STIFFENING OF SOFT STOREY IN AN R.C FRAME BUILDING: A CRITICAL REVIEW

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Abstract : The urban multi-storey buildings in India today have open ground storey primarily being adopted to accommodate parking, communication hall, reception lobbies or offices etc. Providing open ground storey in buildings reduce the stiffness of the lateral load resisting system. Many collapse of buildings observed during past earthquakes due to open ground storey. The present paper review on the seismic performance of soft storey of RC frame building using static and dynamic analysis. Analysis are carried out using various software like Etabs, Staad Pro and Sap2000. It is observed that, increasing the size of columns in an open ground storey to balance the stiffness is adopted. To strengthening the soft storey building the different techniques are provided i.e. shear walls, dampers and bracing which improve the seismic behaviour of the structure and also reduces the stiffness irregularity. Thus by improving lateral strength and stiffness, the maximum building resistant against collapse during earthquakes.

Keywords* - Stiffening, Soft Storey, Static Analysis, Dynamic Analysis, *RC Frame Building, Open Ground Storey, Equivalent Diagonal Struts

I. INTRODUCTION

The presence of walls in upper storeys makes the building many times stiffer in the upper storeys than in the open ground storey as shown in Figure (a). Thus, the upper storeys move almost together as a single block, and most of the horizontal displacement of the building occurs in the open ground storey and columns in the open ground storey are severely stressed as shown in Figure (b). If the columns are weak they do not have the required strength to resist these high stresses, they may be severely damaged or even lead to collapse of the building as shown in Figure(c). After the collapses of R.C frame buildings in Bhuj Earthquake the IS Code 1893(Part-I) 2002 "Criteria for earthquake resistant design of structures" had involved the special design provisions related to soft storey buildings. As per IS 1893-2002 (Part-I) Soft Storey is defined as storey in which lateral strength is less than 80% of that in the storey above. But the stiffness irregularity remains in the building as per this code. So new code (IS 1893 -2016(Part-I)) recommends that storey in which lateral strength of all structural members less than that in the storey above is treated as soft storey. Thus to improve lateral strength of building stiffness balance in storey related to upper stories is essential.

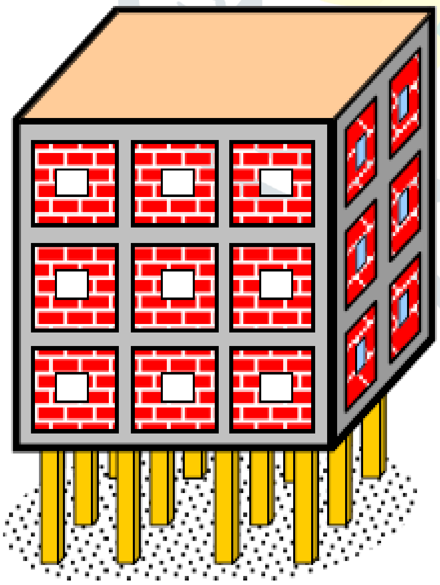

Figure: (a) Open Ground Storey

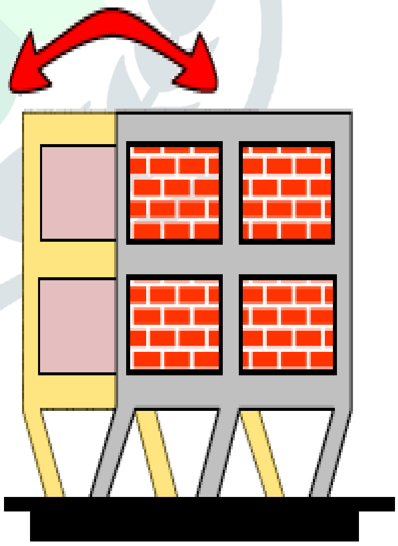

Figure: (b) Highly Stressed Columns

Figure: (c) RC Frame Buildings collapsed during 2001 Bhuj earthquake.

II. METHODS FOR ANALYSIS

Main aspects of seismic method of analysis based on Indian standard 1893 (Part-1) code "Criteria for Earthquake Resistant Design of Structures" are Static Analysis and Dynamic Analysis which are described below.

[A] Static Analysis

1. **Equivalent Static Method:** Seismic analysis of most of the structure are still carried on the basis of lateral force assumed to be equivalent to actual dynamic loading. The base shear which is the total horizontal force on the structure is calculated on the base of structure mass and fundamental period of vibration and corresponding mode shape. The base shear is distributed along the height of structure in terms of lateral forces according to IS 1893 (Part-1) code.
2. **Push Over Analysis:** Non Linear static analysis is the method of seismic analysis in which performance of the structure is characterized by capacity curve that represents the relation between the base shear force and displacement of roof. Analyis is carried out under vertical loads & gradually increasing lateral loads to estimate deformation and damage pattern of structure.

[B] Dynamic Analysis

1. **Response Spectrum Method:** The approach permits the multiple modes of response of a building to be taken into account. This is required in many building codes for all except for very simple or very complex program. The structural response can be defined as a combination of many modes. Software analysis can be used to determine these modes for a structure. For each mode, a response is obtained from the design spectrum, corresponding to the modal frequency and modal mass and then they are combined to evaluate the total response of the structure. In this the magnitude of forces in all direction is calculated and then effects on the building is observed.
2. **Elastic Time Historey Method:** It overcomes all the disadvantages of a response spectrum analysis, It requires greater computational efforts and mathematical models using software. It is a step by step analysis of structure to specified loading that may vary with time.

III. LITERATURE REVIEW

The various researches carried out study on seismic analysis for an RC Frame buildings are reviewed below.

