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RESPONSE STUDY OF MULTI-STORIED BUILDINGS WITH PLAN IRREGULARITY SUBJECTED TO EARTHQUAKE AND WIND LOADS USING LINEAR STATIC ANALYSIS

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Abstract: *In the event of an earthquake or wind load conditions on a building, people can be evacuated safely before the building collapses. Major causalities in the earthquakes around the world are due to the structural collapses. The major structures that collapse are mainly due to their irregularities horizontally and vertically. If we start up with a good configuration and a reasonable framing system, even a poor design cannot harm its ultimate performance too much. In these modern days, most of the structures are involved with architectural importance and is highly impossible to plan with regular shapes. Hence, extensive research is required for achieving ultimate performance even with a poor configuration. In the present work, it is focused to study "Linear Behavior of the Buildings with Plan Irregularities Under Earthquake And Wind Loads". Method of analysis adopted in this work is Linear Static Analysis. Four types of 20- Storied 3-D frames are taken into consideration for this study i.e., a symmetrical plan configuration and three other frames with unsymmetrical plan configuration of L, inverted 'U' and T-shapes. From the studied results of the analysis of four frames, it is observed that in the regular frame, there is no torsional effect in the frame because of symmetry i.e., due to the centre of mass coincides with the centre of rigidity and also the lateral displacements are same in the direction of earthquake force. The same is observed in the case of wind loads. The responses for an irregular building are different for the columns which are located in the plane perpendicular to the action of force. This is due to the torsional rotation in the structure and additional lateral forces that have been added to the lateral loads due to earthquake loads. In the case of U shaped plan configuration the responses in the corner columns of two limbs are same in the earthquake loads and is not equal in the case of wind loads. Because of these variations in responses, it is healthier to study the response for each and every irregular building instead of taking a broad view.*

Keywords:
configuration ,irregular, linear, response, torsional

INTRODUCTION

IS 1893 (part-1) :2002 [1] has recommended building configuration system for the better performance of RC building 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. IS 1893 : 2002 (part1) has explained building configuration system for better performance of RC buildings during earthquakes. 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. The two types irregularities are 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 plan. The response and behavior of the structures under earthquake and wind loads is to be studied. For this purpose, Four RC building frames are selected and is proposed to analyse all the frames that are to be considered and modeled. STAAD [2] analysis package is proposed for the analysis of all structures, to get the all nodal displacements. Frames to be considered in this study are a symmetrical plan configuration of square shape and unsymmetrical plan configuration of L, inverted 'U' and T-shapes as shown in Figure 1. It is

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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 ESA (linear static analysis) method, even though the IS 1893(Part 1) : 2002 has recommended dynamic analysis (linear dynamic analysis). Lateral loads of all the four frames due to Wind load is proposed to determine as per ASCE-7 : 2002 [3] in the analysis of the building frames.

