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STRUCTURAL BEHAVIOR OF VERTICAL IRREGULAR STRUCTURES UNDER DYNAMIC LOADS

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ABSTRACT

Major structural collapses occur when a building is under the action of Dynamic Loads which includes both Earthquake ,Wind loads and moving loads. In these modern days, most of the structures are involved with architectural importance and it is highly impossible to plan with regular shapes. These irregularities are responsible structural collapse of buildings under the action of dynamic loads; extensive research is required for achieving ultimate performance even with a poor configuration.

In the present work "study on effects of vertical irregularities of R.C frame structure by Non – Linear static analysis" considering four types of 10- storied 3D frames (i.e., a symmetrical elevation throughout its height and three other frames with unsymmetrical vertical configuration starting from sixth floor placed at corner, at the centre and at the edge of the plan respectively.

From the studied results, the analysis of four frames, it is observed that in the regular frame there is no torsional effect because of symmetry. But, in the case of irregular frames there is a considerable torsional effect. Based on the study,obtained different capacity curves for four different configurations.

Keywords: Earthquake, Response, Non-Linear, Vertical

I. INTRODUCTION

The irregularity in the building structures may be due to irregular distributions in their mass, strength and stiffness along the height of building. When such buildings are constructed in high seismic zones, the analysis and design becomes more complicated. There are two types of irregularities-

1. Plan Irregularities

2. Vertical Irregularities.

Vertical Irregularities are mainly of five types-

i a) Stiffness Irregularity — Soft Storey-A soft storey is one in which the lateral stiffness is less than 70 percent of the storey above or less than 80 percent of the average lateral stiffness of the three storeys above.

b) Stiffness Irregularity — Extreme Soft Storey-An extreme soft storey is one in which the lateral stiffness is less than 60 percent of that in the storey above or less than 70 percent of the average stiffness of the three storey's above.

ii) Mass Irregularity-Mass irregularity shall be considered to exist where the seismic weight of any storey is more than 200 percent of that of its adjacent storey's. In case of roofs irregularity need not be considered.

iii) Vertical Geometric Irregularity- A structure is considered to be Vertical geometric irregular when the horizontal dimension of the lateral force resisting system in any storey is more than 150 percent of that in its adjacent storey.

iv) In-Plane Discontinuity in Vertical Elements Resisting Lateral Force-An in-plane offset of the lateral force resisting elements greater than the length of those elements.

v) Discontinuity in Capacity — Weak Storey-A weak storey is one in which the storey lateral strength is less than 80 percent of that in the storey above.

As per IS 1893, Part 1 Linear static analysis of structures can be used for regular structures of limited height as in this process lateral forces are calculated as per code based fundamental time period of the structure. Linear dynamic analysis are an improvement over linear static analysis, as this analysis produces the effect of the higher modes of vibration and the actual distribution of forces in the elastic range in a better way.

Buildings are designed as per Design based earthquake, but the actual forces acting on the structure is far more than that of DBE. So, in higher seismic zones Ductility based design approach is preferred as ductility of the structure narrows the gap. The primary objective in designing earthquake resistant structures is to ensure that the building has enough ductility to withstand the earthquake forces, which it will be subjected to during an earthquake.

II.NON-LINEAR STATIC PUSHOVER ANALYSIS

The pushover analysis of a structure is a static non-linear analysis under permanent vertical loads and gradually increasing lateral loads. The equivalent static lateral loads approximately represent earthquake induced forces.

A plot of the total base shear versus top displacement in a structure is obtained by this analysis that would indicate any premature failure or weakness. The analysis is carried out up to failure, thus it enables determination of collapse load and ductility capacity.

