness of the first floor is significantly less strong or more flexible, a large portion of the total building deflections tends to concentrate in that floor. The presence of walls in upper stories makes them much stiffer than the open ground storey of the building. Due to these provisions, the lateral displacement of 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. 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.

Fig 3: Collapse of Multi-Storey Building Due To Soft Storey.

2.4 METHODS OF SEISMIC ANALYSIS -

There is various method of seismic analysis discussed in this chapter which are as follows:

1. Linear Analysis
   (a) Static Analysis Methods
   (b) Response Spectrum Methods
   (c) Time History Methods
2. Non-Linear Analysis
   (a) Static (pushover –force or displacement control)
    1. P-delta analysis.
    2. Large displacement analysis.

2.5 LOADINGS & LOADING CASES:

An accurate estimation of all loads acting on the structure should be made before it can be properly designed. A structure may be subjected to one or more of the following loads.

- ***Dead Loads -*** The dead loads include the weight of materials permanently fixed to the structure, such as beams, floors, walls, columns, and fixed service equipment's. The dead load can be calculated if sizes and types of structural materials are known.

- ***Live Loads -*** The live loads are the movable loads that are not permanently attached to the structure. These loads are applied during a part of its useful life. Loads due to people, goods, furniture, equipment, machinery, etc. are the live loads.
- ***Wind Loads -*** Wind loads act on all exposed surface of structure. These loads depend upon the velocity of wind and the type of structure.
- ***Snow loads -*** Snow loads occur due to accumulation of snow on roofs and exterior flat surfaces in cold climates. The unit weight of snow is usually taken as 1 kN/m^2
- ***Earth pressure -*** Earth pressures produce lateral force against the structure below the ground surface or fill surface. The earth pressure is normally treated as dead load.
- ***Water pressure -*** Like earth pressure, water pressure also produces a lateral force against the structure below the water level. It may also cause an upward force on the bottom of the structure due to uplift pressure. It must be counteracted by the dead load of the structure.
- ***Earthquake loads -*** The force due to an earthquake may act vertically, laterally or torsion ally on ·a structure in any direction. The worst condition should be anticipated and the relevant code consulted. The earthquake load is usually assumed as a fraction of the dead load, depending upon the seismicity of the zone.

2. CALCULATION OF DESIGN HORIZONTAL SEISMIC COEFFICIENT ACCORDING TO IS 1893:2012 AND EQUIVALENT STATIC ANALYSIS USING STAAD PRO

3.1 Calculation of design horizontal seismic coefficient according to IS 1893:2012

The total design seismic base shear (V_B) along any principal direction shall be determined by following expression

$$V_B = W \times A_h$$

Where,
W = total weight of the building calculated using the structural details and
A_h = calculated as shown below:

$$A_h = \frac{Z\,I\,S_a}{2\,R\,g}$$

Where,
Z = Zone factor given in Table 2 of IS 1893:2002, is for the Maximum Considered Earthquake (MCE) and service life of structure in a zone. The factor 2 in the denominator of Z is used so as to reduce the Maximum Considered Earthquake (MCE) zone factor to the factor for Design Basis Earthquake (DBE).

I = Importance factor, depending upon the functional use of the structures, characterized by hazardous consequences of its failure, post-earthquake functional needs, historical value, or economic importance (Table 6 of IS 1893:2002).

R = Response reduction factor, depending on the perceived seismic damage performance of the structure, characterized by ductile or brittle deformations. However, the ratio (I/R**)** shall not be greater than 1.0 (Table 7 of IS 1893:2002). The values of R for buildings are given in Table 7 of IS 1893:2002.
Sa/g = Average response acceleration coefficient for rock or soil sites as given by Fig. 2 of IS 1893:2002 and Table 3 of IS 1893:2002 based on appropriate natural periods and damping of the structure. These curves represent free field ground motion.

3.2 Design lateral force at each floor I -

The design base shear (V_B) shall be distributed along the height of the building as per the following expression:

$$Q_i = V_B \frac{W_i \, h_i^2}{\sum_{j=0}^{n} W_j \, h_j^2}$$

Where,
Q_i =Design lateral force at floor *i*,
W_i =Seismic weight of floor *i*,
h_i =Height of floor *i* measured from base, and
n = Number of storeys in the building is the number of levels at which the masses are located.

3.3 STEPS FOR EQUIVALENT STATIC ANALYSIS USING STAAD PRO -

The various steps involved in modeling are as follows.

1. Create a model as per specification required by applying size of building, height of each floor etc, Selection of suitable Units
2. Define the properties of various material used in the models.
3. Define the section properties of various structural element of the model.
4. Model making
5. Assign the fixed support in command-support specification- fixed
6. Assign the member properties same as above.
7. Assign the loading such as Dead Load, Live Load and Seismic Load. Apply the dead load to all structure, Live load on floor member only.
8. The load combination as per IS 1893-2002 code as X direction & Z direction

1) 1.5 (DL + LL)
2) 1.2 (DL + LL ± EL)
3) 1.5 (DL ± EL)
4) 0.9 DL ±1.5 EL

9. The seismic load applied as a nodal force at each floor level as per calculation.
10. Then Analysis- Perform Analysis and Run Analysis.
11. After analysis go to Post processing here we get the required result of analysis i.e. node displacement, support reaction & beam displacement, etc
12. In output file we get the result of structure so we know which member fail and it result. It should be noted that no member should fail and if the member fails the change the dimensions. Repeat the procedure until we get the satisfactory results in which the members do not fail
13. The Structure can be design for Strong Column-Weak Beam
14. Write the displacement at each floor level and maximum displacement at top level.
15. Find the all capacity curve in X & Z direction and comparing them

4. CONCLUSIONS -

RC frame buildings with open bottom storey are known to perform poorly during in strong earthquake shaking. Thus, it is clear that such buildings will exhibit poor performance during a strong shaking. This hazardous feature of Indian RC frame buildings needs to be recognized immediately and necessary measures taken to improve the performance of the buildings Since the behaviour of the soft storey is different during a quake, the structural member undergoes damage and to provide member to withstand that additional forces due to soft storey heavy or bulky member need to be provided.

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