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LINEAR DYNAMIC ANALYSIS OF RC FRAMED BUILDINGS

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ABSTRACT

Multistoried buildings with open ground floor are inherently vulnerable to collapse due to earthquake load, their construction is still widespread in the developing nations due to social and functional need for provide car parking space at ground level. Engineering community warned against such buildings from time to time. Dynamic analysis shall be performed to obtain the design seismic force, and its distribution to different levels along the height of the building. It should be performed for both regular and irregular building. These are provisions in IS 1893 (part 1) 2002, with respect to height of building and according to irregularity of the building. In regular building greater than 40m height in zone IV and V is required and greater than 90m height in zone II and III. In irregular building greater than 12m height in zone IV and V is required and greater than 40m height in zone II and III.

In this case study R.C.C. building is modeled and analyzed in four cases. I) Model with bare framed. II) Model with infill walls. III) Model with shear walls at bottom storey. IV) Model with steel bracing system at bottom storey

Keywords: Equivalent static analysis, Response Spectrum Method, Storey Drift, Lateral displacement, Base Shear, Reinforced concrete building, Displacement.

I. INTRODUCTION

Earthquakes are one of the most life threatening, environmental hazardous and destructive natural phenomenons that causes shaking of ground. This result in damage to structures, hence we need to design the buildings to withstand these earthquakes which may occur at least once in the life time of the structure. Structures possess less stiffness and strength in case of irregular configured frames; to enhance this, lateral load resisting systems are introduced into the frames. The main objective of this paper is to study the seismic behavior of concrete reinforced building.

During earthquake motions, deformations take place across the elements of the load-bearing system as a result of the response of buildings to the ground motion. As a consequence of these deformations, internal forces develop across the elements of the load-bearing system and displacement behavior appears across the building. The resultant displacement demand varies depending on the stiffness and mass of the building. In general, buildings with higher stiffness and lower mass have smaller horizontal displacements demands. On the contrary, displacement demands are to increase. On the other hand, each building has a specific displacement capacity. In other words, the amount of horizontal displacement that a building can afford without collapsing is limited. The purpose of strengthening methods is to ensure that the displacement demand of a building is to be kept below its displacement capacity. This can mainly be achieved by reducing expected displacement demand of the structure

Member or local retrofitting deals with an increase of ductility of components with adequate capacities to satisfy their specific limits the technique employed for seismic retrofitting are illustrated in Fig. 1.1.

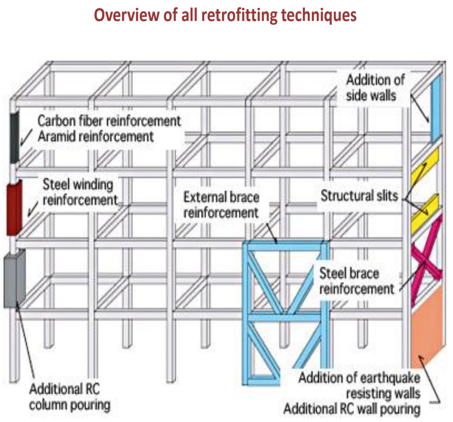


Figure 1.1: Overview of all retrofitting techniques

Objectives of Study

In this study R.C.C. building is modeled and analyzed in four Parts

i).Model with bare framed Model ii).infill walls iii) model with shear walls in bottom storey. iv) Model with steel bracing system in bottom storey.

The performance of the building is evaluated in terms of Storey Drifts, Lateral Displacements, Lateral Forces, Storey Stiffness, Base shear, Time period, Torsion. That infill wall at bottom open storey system significantly contributes to the structural stiffness and reduces the maximum inter story drift, lateral displacement of R.C.C building than the steel braced system.

II. METHODS OF DYNAMIC ANALYSIS

For seismic performance evaluation, a structural analysis of the mathematical model of the structure is required to determine force and displacement demands in various components of the structure. Several analysis methods, both elastic and inelastic, are available to predict the seismic performance of the structures.

Equivalent Static Analysis

The force demand on every component of the structure is obtained and compared with available capacities by performing an elastic analysis. Elastic analysis methods include code static lateral force procedure, code dynamic procedure and elastic procedure using demand-capacity ratios. These methods are also known as force-based procedures which assume that structures respond elastically to earthquakes

Seismic analysis of most of the structures are still carried out on the basis lateral(Horizontal) force assumed to be equivalent to the actual(Dynamic) loading. The base shear which is the total horizontal force on the structure is calculated on the basis of structural mass and fundamental period of vibration and corresponding mode shapes.