This type of analysis enables weakness in the structure to be identified. The decision to retrofit can be taken in such studies

III. MODELING

The analysis of frames with different vertical irregularities is to be performed. For this purpose, four frames are selected as shown in Figure 1. Frame-1 is a regular frame that consists of ten storeys with a symmetrical plan configuration of square shape provided with 4 x 4 bays as shown in Figure 1 and is considered whose centre of mass coincides with the centre of rigidity. Three other frames (4 x 4 bays up to sixth floor and 2 x 2 bays from sixth floor to tenth floor) with unsymmetrical vertical configuration starting from tenth floor, placed at corner, at the center and at edge of the plan respectively are also considered. All these are

10-storied building frames with floor heights of 3m except ground floor and bay size of 4m x 4m.height of ground floor is 2m and the total height of the all building frames is 22m (Figure 2) .

As per IS code 1893 -2002, the natural time period is 2.025 sec.

Number of members, nodes and supports of all four building frames are given in the Table 1. Material properties considered for the analysis using ETABS are given in the Table 2. Physical properties of members selected for the analysis are given in the Table 3. Dead load and Live loads considered for the analysis are given in Table 4. Earthquake loads considered for the calculation of seismic weights are as per the IS 1893(Part 1): 2002 and are given in the Table 5.

Details of Geometry for Symmetric and Unsymmetrical frame

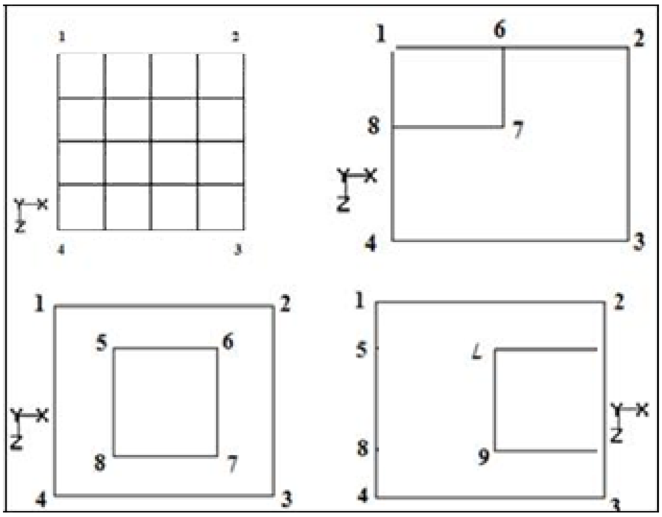

Fig. 1: Frames of Different Configuration (1, 2, 3 and 4)

Earth quake load parameters

Parameters	Values
seismic zone factor, Z	0.1, 0.16, 0.24 & 0.36
Importance factor, I	1
Response reduction factor,	5

R	
Percentage damping	5%
Soil type	Soft Soil
Average response acc.coeff.,(Sa/g)	2.5

Model Geometry

Floor	Column Size mm x mm	Beam Size mm x mm	Load For Walls kN / m	Live Load kN/ m^2	Floor Finish + Unknown force kN / m^2	Floor Height mm
For Symmetric frames						
G.Floor	C1-300 x 600	230 x 420	12	2	1.5	2.1
1st Floor to Top Floor	C1-300 x 600	230 x 420	12	2	1.5	3.12
For Unsymmetric frames						
G. Floor	C1-300 x 600 C2-230 x 450	230 x 420	12	2	1.5	2.1
1^{st} to 5 th Floor	C1-300 x 600 C2-230 x 450	230 x 420	12	2	1.5	3.12
6^{th} to 9^{th} Floor	C1-300 x 600	230 x 420	12	2	1.5	3.12
Top Floor	C1-300 x 600	230 x 420	3	2	1.5	3.12

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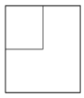
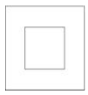
Table 1: Members of All Frames

Type of Frame	Geometry Fig	Design of Geometry
Symmetric frame		G +10 stories with plan dimensions of 16 X 16m
Unsymmetrical frame I		Plan dimensions 16 X16m up to 5th floor and 8 X 8m from 6th floor to 10th floor
Unsymmetrical frame II		Plan dimensions 16 X16m up to 5th floor and 8 X 8m from 6th floor to 10th floor
Unsymmetrical frame III		Plan dimensions 16 X16m up to 5th floor and 8 X 8m from 6th floor to 10th floor