1. **Vijayanarayanan AR and Rupen Goswami (2017)** Seven methods are studied to estimate the storey stiffness in multi Storey Building namely Sub- Assemblage Method, Storey Frame Method, Box Frame Method, Equivalent Stiffness method, Single Storey Method, Lateral force method and Fundamental Lateral Translational Mode Shape Method.
   It is observed that first three Method use simple closed form equation while last four methods use results from linear elastic structural analysis.
   Hence it is concluded that fundamental lateral translational mode shape method is most appropriate method because it uses dynamic characteristic of building to estimate the storey stiffness.
2. **Jaswant N. Arlekar, Sudhir K. Jain and C.V.R. Murty (1997)** A typical four storey RC Frame of Nine different models of the building are studied (1) Soft Storey with upper storey 220mm thick wall. (2) Soft Storey with upper storey 110mm thick wall. (3) Bare Frame (4) Full Infill Masonry (5) Central Core of 220mm thick Masonry Walls with in panels and full masonry walls in upper storey (6) RC Wall at Central core and 100mm thick walls on upper storey (7) Increase Size of Column (8) Concrete Wall Centre Core with soil flexibility (9) Concrete Wall center Core And Column with soil flexibility.
   It is observed that the displacements and forces from the equivalent static method are consistently larger by about *20%* than those from the multi-modal dynamic analysis method. Storey stiffness is higher in Model 7 is about 77% of 2nd storey. The Natural Period of Codal Results are not equal to Etabs Analysis. Sudden Change Displacement is observed in Models 1, 2, 5, 8, 9 and Smooth Displacement Profile Models 3, 4, 6, and 7. Bending Moment & Shear Force in Columns are severely higher for 1st Storey Columns.
   Hence, it is concluded that achieved Stiffness & Strength by Provision of stiffer column & Concrete Service Core.
3. **Hemant B. Kaushik, Durgesh C. Rai, and Sudhir K. Jain (2009)** A typical four storey RC Frame of Eleven different models of the building are studied for strengthening scheme using SAP2000. (1) Bare Frame (2) Open 1st Storey Frame (3) Fully infilled Frame (4) OFS + 1st Storey Members(Beam & Column size) Design for higher forces (5) OFS+ 1st Storey

Columns Design for higher forces (6) OFS + Studs (7) Extra Y-Column Provided alternatively (8) All Bay Extra Y-Columns (9) Diagonal Bracing alternatively (10) All Bay Diagonal Bracing (11) Lateral buttress.

It is observed that the yield lateral force for the frame Model 11 (Lateral buttress) was found to be more than other Frames. Lateral strength of the braced frame Model 9 (Bracing) was found to be maximum among all the frames used in different strengthening schemes. The lateral load carrying capacity of the frame used in Model 3 (fully infilled frame) was found to reduce drastically after the failure of masonry infills in the first and upper stories. After this, the lateral load behavior of the fully infilled frame became just like a bare frame.

Hence, it is concluded that Strengthening scheme in which extra columns Models -7, 8 & 9 were provided in open 1st storey were found to be significantly more effective in improving both lateral strength & Ductility of such frame.

4. **Rahul M. P and Dr. K Subha (2015)** The paper deals with use of viscous dampers and shear walls in the building. A ten storey building with a open ground storey is analyzed with and without braced type viscous dampers as well as shear wall Non-linear pushover analysis is carried out using SAP2000 software.
   It is observed that, by the provision of viscous dampers , maximum drift is reduced by 42% and 44% for dampers and shearwall respectively. The base shear obtained are lesser for model with damper than normal frame and very higher for the shearwall.
   Hence it is concluded that using shearwall and viscous damper in the structure, maximum response and drift gets reduced in structure during seismic loading.
5. **M.R Amin, P.Hasan and B.K.M.A Islam (2011)** The attempt had been made to investigate the effect of soft storey on four different models of multi storied reinforced concrete building frame, ie.(3, 6, 9 and 12 storey) with identical plan were analyzied using Etabs software.
   It is observed that inter storey drift ratio was found increasing below the mid storey level and maximum ratio was obtained where the soft storey was located.
   Hence it is concluded that as the building height increase, location of soft storeygoes downwards from mid storey level to produce maximum lateral drift.
6. **Devendra Dohare and Dr Savita Maru (2014)** The investigation had been made to study the seismic behaviour of soft storey building with different arrangement in soft storey building using static and dynamic analysis.
   It is observed that RC Frame building having brick masonry infill on upper floor with open ground storey subjected to earthquake loading, base shear can be more than twice to predicted by equivalent earthquake force method.
   Hence it is concluded that providing infill improves the structure during earthquake when compared to soft storey.

IV. CONCLUSION

1. Researches had proved that RC frame building with open ground storey is vulnerable during earthquake due to stiffness irregularity.
2. Many Researcher studied to increase only lateral strength of soft storey building and not the ductility of such frames.
3. It had been studied that using shear walls, dampars and bracing maximum response and drift gets reduced in the structure during seismic loading .
4. The provision of stiffer columns in the open ground storey structures also reduces the storey drift and strength demands.
5. The provision of infill walls improve the structure during earthquake when compared with soft storey.
6. Codal provision is insufficient describing the guidelines about the stiffness calculation and irregularity for RC Frame buildings.
7. The values of fundamental natural time period for a the building using softwares like etabs, staad pro or Sap2000 and IS code varies drastically.
8. The seismic performance of the building is depended on mass and stiffness irregularity.
9. Thus by improving lateral strength and stiffness, the maximum building resistant against collapse during earthquakes.

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