Response Spectrum Method

Response Spectrum is the plot between time period and the response quantity (which may vary depending upon the study). This concludes that the procedure works well when the building is regular in plan and elevation. The advantage of response spectrum analysis over equivalent static analysis is that multiple modes can be considered at once. This is required in many building codes for all except for very simple or very complex structures

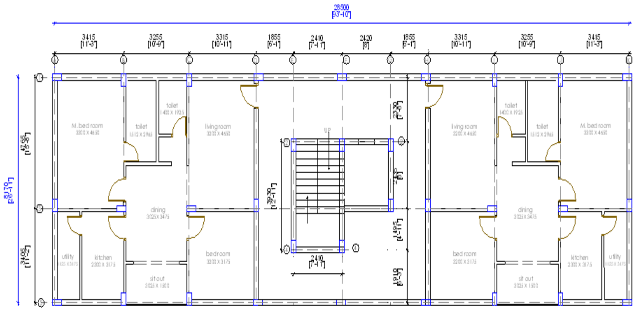
The procedure of dynamic analysis of irregular type of buildings should be based on 3D modeling of building that will sufficiently represent its stiffness and mass distribution along the height of building so that its response to earthquake could be predicted with sufficient accuracy. The procedure involves calculation of mode shape using characteristic equation also called as Eigen equation. Modal participation factors are obtained and according to the prospects of the code mass participation of the building in the first mode must be greater than 90%. And lateral forces for different mode shapes are calculated using formulae which is combined to represent the peak response using three approaches mentioned below.

- Maximum Absolute Response
- Square Roots of the Sum of Squares (SRSS)
- Complete Quadratic Combination (CQC)

The result of a response spectrum analysis using the response spectrum from a ground motion is typically different from that which would be calculated directly from a linear dynamic analysis using that ground motion directly, since phase information is lost in the process of generating the response spectrum.

III. ANALYSIS AND RESULT

A hypothetical building is assumed for seismic analysis that consists of a G+5 R.C.C. residential building. The plan of the building is irregular in nature as it has all columns not at equal spacing. The building is located in Seismic Zone V and is founded on medium type soil. The building is 24.00 m in height 28.50m in length and 8.17m in width.



Building Plan

Design parameter

Structure = OMRF
Floors = G.F + 5 Upper Floors
Ground storey height = 4.0m
Typical storey height = 4.0m
Depth of Foundation = 3.0 m
Live load = 2.0 kN/m^2 [typical floor]
3.0 kN/m^2 [corridors, staircase]
1.5 kN/ m^2 [terrace]
Floor finish = 1.0 kN/m^2
Water proofing = 1.0 kN/m^2
Storey height = 4 m
Walls Thickness = 230 mm
Materials = Fe415 & M20
Zone = V
Size of columns = 230mm x 525mm
Sizes of beams = 230mm x 450mm
Thickness of slab = 125mm

Calculation of Design Seismic Force by Seismic coefficient Method

.

Floor Level	**W(kN)**	**hi(m)**	**($W_ih_i^2$)**	**($W_ih_i^2$/ $\sum W_ih_i^2$)**	**Q_i (kN)**	**Vi (kN)**
6	2745	24	1581120	0.330	667	
5	3657	20	1462800	0.305	617	
4	3657	16	936192	0.195	395	
3	3657	12	526608	0.110	222	
2	3657	8	234048	0.04891343	99	
1	2761	4	44176	0.00923229	19	
			4784944			2020

Step by Step Procedure for Response Spectrum Method.

Step-1:

Depending on the location of the building site, identify the seismic zone and assign Zone factor (*Z) (*Use Table 2 along with Seismic zones map or Annex of IS-1893 (2002).

Step-2:

Compute the seismic weight of the building (*W)* As per Clause 7.4.2, IS-1893 (2002) – Seismic weight of floors (*Wi).*

Step-3:

Establish mass *[M]* and stiffness *[K]* matrices of the building using system of masses lumped at the floor levels with each mass having one degree of freedom, that of lateral displacement in the direction under consideration. Accordingly, to develop stiffness matrix effective stiffness of each floor is computed using the lateral stiffness coefficients of columns and infill walls. Usually floor slab is assumed to be infinitely stiff.