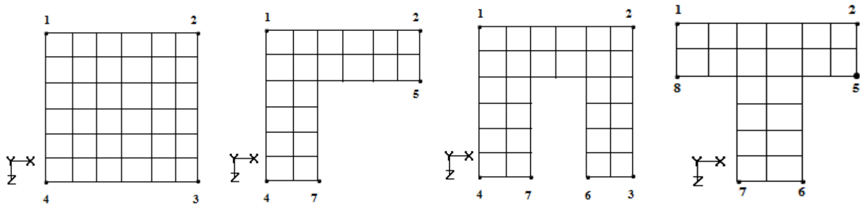


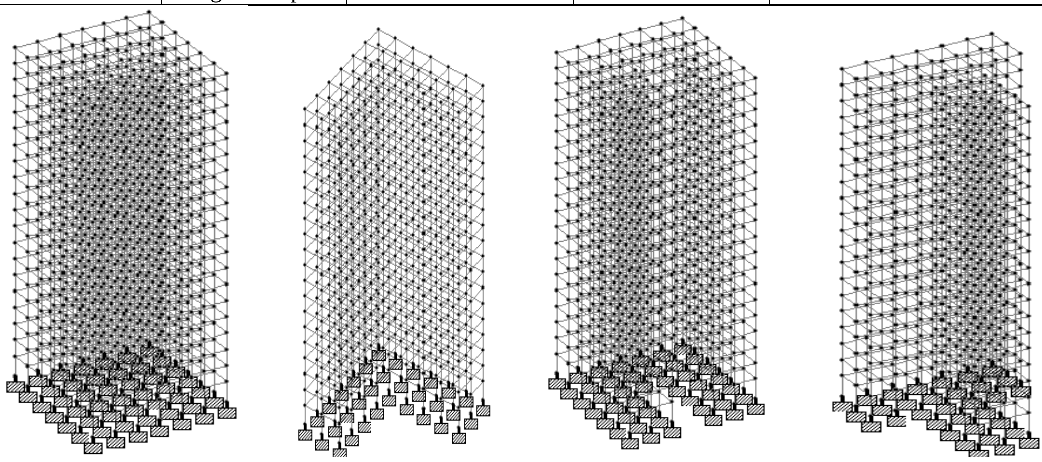
Figure 1 Frames of different configuration (1,2,3 and 4)

MODELING

The analysis of frames with different plan 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 twenty storey with a symmetrical plan configuration of square shape provided with 6 x 6 bays as shown in Figure 1 and is considered whose centre of mass coincides with the centre of rigidity. Three more frames with unsymmetrical and irregular plan configuration of L, inverted 'U' and T-shapes are also considered. All these are 20-storied building frames with floor heights of 4m except ground floor and bay size of 5m x 5m.height of ground floor is 5m and the total height of the all building frames is 81m (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 STAAD 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.

Table 1 Members, Nodes And Supports For All Frames

Building frames	Regularity	Number of members	Number of nodes	Number of supports(fixed)
Frame-1	Regular in plan	2660	1029	49
Frame-2	Irregular in plan	1700	693	33
Frame-3	Irregular in plan	2340	945	45
Frame-4	Irregular in plan	1700	693	33



a) Symmetrical frame b) L-shaped frame c) Inverted U-shaped frame d) T-shaped frame

Figure 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 @ / ^0K	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	450mm x 450mm
Beams for all floors	300mm x 450mm

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-V (zone factor-0.36) on site with medium soil and S_a/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.Wind loads are considered as per ASCE-7 : 2002 in the analysis of building frames. Building classification category as obtained from Table 1.1 in ASCE-7:02. Category can be I, II, III or IV. Basic Wind Speed as described in section 6.5.4 of the ASCE-7: 02 code . The wind speed considered for this work is 85 MPH. In this case it is proposed to take as building structure with coefficient of exposure 0.8 Response of the building frame structures is studied mainly for the dominated load combination i.e. 1.5DL ±1.5EL or WL in both X-direction and Z- direction for the selected columns at different levels including roof displacement.

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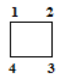
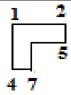
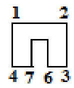
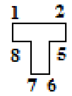
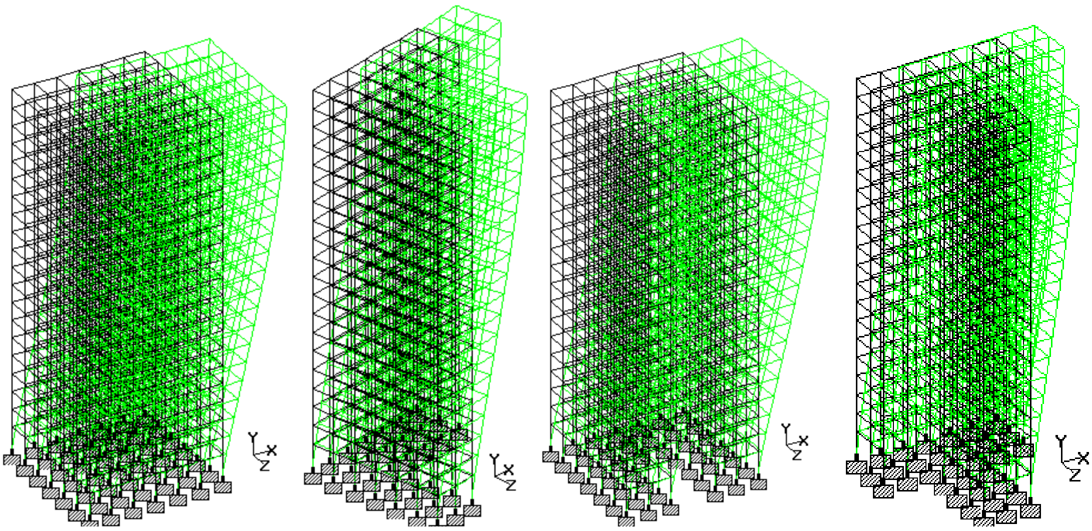
RESULTS AND OBSERVATIONS

