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An Analytical review of Capacity Based Design of four storied R. C. C. framed Building containing Soft Story at Ground Floor

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Abstract:

If any storey has less resistance to earthquake forces in comparison to the other storeys, it is known as a soft-storey. The soft storey can occur at any storey level. It generally occurs at the ground level where distances between columns are provided for parking or any other use. As per IS 1893 "A soft storey is the storey in which the lateral stiffness is having less than 70 percent of stiffness in the storey above or having less than 80 percent of the average lateral stiffness of the three storeys above. Buildings having soft stories are extremely sensitive to earthquake damages. Such building swings back and forth producing high stresses in column members. In case, columns are incapable of taking these stresses or do not posses enough ductile property, they could get damaged. This can lead severe damages to the building. This problem is known as inverted pendulum.

*Some major earthquakes in which damages had been because of soft storey are : **1**. The San Francisco Earthquake occurred in 1906 **2**. The Bingol, Turkey Earthquake which occured on the the 1st of May 2003 **3**. 2001 Bhuj earthquake, India*

Introduction

Building having open first storey in multy storey building is a popular practice in India. This is generally adopted for parking of vehicles or reception facility. A building in which the upper stories have brick infill wall panel and open ground storey, is known as stilt building The open storey is called as stilt floor. A soft storey also known as weak storey. It is a storey in a building that has substantially less resistance or stiffness than the stories above or below. Storey without infill walls has enough shear resistance or sufficient ductile property to resist the stresses generated because of earthquake effect. These features are highly undesirable in buildings built in earthquake prone areas. The soft storey results in to discontinuity of strength stiffness. Soft storey concept has technical and functional advantages over the conventional construction. It helps to reduce spectral acceleration and base shear due to increase of natural period of the vibration of structure as in base isolated structure. Soft storey provides space for parking of vehicles and commercial activities or space for assembly . The Indian seismic code IS 1893:2002 (Clause no.4.20 on Page no.10) defines the soft storey as the storey in which the lateral stiffness is less than 70% of stiffness in the storey immediately above, or less than 80% of combined stiffness of three stories above. Earthquake in past years has increased awareness for the need to determine and improve the seismic performance of multistoried buildings. There are various factors affecting the seimic behavior of building. Stiffness irregularity in the vertical direction is main reason which causes formation of soft storey.

Features supporting soft storey construction:

1. It is important to provide the stiff column at open ground storey .The effects of stiffness is very important. Stiffness of a column means resistance to deformation of column. The larger is the stiffness, greater is the force required to

deform the column . The drift and the strength demands in the first storey columns are very large for buildings with soft ground storeys hence it is important to provide the more stiff columns at open ground storey.

2. Providing adjacent infill wall panels at each corner of open ground storey in building frameis also a way to improve stiffness. Masonry walls are normally considered as non-structural elements and stiffness imparted by walls is generally not taken in to account. Masonry walls help to increase the strength and stiffness of RC frame and hence help to decrease lateral drift and energy dissipation capacity due to cracking of infill and friction between infill and frame. This increase the redundancy of building and reduces bending moment in beams and columns. It has some disadvantages also. It induces high initial stiffness and compressive strength. This also generates torsional effect in the structure if it is not symmetrically placed. During analysis of multi storey structures, designers usually neglect the effect of masonry walls in resisting earthquake generated loads. Dead weight of masonry is only considered and analysis is carried out.

Avoiding Soft Storey Problem

As the guidelines of IS 1893: 2002 for buildings suggest for soft storey buildings or buildings with a flexible storey, such as the ground storey consisting of open spaces for parking that is stilt buildings, special provisions are to be made for increasing the lateral strength of the soft storey. Dynamic Analysis Method of building is applied to analyze the strength and stiffness effects of infill walls and inelastic deformations in the members of frame, particularly in the soft storey of the structure. The members in frame are designed accordingly. Alternatively, the following design criteria are to be adopted after carrying out the earthquake analysis, neglecting the effect of infill walls in other storeys of building.

a)Columns and beams of the soft storey are to be designed to resist two and half times the shears and moments calculated under seismic loads as specified in the other relevant clauses of the code.

