

Seismic Behavior of Structure with Soft Storey

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Abstract— *The structural behavior during seismic event is the function of the earthquake characteristics, structural configuration, material used and quality of construction. It has been found from the past experiences that uniform structural configuration, stiffness, adequate strength and ductility are the main attributes for satisfactory performance of building structures during earthquakes. The irregularity in mass and stiffness distribution produces unsatisfactory performance of structures sometimes leading to catastrophic failure. The soft storey is a kind of vertical irregularity commonly observed in the form of open ground storey meant for parking purpose which has relatively lesser stiffness compared to stories above it. However it can occur at any storey level due to more storey height or due to more opening in that storey. In early times the soft storey at ground level was deliberately provided to reduce the level of seismic forces on the structures. But later on, sudden collapse of soft ground structures occurred due to increased story drift at first floor resulting in concentration of plastic hinges in ground story columns. This review paper deal with seismic effects on softstorey, remedial measures and methods of design .*

Keywords—*Nonlinear analysis, Plastic Hinges, Structural configuration, Stiffness, Softstorey*

I. INTRODUCTION

1.1 General:

Soft story irregularity is one of the main reasons of the building damage during past earthquakes. Soft story due to increased storey height is a well known subject but soft storey may also arise due to abrupt changes in amount of infill walls between stories, which are usually not considered as a part of load bearing system. This study investigates seismic behavior of soft storey at ground level using dynamic response for reinforced concrete buildings.

The soft storey is a vertical irregularity of the buildings, and the 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 stories above as mentioned in IS 1893:2002. The ground level opening jeopardizes the structure by creating abrupt change in stiffness inviting soft story behavior. These openings often accommodate parking spaces, large windows and expansive lobbies in residential and retail buildings. Without proper design, such structures do not perform satisfactorily against the lateral forces during earthquake. This is the review paper explained various method of nonlinear analysis and its effects on softstorey of RC structure.

1.2 Seismic behavior of soft storey

A “soft storey is the one in which the lateral stiffness is less than of 70% of that in storey immediately above , or less than 80% of the combined stiffness of three stories above.” The essential characteristic of a “weak” or “soft” storey consist of a discontinuity of strength or stiffness, which occurs at the second storey connections. The much stiffer upper stories behaves like a rigid block, and most of the horizontal displacement of the building occurs locally in the soft storey alone. This makes the building behave like an inverted pendulum, with the ground storey columns acting as the pendulum rod while the rest of the building act as a rigid pendulum mass which swings back-and-forth during earthquake shaking, and the columns in the open ground storey are severely stressed. In such building the dynamic ductility demand during the probable earthquake gets concentrated in the soft storey and the upper storeys tend to remain elastic. Hence whereas the ‘soft’ storey is severely strained causing its total collapse, much smaller damages occurs in the upper storeys.

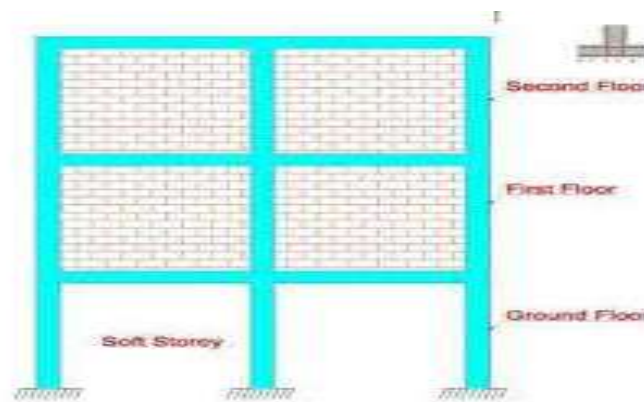


Fig.No.1.1.Open Ground Storey(Soft Storey)

II. LITERATURE REVIEW

2.1 Somani Kishangopal & Sangave Prakarsh (2015)[1]

In their study explained the comparison of base shear for medium rise RC framed buildings having P+5, P+7, P+9 and P+11 storeys for various seismic zones (III, IV & V) and for various soil conditions (Hard & Medium) as per IS 1893(part 1): 2002. This work helped to understand the effect of earthquake with increase in height of RC framed buildings on base shear for various seismic zones and soil conditions. The result shows that the effect of infill stiffness on structural response is significant under lateral loads. It is found that the presence infill walls increases the base shear by 60-65% more than bare frame by both seismic coefficient method and response spectrum method.

2.2 R. Davis , D. Menon & A. M. Prasad(2008)[2]

In their study conclude that the magnification factor (MF) increases with the height of the building, primarily due to the higher shift in the time period. Also it is seen that when large openings are present and thickness of infills are less, there is a reduction in MF. The MF obtained from nonlinear analysis is much less than that generated from linear dynamic analysis.