In this study nodal displacements and drifts of the selected columns that are determined are studied and observed for a comparison. Also, considered the different load combinations, both in earthquake and wind loads. 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

Table 6 Nodal displacements of the frames 1,2,3 and 4 and for the selected columns at ground, 10th and roof levels for earthquake load combinations in X-Direction

CORNERS	LOAD COMBINATION	FLOOR LEVEL				
			X - NODAL DISPLACEMENTS (mm)			
			FRAME-1	FRAME-2	FRAME-3	FRAME-4
CORNER-1	(1.5DL+1.5(+ELX))	Roof	433.354	387.543	426.976	392.633
		10th Floor	266.206	238.36	259.819	239.3
		Ground Floor	26.489	24.031	25.945	23.943
CORNER-2	(1.5DL+1.5(+ELX))	Roof	432.77	386.984	426.425	392.062
		10th Floor	266.223	238.372	283.166	239.314
		Ground Floor	26.952	24.131	24.433	24.045
CORNER-3	(1.5DL+1.5(+ELX))	Roof	432.77		499.278	
		10th Floor	266.223		283.166	
		Ground Floor	26.952		24.433	
CORNER-4	(1.5DL+1.5(+ELX))	Roof	433.354	480.868	503.473	
		10th Floor	266.206	271.988	283.517	
		Ground Floor	26.849	23.398	24.268	
CORNER-5	(1.5DL+1.5(+ELX))	Roof		412.127		419.408
		10th Floor		251.323		252.901
		Ground Floor		25.076		24.955
CORNER-6	(1.5DL+1.5(+ELX))	Roof			499.386	481.077
		10th Floor			283.164	274.133
		Ground Floor			24.405	23.794
CORNER-7	(1.5DL+1.5(+ELX))	Roof		480.758	503.363	481.186
		10th Floor		271.99	283.519	274.131
		Ground Floor		23.427	24.296	23.766
CORNER-8	(1.5DL+1.5(+ELX))	Roof				420.266
		10th Floor				252.87
		Ground Floor				24.814



a) Frame-1 **b) Frame-2** **c) Frame-3** **d) Frame-4**

Figure 3 Deformed shape of the 3-D Frame for the load combination (1.5DL+1.5ELX)for the frames 1,2,3 and 4

Frame-1: The roof displacement for the four corners 1, 2, 3 and 4 of the Figure 1 for the load case 1.5DL+1.5ELX is 433.354mm, 432.77mm, 432.77mm and 433.354mm for the frame-1, which is a regular frame. It is observed that, there is no torsional effects in the frame because of symmetry that is the centre of mass coincides with the centre of rigidity and the lateral displacements of the four corners are same in the direction of earthquake force. The displacements at the positive corners are more than the displacements at the negative corners in all the cases but the amount of difference in the displacement is very slight. The roof displacement values are same in the case of earthquake loads in positive X, negative X, positive Z and negative Z load combinations. Displacement distribution throughout the height of the columns in the eight load combinations i.e. 1.5DL ±1.5EL or WL in both X-direction and Z- direction is same. This is due to that the building is a regular building in all aspects . The same is observed in the case of wind loads. It is also observed that the earthquake load is dominating than the wind load of given intensity and exposure for this regular building and the responses in all the nodes in the case of earthquake is more than the wind load . As per clause 7.11.1 of IS 1893(Part 1)-2002, the storey drift limitation shall not exceed 0.004 times the storey height that is (0.004x4) = 16mm. It is observed that the storey drift limitation exceeds slightly for the bottom floors and is within the limits for the top floors. It might be overcome this by increasing the stiffness of columns at the bottom floors.