Step-4:

Using *[M]* and *[K]* of previous step and employing the principles of dynamics compute the modal frequencies, (ω) and corresponding mode shapes, (Φ).

Step-5:

Compute modal mass *Mk* of mode *k* using the following relationship with *n* being number of modes considered

$$\mathbf{M_k} = \frac{[\sum_{i=1}^{n} w_i \emptyset_{ik}]^2}{g \sum_{i=1}^{n} w_i \emptyset_{ik}^2} \qquad \text{[Clause 7.8.4.5a of IS 1893 (2002)]}$$

Step-6:

Compute modal participation factors *Pk* of mode *k* using the following relationship with *n* being number of modes considered

$$P_k = \frac{\sum_{i=1}^{n} w_i \emptyset_{ik}}{\sum_{i=1}^{n} w_i \emptyset_{ik}^2} \qquad \text{[Clause 7.8.4.5b of IS 1893 (2002)]}$$

Step-7:

Compute design lateral force (*Qik*) at each floor in each mode (i.e., for *ith* floor in mode *k*) using the following relationship,

$Q_{ik} = A_k \ \Phi_{ik} P_k W_i$ [Clause 7.8.4.5c of IS 1893 (2002)]

A = Design horizontal acceleration spectrum value as per Clause 6.4.2 of IS 1893 using the natural period

$$T_k = \frac{2\Pi}{\omega}$$

Step-8:

Compute storey shear forces in each mode (*ik V*) acting in storey *i* in mode *k* as given by,

$$\mathbf{V_{ik}} = \sum_{j=i+1}^{n} Q_{ik}$$

Step-9:

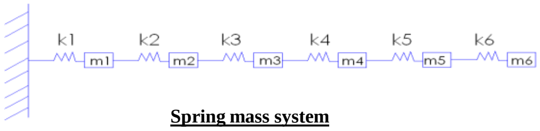
Compute storey shear forces due to all modes considered, *Vi* in storey *i*, by combining shear forces due to each mode in accordance with Clause 7.8.4.4 of IS 1893 (2002). i.e., either CQC or SRSS modal combination methods are used.

Step-10:

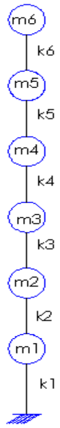
Finally compute design lateral forces at each storey as,

$$F_{roof} = V_{roof}$$
$$F_i = V_i - V_{i+1}$$

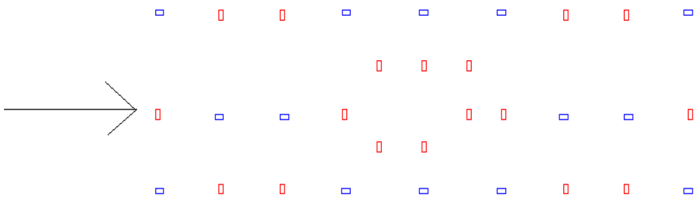
Dynamic Analysis



Spring mass system



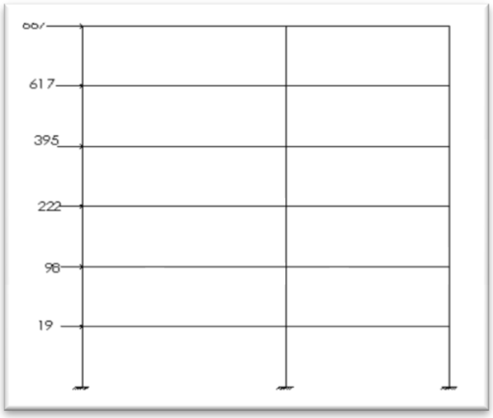
Lumped mass system



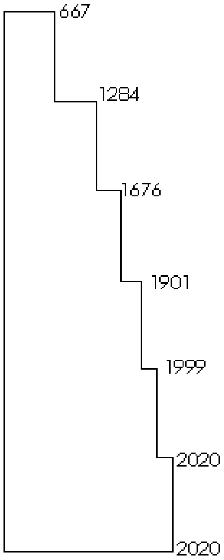
Stiffness Calculation Diagram from Plan.

$$\begin{bmatrix} M1 & 0 & 0 & 0 & 0 & 0 \\ 0 & M2 & 0 & 0 & 0 & 0 \\ 0 & 0 & M3 & 0 & 0 & 0 \\ 0 & 0 & 0 & M4 & 0 & 0 \\ 0 & 0 & 0 & 0 & M5 & 0 \\ 0 & 0 & 0 & 0 & 0 & M6 \end{bmatrix}$$