Building frames	Regularity	Number of members
Frame-1	Regular in Vertical	2145
Frame-2	Irregular in Vertical	1353
Frame-3	Irregular in Vertical	1353
Frame-4	Irregular in Vertical	1353

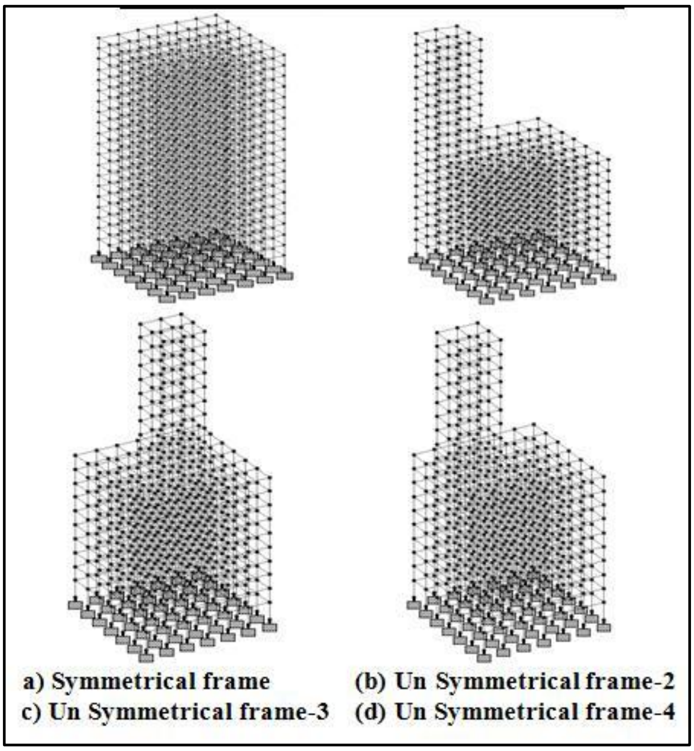


Fig. 2 Selected Frames with Shapes, Supports, Nodes and Framing

Table 2: Material Properties Considered for the Analysis

Modulus of elasticity (E) kN/m^2	Poisson ratio	Unit Weight kN/m^3	Coefficient of thermal expansion @ / ^{0}K	Damping Ratio
2.17185E+007	170 E-3	23.561	1E-005	0.05

Table 3: Physical properties of the columns and beams

Member	Size	
Columns for all floors in Symmetric frame	300 x 600mm	(C1)
Columns for Unsymmetric frame	300 x 600mm	(C1)
	230 x 450mm	(C2)
Beams for all floors	230 x 420mm	

Table 4: Dead load and Live loads considered for the analysis

Type of load	Load value
Dead load	
On floor slabs	
Self weight	3.75 kN/m^2
partition wall (assumed)	2.00 kN/m^2
floor finish (assumed)	1.00 kN/m^2
Total dead load on floors	6.75 kN/m^2
On roof slab	
Self weight	3.75 kN/m^2
weathering course (assumed)	2.00 kN/m^2
Total dead load on roof	5.75 kN/m^2
Live load	
On floor slabs	
Live load on floors	2.50 kN/m^2
On roof slab	
Live load on floors	1.50 kN/m^2

Table 5: Loads considered for the calculation of seismic weights

Loads on the floors
Full dead load acting on the floor plus 25 percent of live load (since, as per clause 7.3.1 Table 8 of IS 1893(Part 1):2002, for imposed uniformly distributed floor loads of 3 kN/m^2 or below, the percentage of imposed load is 25 percent) = 6.75+((25/100)x2.5) = 7.375 kN/m^2
Loads on the roof slab
Full dead load acting on the roof (since, as per clause 7.3.2, for calculating the design seismic forces of the structure, the imposed load on roof need not be considered.) hence take the load as 5.75 KN/m ^{2} For the analysis purpose, these structures are assumed to be located in zone-II, III, IV & V (zone factor-0.1, 0.16, 0.24 & 0.36) on site with soft soil and Sa/g value taken from the figure 2 of IS-1893: 2002 i.e., Response spectra for rock and soil sites for 5% damping. These structures are taken as general building and hence Importance factor is taken as 1 and the frames are proposed to have ordinary RC moment resisting frames and hence the Reduction factor is taken as 3.