*Frame-2:*The response and drifts due to earthquake and wind loading in both positive and negative X-direction for the corner columns 1 and 2 is nearly equal in the corresponding levels. Also, the response and drifts of the corner columns 4 and 7 is nearly equal in the corresponding levels.
When comparing the responses due to earthquake load in positive X-direction of corner columns 1 and 4 , the responses of the corner column 1 at ground,10^{th} and roof levels are 24.031, 238.360, 387.543 mm respectively and the corresponding responses in the corner column 4 are 23.398, 271.988 and 480.868mm .It is observed that the responses of the column 4 is more than the column 1. This is due to the less stiffness in the frame joining the columns 4 and 7 than the frame joining columns 1 and 2 and also due the torsional effect caused by the eccentricity in centre of mass and center of stiffness The drifts of the corner columns 1 and 4 are differed to an amount of about 6mm to 7mm at the roof and about 1mm to 2mm at the bottom floors. Comparing the responses due to earthquake load of corner columns 2 and 5 , the responses of the corner column 2 at ground,10^{th} and roof levels are 24.131, 238.372, 386.984 mm respectively and the corresponding responses in the corner column 5 are 25.076, 257.323 and 412.127 mm. It is observed that the responses of the column 5 is more than the column 2. Here this is due the torsional effect caused by the eccentricity in centre of mass and center of stiffness. The drifts of the corner columns 2 and 5 are nearly equal at the corresponding levels.

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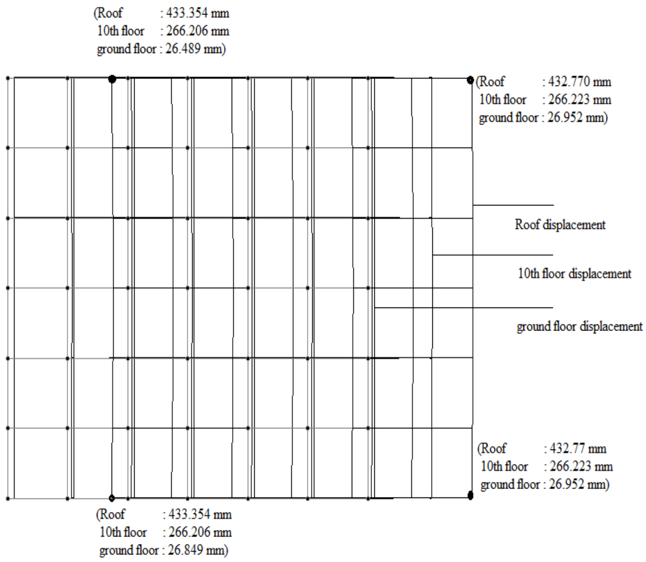
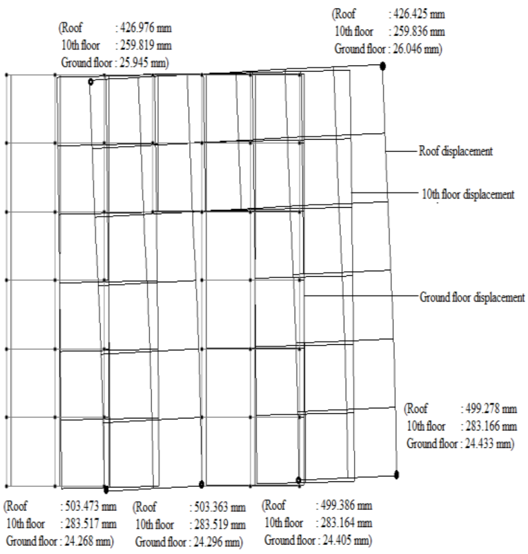
When comparing the responses due to wind load in positive X-direction of corner columns 1 and 4 , the responses of the corner column 1 at ground,10^{th} and roof levels are 10.762, 88.507, 121.756 mm respectively and the corresponding responses in the corner column 4 are 21.092, 192.963 and 286.596mm . It is observed that the responses of the column 4 is more than the column 1. This is due to the less stiffness in the frame joining the columns 4 and 7 than the frame joining columns 1 and 2 and also due the torsional effect caused by the eccentricity in centre of mass and centre of stiffness The drifts of the corner columns 1 and 4 are differed to an amount of 4mm at the roof and about 10mm at the bottom floors. Comparing the responses due to wind load of corner columns 2 and 5 , the responses of the corner column 2 at ground,10^{th} and roof levels are 10.876, 88.502, 121.035 mm respectively and the corresponding responses in the corner column 5 are 14.962,121.083,165.701mm It is observed that the responses of the column 5 is more than the column 2. This is due the torsional effect caused by the eccentricity in centre of mass and centre of stiffness. The drifts of the corner columns 2 and 5 are differed to an amount of 0.5mm at the roof and about 4mm at the bottom floors. Figure 4 shows that the floor and roof (ground, 10^{th} and roof slab) displacements for the load combination 1.5DL+1.5ELX.