Determination of eigen values and eigenvectors

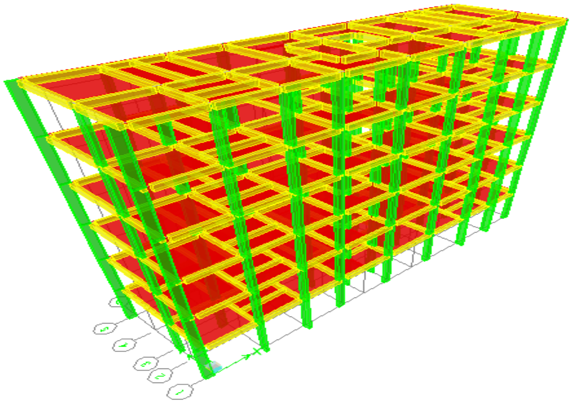


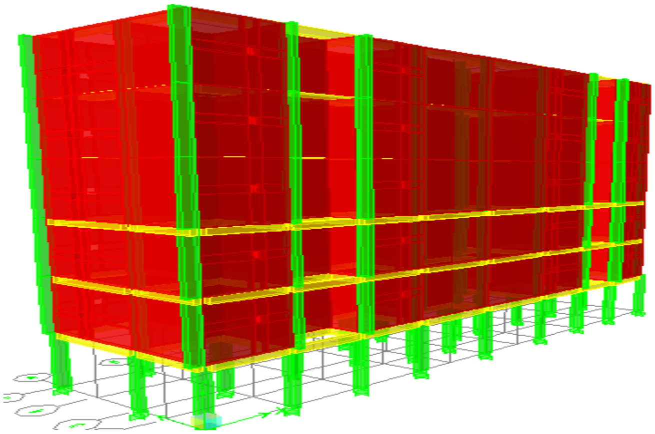
Lateral Force Diagram (kN)



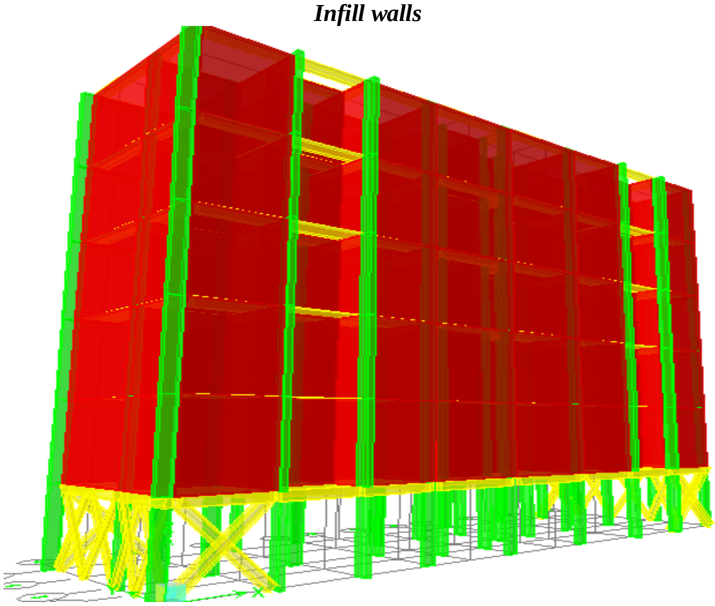
Base Shear Diagram(kN)