2.3 Arlekar et.al (1997)[6]

In their paper the behavior of RC framed OGS building when subjected to seismic loads A four storeyed OGS building was analysed using Equivalent Static Analysis and Response Spectrum Analysis to find the resultant forces and displacements. This paper they analyzed the behavior of Open ground storey frame is quite different from that of the bare frame and also the effects on plan aspect ratio, relative stiffness, and number of bays on the behavior of infilled frame.

2.4 Hashmi & Madan (2008)[9]

Conducted non-linear time history and pushover analysis of Open ground storey buildings. The study concludes that the MF prescribed by IS 1893(2002) for such buildings is adequate for preventing collapse.

2.5 Kanitkar R. and V. Kanitkar (2004)[10]

In this paper authors have carried out elastic and inelastic analyses of a typical five-storey residential stilt building with the intent of reviewing the new provisions. This paper describes the results of the said analyses. In addition, the paper briefly discusses the validity of the new provisions and pinpoints areas requiring further investigations.

2.6 Krushna B. Avhad (2014)[11]

In their paper studied the comparative performance of OGS buildings designed according to various MFs using nonlinear analysis. As the more realistic performance of the OGS building requires the modelling the stiffness and strength of the infill walls.

III. FACTORES TO BE CONSIDERED FOR SEISMIC EFFECT ON SOFTSTOREY

Experimental studies & IS code suggested following factor with to be considered for analyzing the seismic effects on soft storey:

3.1 Structural Irregularity-

The structural configuration system has played a vital role in catastrophe. The IS: 1893(part 1):2002 has recommended building configuration system in section 7 for better performance of RC building during earthquake. The building configuration has been described as regular or irregular in terms of size and shape of the building, arrangement of structural elements and the mass. Regular building configuration are almost symmetrical (in plane and elevation) about the axis and have uniform distribution of the lateral force-resisting structure such that it provides a continuous load path for both gravity and lateral loads. A building that lacks symmetry and has discontinuity in geometry, mass, or load resisting element is called irregular. These irregularities may cause interruption of force flow and stress concentrations. Asymmetrical arrangement of masses and stiffness of elements may cause a large torsional (where the centre of mass does not coincide with the centre of rigidity).The section 7 of IS: 1893 -2002 enlists the irregularity in the building configuration system. These irregularities are categorized in two types-

- Vertical irregularities-it refers to sudden change of strength, stiffness, and geometry and mass results in irregular distribution of forces or deformation over a height of building.
- Horizontal irregularities –it refers to asymmetrical plan shapes (e.g. L,T,U) or discontinuities in the horizontal resisting elements (diaphragms) such as cut-outs, large opening, re-entrant corner and other abrupt change resulting in torsion deformation and stress concentration.



Fig.No.3.1. Vertical irregularity

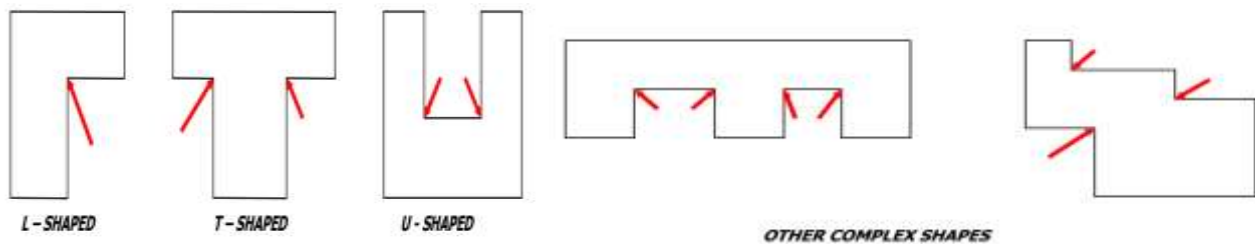


Fig.No.3.2. Plan Irregularity

3.2 Base shear-

It is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure. Calculations of base shear (V) depend on: soil conditions at the site The total design lateral force or design seismic base shear VB along any principal direction (cl.7.5.3 of 1893(Part 1)-2002) shall be determined from the following equation:

$$VB=Ah \times W$$

Where A_h is design horizontal seismic coefficient and W is the seismic weight of the building as given in cl. 7.42 of 1893(Part 1)-2002.