(1.5DL+1.5(ELX))



(1.5DL+1.5(ELX))

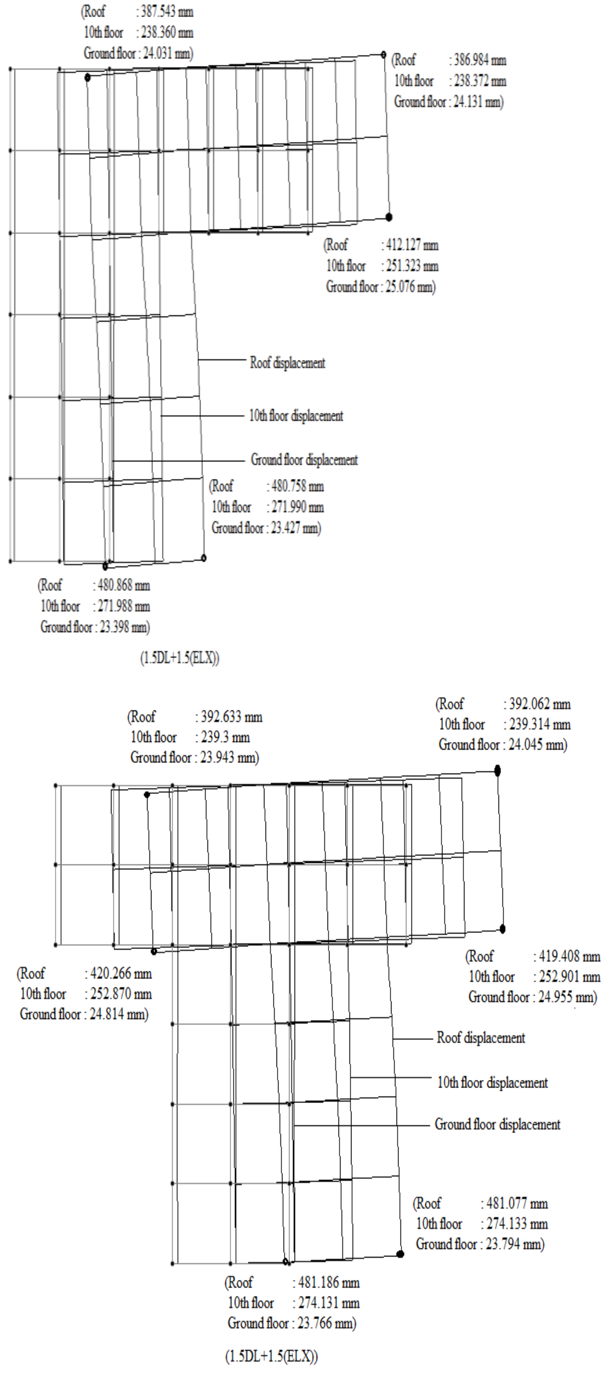


Figure 4 Ground, 10th floor and roof displacements of frames for load combination 1.5DL+1.5ELX

GENERAL CONCLUSIONS

1. The roof displacement for the corners of a regular frame is same. It is observed that, there are no torsional effects in the frame because of symmetry, that is the centre of mass that coincides with the centre of rigidity and the lateral displacements of the four corners are same in the direction of earthquake force. The same is observed in the case of wind loads.