Bare Model

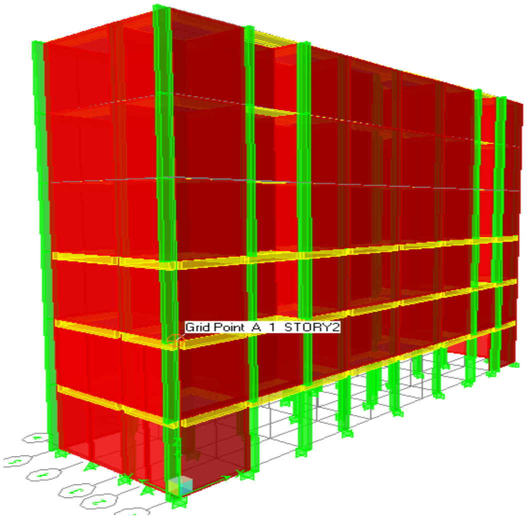




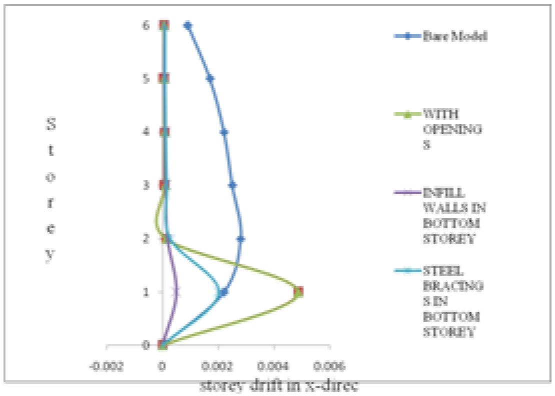
Infill walls



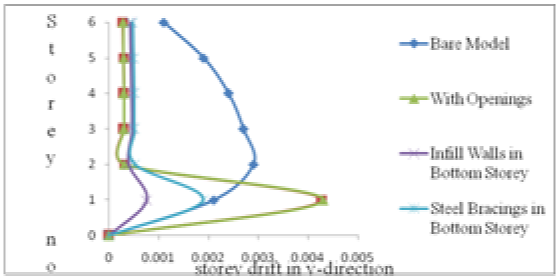
Steel Bracings in open bottom storey



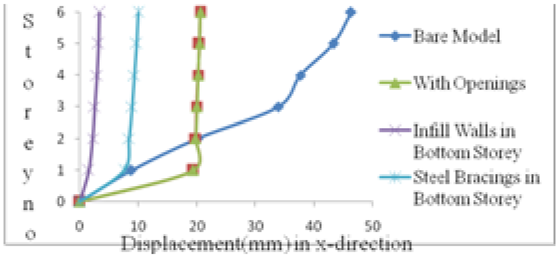
shear walls in Open Bottom Storey



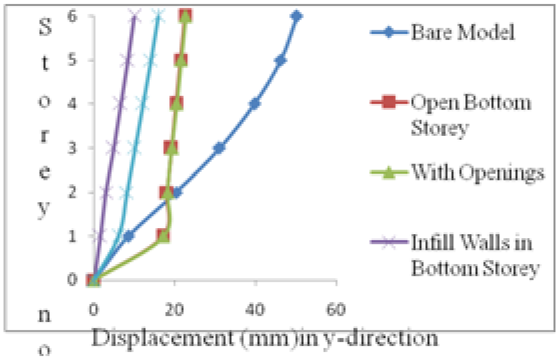
Storey Drift of Building in Longitudinal direction



Storey Drift of Building in Transverse direction Lateral Displacements



Lateral Displacements of Building in Transverse direction



Lateral Displacements of Building in Transverse direction

IV. CONCLUSIONS

- Storey drift of the infill wall and steel braced system at bottom storey is within the limit as clause no 7.11.1 of IS-1893 (Part-1):2002.
- Storey Stiffness of the infill wall and steel braced model at bottom storey is within the limit as clause no 4.20 of IS-1893 (Part-1):2002.
- Deflection in case of bare frame is very large, when compared to other cases. The presence of infill wall can affect the seismic behavior of frame structure to large extent, and the infill wall increases stiffness of the structure.
- The increase in the opening percentage leads to a decrease on the lateral stiffness of in filled frame.
- It is found that the infill wall system at bottom storey significantly contributes to the structural stiffness and reduces the maximum inter story drift, lateral displacement of R.C.C building than the steel bracing system.
- It is found that the X type of steel bracing system at bottom storey has less torsion effect and less Base Shear than the infill wall system.

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

V. FUTURE SCOPE

In IS:1893, two methods, one Seismic Coefficient and other Response Spectrum method is described to carry out the analysis for Earthquake forces. is also provided to decide upon the method to be used, depending upon Building Ht. and Zone. At the bottom of this table, it is clearly mentioned that building with irregular shape and/or irregular distribution of mass and stiffness in horizontal and/or vertical plane, shall be analyses as per Response Spectrum Method. For all practical reasons, no building is uniform in all the respects (i.e. shape, mass/stiffness distribution in horizontal and vertical plane). Response Spectrum method, being time consuming and tedious process, most of time, we resort to computer applications. Now while, modeling the structure, in most of available software usually, we model the space frame, neglecting the in-fill wall Stiffness

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