Or

b) The Columns are designed and detailed for the calculated storey shears and moments. Shear walls are provided symmetrically in both directions of the building as far away from the centre of the building as feasible. These are to be designed exclusively for 1.5 times the lateral storey shear force calculated as before. If we face soft storey problem in the existing building we need to take some measures to avoid the problem in future. In existing buildings, it is better to provide lateral bracing to control the openness of a ground story. Methods of retrofitting include providing shear walls that are parallel to the open sides adopted in following manner.

• Diagonal bracing, such as X-braces. Usually made of steel, these **braced frames** are often seen
in storefront retrofit situations.

• Steel or reinforced concrete frames to resist lateral forces, can be provided around openings. These column-beam frames should have moment-resisting joints.

EXPERIMENTAL PROGRAMME

A four storey building with rigid jointed RCC frame is considered for design. Frame will be designed on the concept of Capacity based design method in which we provide required strength and ductility in the structural elements for successful response and collapse prevention during earthquake so that energy dissipation mechanism is available to withstand earthquake forces.

METHODOLOGY:

1.Assuming Preliminary Data

- Considering Preliminary Data of geometry of the typical structure.(G+3) multistory rigid jointed RCC frame.
- Assume location of structure in zone V.
- Assuming floor loads as per IS code .
- Assuming grade of Concrete & reinforcement.
- Assuming various properties of material such as unit weight and modulus of elasticity of concrete & masonry.

2.Determination of load

- Dead Load Calculation
- Live load calculation
- Earthquake load calculation

3.Design Procedure

- Seismic Analysis of frame
- Calculations for flexural capacity of beams
- Calculations for established strong column weak beam mechanism.
- Determination of moment magnification factor for columns.
- Capacity design for shear in beams
- Capacity design for shear in column
- Detailing of reinforcement

RESULTS AND DISCUSSION

Analysis owas carried out with following data.

1.Type of Structure: Multy story rigid jointed frame
2.Zone: V
3.No of Stories G+3
4.Imposed load 2kN/m^2 and 4kN/m^2

5.Trrace Water Proofing 5 N/mm^2
6.Floor Finish 0.5N/mm^2
7.Depth of slab 150mm
8.Materials M20Concrete & Fe 415 steel
9.Unit weight of RCC 25 kN/m^3
10Unit weight of masonry 20 kN/m^3
11.Modulus of Elasticity 2.23x10^{7}Kn/mm^2
12.Bay width 5.20m
13.Height of storey 3.50m
14Dimensions of Beams 300x450mm
15.Dimensions of Beams 300x450mm
16.Total height 14.00m
17.Seismic coefficients

A_h	**0.09**
Z	**0.36**
R	**5**
S_a/g	**2.5**

Modeling and analysis of structure on STAAD PRO was carried out with all load combinations as per IS1893 (PART 1):2002 The maximum effect for columns and beams for all load combinations was considered for design. In our design approach the design forces of columns are not completely based on linear elastic analysis. These forces depend upon the actual flexural capacities of beams framing in to same joint, so that plastic hinges may not form at the base of column above and at the top of column below the joint(except at the base of the column of a ground storey).

Reinforcement in beams is provided to resist stresses under hogging and sagging condition which may arise due to the mechanism of hinge formation in beams. Elimination of possibility of column sway mechanism in soft story is ensured by moment capacity verification of columns with beams at every joint of the frame with the formation of beam mechanism only. Columns are designed for magnified moments, if the sum of resisting moments of the columns, taking in to account the action of axial load , is greater than the sum of resisting moments of all adjacent beams for each direction of the seismic action.

CONCLUSION:

The main cause of damages in framed building during earthquake is the soft storey sway mechanism. Designing of structure with strong column weak beam philosofy facilitates elimination of column sway mechanism. This is as per IS:13920:1993.Proceedure of Capacity based Design Method is used for the solution of a structure having soft story with an objective to avoid concentration of ductility requirement in soft storey elements by distributing it throughout the structure by design of strong column and weak beam structure.

Capacity based design method helps to avoid concentration of ductility demand in the soft storey members. Energy dissipation was found to occure primarily in beams. Columns were found to enjoy flexural yielding except at the base and at top floor levels of building where formation of hinges were expected. A dynamic magnification factor of 1.2 for column moments proved satisfactory.

References:

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