General Consideration

- Analyzed for G+10 storey structure with a 16m x 16m plan area for symmetric space frames and 16x16 m up to 5^{th} floor and 8x8 m from 6^{th} floor to 10^{th} floor for unsymmetrical frames.
  Considered under permanent vertical loads and lateral loads are earthquake damping is 5%.
- Base shear is checked to reference code IS 1893-2002.
- The built –in default hinges properties for steel and concrete members are based on ATC-40 and FEMA-273 criteria.

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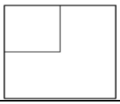
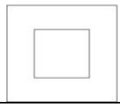
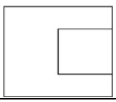
IV.RESULTS AND OBSERVATIONS

In this study nodal displacements and drifts of the selected columns that are determined are studied and observed for a comparison. Also different load combinations in earthquake considered. Frame wise observations are discussed in detail with floor displacement figures. Only few results and figures are presented in this paper. Figure 3 shows the deformed shapes of all the frames for load combination of 1.5DL+1.5ELX

COMPARISION I

Table 6: Comparison between capacity curves of Symmetric frame with three of Unsymmetrical frames at Zone II

Type of Frame	Geometry	Maximum Base force(kN)	Maximum Displacement (m)
Symmetric		2320.437	0.2185
Unsymmetrical I		1380.225	0.1939
Unsymmetrical II		1673.296	0.2019
Unsymmetrical III		1277.306	0.2406

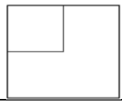
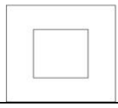
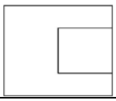
From table 6, following observations were made

1. It observed that symmetric frame can resist more base force of 2320.437kN corresponding to a displacement of 0.2185m than unsymmetrical casesI,II&III at seismic zoneII.
2. While comparing unsymmetrical frames (i.e among I,II&III) structure having unsymmetrical at corner offer less resistance to seismic load than unsymmetrical at centre& edge at seismic zone II.
3. Among all considered unsymmetrical cases (i.e I,II& III) structure with unsymmetrical at centre can resist more base force of 1673.296kN corresponding to a displacement of 0.2019m.

COMPARISION II

Table 7: Comparison between capacity curves of Symmetric frame with three of Unsymmetrical frames at Zone III

Type of Frame	Geometry	Maximum Base	Maximum Displacement

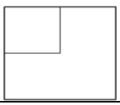
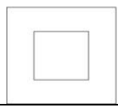
		force(kN)	(m)
Symmetric		2147.4365	0.1247
Unsymmetrical I		1400.2252	0.1939
Unsymmetrical II		1671.0431	0.1120
Unsymmetrical III		1569.0448	0.2742

From table 7, following observations were made

1. It observed that symmetric frame can resist more base force 2147.4365kN corresponding to a displacement of 0.1247m than unsymmetrical cases I,II&III at seismic zoneIII.
2. While comparing unsymmetrical frames (i.e among I,II&III) structure having unsymmetrical at corner offer less resistance to seismic load than unsymmetrical at centre& edge at seismic zone III.
3. Among all considered unsymmetrical cases (i.e I,II& III) structure with unsymmetrical at centre can resist more base force of 1671.0431kN corresponding to a displacement of 0.1120m.