2. The responses in the case of earth quake load is more than wind load, this is due to that the earthquake load is dominating than the wind load of given intensity and exposure for the regular building.
3. It is observed that, the storey drift values in the regular building are more in the bottom floors than at the top floors both in earthquake and wind loads this is due to that the shear is dominating the bending.
4. The responses and drifts for an irregular building are nearly same for the columns which are located in the plane parallel to the action of force. This slight change is due to the torsional rotation in the structure. Even though there is torsional rotation in the structure , this will not have an effect much in the magnitude of displacements in the columns which are located in the 2-D frame parallel to the action of force.
5. The responses for an irregular building are different for the columns that are located in the plane perpendicular to the action of force. This is due to the torsional rotation in the structure. There is much variation in the magnitude of displacements in the columns which are located in the 2-D frame perpendicular to the action of force. Additional lateral forces will add to the existing lateral loads due to earthquake loads, hence increase in the displacements.(example -frame-2,columns 1 and 4)
6. The response of few columns of a regular frame is more than, in the particular columns of irregular frame. This is due to that the negative additional lateral force developed by the torsional effects.
7. The response of few columns of a regular frame is less than, in the particular columns of irregular frame. This is due to that the additional lateral force developed by the torsional effects.
8. In the case of U shaped plan configuration the responses in the corner columns of two limbs are same in the earthquake loads and is not equal in the case of wind loads .The response is more in windward limb than in leeward limb. This is due to that the lateral loads are acting in earthquake are joint lateral forces, where as in the case of wind loads lateral loads will act on the windward facade only. Because there is no connectivity in between the two limbs, there no possibility of redistribution.

FUTURE SCOPE OF WORK

The importance of the configuration of a building was aptly summarised by Late ***Henry Degenkolb***, an expert Earthquake Engineer of USA, as "If we have a poor configuration to start with, all the engineer can do is to provide a band-aid to improve a basically poor solution as best as he can. Conversely, if we start-off with a good configuration and reasonable framing system, even a poor engineer cannot harm its ultimate performance too much.". But with an extensive research results, the ultimate performance can be achieved even with a poor configuration.

It is highly impossible to get general conclusions by analysing few irregular frames, however to get better understanding, it is required to study the responses and behaviour of more number of unsymmetrical shapes both in plan and vertical irregularities. In these modern days , most of the structures are involved with architectural importance, hence it is highly impossible to plan with regular shapes. In the present study, analysis is based on the linear static analysis. This is not sufficient to study the nonlinear behaviour of the structure. A great amount of research in nonlinear static analysis i.e., push over analysis is in progress and simultaneously a great focus is also in the direction of nonlinear dynamic analysis. To know the complete behaviour of the structure with irregularity from linear stage to the collapse stage, nonlinear dynamic analysis study is required. This is possible, only by performing the simulation using Finite Element Method or Applied Element Method [4,5] coding.

Hence there is lot of scope for future studies in the behaviour of the very irregular shapes both plan and vertical, by performing nonlinear static analysis using pushover analysis and nonlinear dynamic analysis using Finite Element Method (FEM) or Applied Element Method (AEM).

REFERENCES

1. IS 1893 (Part-1):2002. Criteria for Earthquake Resistant Design Of Structures, General Provisions and Buildings (Fifth Revision).
2. STAAD pro V8*i*, 2007 Version, general-purpose structural analysis and design solution, Bentley California, USA, 2007
3. ASCE-7:2002 , Minimum design loads for buildings and other structures.2002
4. Kimiro Meguro and Hatem Tagel-Din: Applied Element Method for Structural Analysis: Theory and Application for Linear Materials, Structural Eng./Earthquake Eng., International Journal of the Japan Society of Civil Engineers (JSCE), Vol. 17, No. 1, 21s-35s, April 2000
5. Hatem Tagel-Din and Kimiro Meguro: Applied Element Method for Simulation of Nonlinear Materials, Theory and Application for RC Structures, Structural Eng./Earthquake Eng., International Journal of the Japan Society of Civil Engineers (JSCE) Vol. 17, No. 2, 137s-148s, July 2000