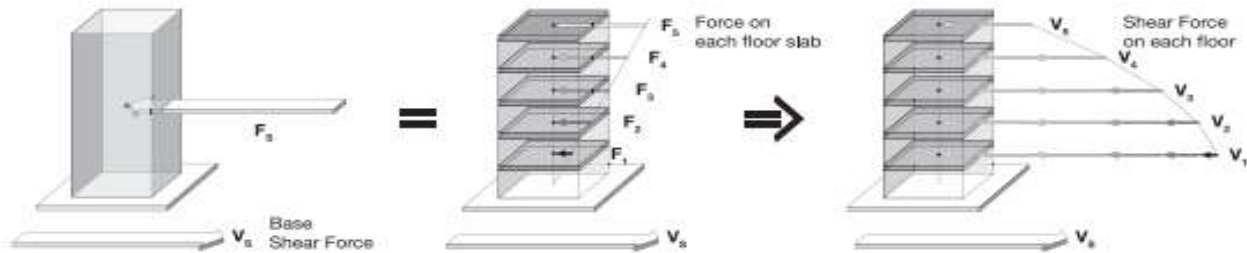


Fig.No.3.3. lateral forces and shear forces generated in building due to ground motion (L. Teresa Guevara-Perez et.al)[12]

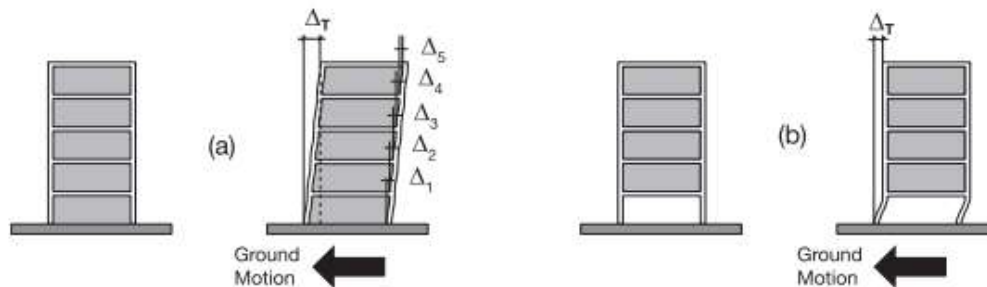


Fig.No.3.4. Distribution of total displacement generated by an earthquake in: (a) a regular building; and (b) building with soft story irregularity. (L. Teresa Guevara-Perez et.al)[12]

3.3 Magnification Factor-

It is a factor which is considered when any building frame is designed ignoring its infill wall but considering its weight i.e. for Open ground storey or soft storey type of building. Since we know that the function of infill wall in a building is to provide stiffness to the building, but since we neglect infill wall in such building, the purpose of providing that stiffness and help any building to stand is provided by other element which is column. Whatever load the building was withstanding is now multiplied by this MF value so that it can stand still by providing sufficient stiffness.

3.4.Adequate strength & ductility-

To provide soft storey adequate strength & ductility following remedial measures are to be considered: i) Increasing stiffness of column ii) Keeping minimum relative distance between centre of rigidity and centre of mass.iii) strengthening is introduced which consists of steel eccentric bracings placed at first storey which results in increased stiffness of that storey

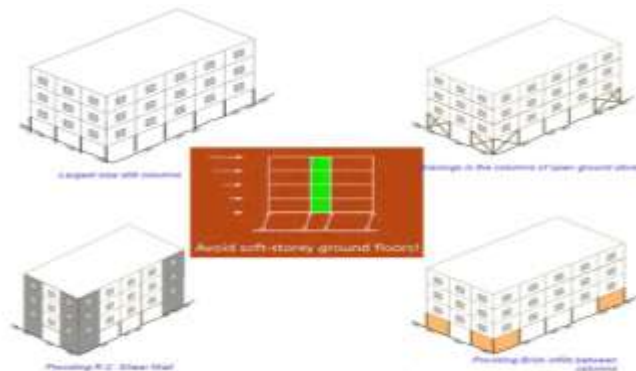


Fig.No.3.5. Remedial measures for soft storey

IV. SEISMIC METHODS OF ANALYSIS

There are different methods of analysis which provide different degrees of accuracy. The dynamic analysis in general process can be categorized on the basis of three factors: the type of externally applied loads, the behavior of structure or structural materials, and the type of structural model selected. Based on the type of external action and behavior of structure, the analysis can be further classified as:

- Linear Static Analysis.
- Linear dynamic Analysis.
- Non Linear Static Analysis.
- Non linear dynamic analysis.
- The linear static analysis or equivalent static analysis can only be used for regular structure with limited height.
- Linear dynamic analysis can be performed in two ways either by mode superposition method or response spectrum method and elastic time history method.
- Non linear static analysis is an improvement over the linear static or dynamic analysis in the sense that it allows the inelastic behavior of the structure.
- Non linear dynamic analysis or inelastic time history analysis is the only method to describe the actual behavior of the structure during an earthquake.

V. CONCLUSION

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 earthquak. To avoid this experimental studies and Indian Standard code are recommended remedial measure and designing method to improve the performance of the buildings.

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