International Journal of Engineering Research
Volume No.4, Issue No.11, pp : 631-634
ISSN:2319-6890)(online),2347-5013(print)
01 Nov. 2015

Effect of Vertical Irregularities of RC Framed Structures by Using Non-Linear Static Analysis

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Abstract : Major structural collapses occur when a building is under the action of Dynamic Loads which includes both Earthquake and Wind 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 for structural collapse of buildings under the action of dynamic loads. Hence, extensive research is required for achieving ultimate performance even with a poor configuration. In the present work, "Effect Of Vertical Irregularities of RC framed Structures by Using Non-Linear Static Analysis", considering four types of 10- Storied 3-D frames (i.e., a symmetrical elevation configuration throughout its height and three other frames with unsymmetrical vertical configuration starting from sixth floor, placed at corner, at the center and at edge of the plan respectively) it is focused to study their response using Non-Linear Static Analysis. From the studied results of the analysis of four frames, it is observed that in the regular frame, there is no tensional effect in the frame because of symmetry. The response for vertically irregular buildings is different for the columns which are located in the plane perpendicular to the action of force. This is due to the tensional rotation in the structure.

Keywords : Earthquake, Response, Non-Linear, Vertical

I. Introduction

A building is said to be a regular when the building configurations are almost symmetrical about the axis and it is said to be the irregular when it lacks symmetry and discontinuity in geometry, mass or load resisting elements. Asymmetrical arrangements cause a large torsion force. IS 1893: 2002 (part1) has explained building configuration system for better performance of RC buildings during earthquakes. The building configuration has been described as regular or irregular in terms of the size and shape of the building, arrangement of structural the elements and mass. There are two types of irregularities 1) Horizontal irregularities refers to asymmetrical plan shapes (L, T, U and F) or discontinuities in horizontal resisting elements such as re-entrant corners, large openings, cut outs and other changes like torsion, deformations and other stress concentrations, 2) Vertical irregularities referring to sudden change of strength, stiffness, geometry and mass of a structure in vertical direction. The main objective of the present work is to study the response of the irregular structures under dynamic loads. In this present study it is proposed to consider the building frames that are irregular in elevation and analyze the response and behavior of the structures under earthquake. For this purpose, four RC building frames are selected and it is proposed to analyze all the frames that are considered and are modeled. ETABS analysis package is proposed for the analysis of all structures, to get the all nodal displacements. Frames considered in this study are 10- Storied 3-D frames with symmetrical elevation configuration throughout its height and three other frames with unsymmetrical vertical configuration starting from sixth floor, placed at corner, at the center and at edge of the plan respectively as shown in Figure 1. It is proposed that the responses of all the above frames are to be determined for all the load combinations. Lateral loads and Storey shears of all the four frames due to earthquake loads is proposed to determine using Non-linear static analysis method.

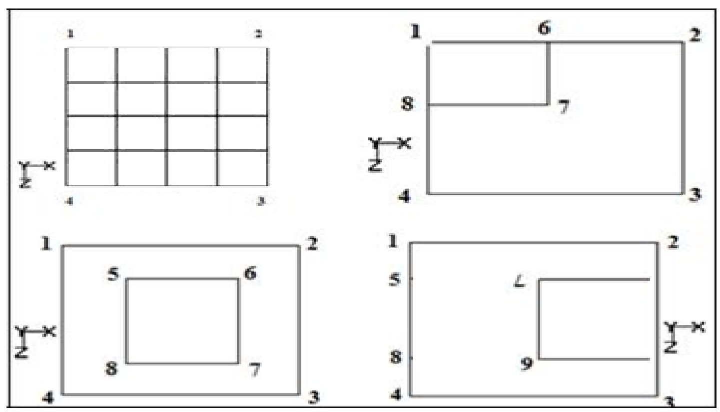

Fig. 1: Frames of Different Configuration (1, 2, 3 and 4)

II. 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 storey's 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

ISSN:2319-6890)(online),2347-5013(print)
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loads considered for the calculation of seismic weights are as per the IS 1893(Part 1): 2002 and are given in the Table 5.

Table 1: Members of All Frames

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

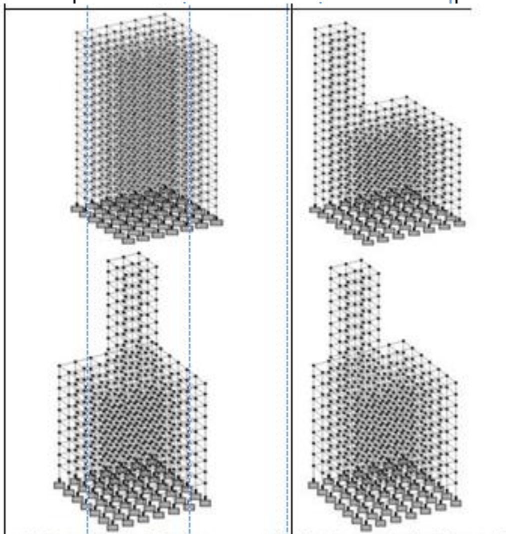

Fig. 2 Selected Frames with Shapes, Supports, Nodes and Framing

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.

III. Results and Observations

In this study nodal displacements and drifts of the selected columns that are determined are studied and observed for a

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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		2449.437	0.2285
Unsymmetrical I		1500.225	0.2039
Unsymmetrical II		1783.296	0.2109
Unsymmetrical III		1577.306	0.2706

From table 6, following observations were made

1. It observed that symmetric frame can resist more base force of 2449.437kN corresponding to a displacement of 0.2285m 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 1783.296kN corresponding to a displacement of 0.2109m.

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 force(kN)	Maximum Displacement (m)
Symmetric		2247.4365	0.1347
Unsymmetrical I		1500.2252	0.2039
Unsymmetrical II		1771.0431	0.122
Unsymmetrical III		1669.0448	0.2842

From table 7, following observations were made

1. It observed that symmetric frame can resist more base force of 2247.4365kN corresponding to a displacement of 0.1347m 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 1771.0431kN corresponding to a displacement of 0.122m.

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		2449.7166	0.1819
Unsymmetrical I		1487.5372	0.2136
Unsymmetrical II		1777.1536	0.2015
Unsymmetrical III		1577.3055	0.2706

From table 8, following observations were made

1. It observed that symmetric frame can resist more base force of 2449.7166kN corresponding to a displacement of 0.1819m 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 1777.1536 kN corresponding to a displacement of 0.2015m.

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 zone V
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.

1. 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.
2. The required data for pushover curve table based on the base force and deformation to draw the capacity curve.
3. The symmetric frame can resist more base force than unsymmetrical frames (i.e I,II&III) at all seismic zones in India.
4. While comparing unsymmetrical frames (i.e I,II&III) structure having unsymmetrical at corner offer less resistance to seismic load than unsymmetrical at centre& edge at all seismic zones in India.
5. Among all considered unsymmetrical cases (i.e I,II& III) structure with unsymmetrical at centre(unsymmetrical II) can resist more base force when compared unsymmetrical I&III at all seismic zones in India.

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 behavior 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. In this thesis, studied effect of vertical irregularities only, we can also study the effects of horizontal irregularities and both horizontal& vertical irregularities.
2. To study the effect of bracing system in vertical irregularities will be more effective.

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