COMPARISION III

Table 8: Comparison between capacity curves of Symmetric frame with three of Unsymmetrical frames at Zone IV

Type of Frame	Geometry	Maximum Base force(kN)	Maximum Displacement (m)
Symmetric		2249.7166	0.1619
Unsymmetrical I		1287.5372	0.1936
Unsymmetrical II		1577.1536	0.1815

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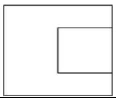
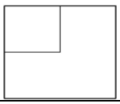
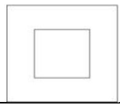
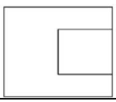
Unsymmetrical III		1377.3055	0.2506

From table 8, following observations were made

1. It observed that symmetric frame can resist more base force of 2249.7166kN corresponding to a displacement of 0.1619m than unsymmetrical cases I,II&III at seismic zone IV
2. While comparing unsymmetrical frames (i.e among I,II&III) structure having unsymmetrical at corner offer less resistance to seismic load than unsymmetrical at centre& edge at seismic zone IV
3. Among all considered unsymmetrical cases (i.e I,II& III) structure with unsymmetrical at centre can resist more base force of 1577.1536 kN corresponding to a displacement of 0.1815m.

COMPARISION IV

Table 9: Comparison between capacity curves of Symmetric frame with three of Unsymmetrical frames at Zone V

Type of Frame	**Geometry**	**Maximum Base force(kN)**	**Maximum Displacement (m)**
Symmetric		2449.7166	0.2285
Unsymmetrical I		1487.5372	0.2136
Unsymmetrical II		1769.1536	0.1997
Unsymmetrical III		1573.3524	0.2729

From table 9, following observations were made

1. It observed that symmetric frame can resist more base force of 2449.7166kN corresponding to a displacement of 0.2285m than unsymmetrical cases I,II&III at seismic zoneV
2. While comparing unsymmetrical frames (i.e among I,II&III) structure having unsymmetrical at corner offer less resistance to seismic load than unsymmetrical at centre& edge at seismic zone V.
3. Among all considered unsymmetrical cases (i.e I,II& III) structure with unsymmetrical at centre can resist more base force of 1769.15kN corresponding to a displacement of 0.1997m.

General Conclusions

The performance of R.C framed structure with and without considering vertical irregularities was investigated using the non-linear static analysis. Following were the major conclusions drawn from the study.

V.CONCLUSIONS

- The performance of R.C framed structure considering with symmetric and unsymmetrical was investigated using the non-linear static analysis.
- The plastic hinges are formed different stages A-B,IO-LS,LS-CP,C,D,E this zone levels based on building performance level severe, moderate, light& very light to decided.
- The required data for pushover curve table based on the base force and deformation to draw the capacity curve.
- The maximum base shear and deformation of R.C framed symmetrical Structure to seismic load at different zones, at zone5 maximum base force is 2449.7166N & displacement is 0.2285m.
- The maximum base shear and deformation of R.C framed unsymmetrical structures to seismic at different zones, at zone2 maximum base shear is 1783.2958N and displacement is 0.2109 for unsymmetrical frame-II.
- The base force will be more in the symmetrical framed structure when compared to the unsymmetrical R.C frame structure.

VI.FUTURE SCOPE OF WORK

In these modern days, most of the structures are involved with architectural importance; hence it is highly impossible to plan with regular shapes. In this present study analysis is based on the Non-linear static analysis. This is not sufficient to study the linear behaviour of the structure.

A great amount of research in nonlinear static analysis i.e., push over analysis is in progress and at the same time a great focus is also in the direction of nonlinear dynamic analysis.

1. . To study the effect of wind-induced cable oscillations in Bridges is useful in analysis of vertical irregularities and also inclined irregularities also
2. To study the effect of bracing system in vertical irregularities will be more effective.
3. To study the effect of damping system in columns, beams and footings will be more effective in analysis of vertical irregularities.
4. To study the effect of spring system in columns, beams and footings will be more effective in analysis of vertical irregularities
5. In this thesis, studied effect of vertical irregularities only, we can also study the effects of horizontal irregularities and both horizontal & vertical irregularities

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