

Effect of Earthquake on Structure for Plan and Elevation Irregularities

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ABSTRACT

The research on asymmetric buildings has been extensive primarily focusing on the stability of a structure when subjected to earthquake. Based on them numerous guidelines have been laid out for to ensure safety. It has in this paper tried to evaluate the effectiveness of the guidelines provided in the IS: 1893 (2002). Asymmetric buildings are more common now than they have ever been and their popularity has been growing primarily due to the functionality they provide. Due to the frequent earthquakes that India suffers being at the junction of two tectonic plates it has become increasingly important to study Indian buildings for seismic safety. The buildings are analysed based on the effect of displacement which is the main cause of damage for Asymmetric Buildings subjected to strong earthquakes to structural collapse. Some of the situations that can give rise to this situation in the building plan are positioning the stiff elements asymmetrically with respect to the centre of gravity of the story.

Keywords— Earthquake, High Rise Structure, asymmetric buildings, Sap200 v19, Irregularities.

INTRODUCTION

Structures have been prone to earthquakes since the first structure was built. Earlier accredited to the wrath of Gods there have been many elaborate rituals in civilizations around the globe to keep the God appeased and cities safe which then evolved into festivals but we now know otherwise. Earthquakes which are some of the most severe natural catastrophes known to man are still a modern menace and though we don't pray our way for safety anymore. Earthquake resistance of buildings has taken a more scientific turn and still is a major area of research. Though, one of the most catastrophic events in nature earthquakes themselves does not kill people although they may result in some of the highest death toll known. The primary damage caused by an earth quake is to a building or a natural structure and not people. The collapses of

such man-made structures like buildings lead to people using them getting crushed or trapped by the debris. The higher the rise the greater is the fall, due to its unique nature earthquakes are more menacing to the more developed urban areas than rural areas as these tend to be more dense populated with more high-rise buildings in a concentrated space for utilizing the expensive commodity effectively. Rapid urbanization has propelled the priority of Earthquake resistance.

All over world, there is high demand for construction of tall buildings due to increasing urbanization and spiralling population, and earthquakes have the potential for causing the greatest damages to those tall structures. Since earthquake forces are random in nature and unpredictable, the engineering tools need to be sharpened for analysing structures under the action of these forces. Earthquake loads are required to be carefully modelled so as to assess the real behaviour of structure with a clear understanding that damage is expected but it should be regulated.

Complex plan buildings should be divided by seismic separation joints introduced between rectangular blocks. The behaviour of buildings during earthquakes will be satisfactory only if all measures are taken to provide a favourable failure mechanism.

LITERATUREREVIEW

To carry out the thesis it has done on linear and nonlinear static analysis of irregular buildings information is received by going through various journals and published papers by various authors which are very helpful in carrying out project successfully.

An asymmetric building is almost unavoidable in current times and hence the seismic behavior of asymmetric buildings has been an important topic for research. The primary source of information for most research is not the experimental data but data observed during the occurrence of actual earthquakes. The codal provisions tend to prevent failure in during earthquakes by increasing the ductility of the buildings. Codes tend to favour imposing restriction on maximum tension reinforcement in flexural members and require closely spaced stirrups at ends of beams. This is primarily done to ensure the formation of a plastic hinge before the failure of the member in diagonal shear. The use of nonlinear dynamic analysis has been recommended in various codes. The results of the time history analysis depend on the selection and scaling of the earthquake ground motions used in the analysis. The selections of

ground motion is generally based the judgment of the researcher. Numerous studies have been conducted to obtain a sound guideline for selecting ground motions for analysis. The general principle is to use at least The near-fault earthquakes are the quakes which are assumed to have a site to source distance of less than 20 km [1NEHRP, 2011], the near-fault earthquakes have different effects form the records of far field earthquakes. The structure may experience shaking and rupture towards form the site known as forward directivity or rupture away form site known as backward directivity. In forward directivity cases double sided pulses are observed and these pulse type motions can severely affect the seismic performance of the structure. The fault normal component is of higher peak ground acceleration than the fault parallel component at the same recording station. Near-fault records have high frequency content forward directivitythe records maycontain large amplitude velocitypulse oflongduration which affect the response and design of both high frequency and long period structures [2Ghobarah, 2004].

It is generally advised to take several ground motions for the purpose of structural design, the study for selection and scaling of the earthquake ground motions for the purpose of nonlinear analysis. The number of ground motions may exceed seven depending on the research needs. It recommends the distant site earthquakes when scaledfor a target spectrum the spectral shape is the primary consideration which isthen followed by earthquake magnitude, site-to-source distance, and local site condition if a pair of ground motions with spectral shape similar to the target spectrum are considered thenthe need forscalingcan be minimized. In case ofnear field earthquakes the two most important factors in selecting ground motions for scaling to a target spectrum are spectral shape and the possible presence of velocity pulses which are present in the near-fault earthquakes especially in the forward directivity region [3C.B. Haselton and Grant].

The effect of p-delta is mainly dependent on the applied load and building characteristics In addition to this it is also depends upon the height, stiffness and asymmetry of the building. The building asymmetry maybe unbalanced mass, stiffness, in plane. In the elastic or inelastic dynamic analyses, the effects of P-Delta sometimes increase the responses and sometimes decrease the responses. The reason is that implementing P-Delta effects in analysis causes change in stiffness matrix of building, thus the natural periods and other dynamic properties of the building will change. If acceleration response corresponding to the new natural period of

building, in response spectrum of the earthquake, is less than acceleration response corresponding to the original natural period, then reduction in building responses for the case with P-Delta can be expected. The effects of P-Delta are quite sensitive to ground motion characteristics such as the frequency content of earthquake. In inelastic analyses, the sensitivity is still important but less than the elastic dynamic cases. In general, the sensitivity to ground motion increases, as the eccentricity increases.

METHODOLOGY AND RESEARCH OBJECTIVES

General

Methodology is an approaching way to obtain a satisfying result about any kind of analysis done in any structure. The analysis is always done in an order to compare the previous situation of a structure and by getting a new result change it accordingly. If a methodology for any structure unsatisfied the comparison then it will have a new way to find the correct approach.

- a) The objective of the present work is to study the effect of earthquake on different type of structures having plan and elevation irregularities considering different time history and power spectral density functions.
- b) The main objective of the thesis is to consider the effect of the changes in the structures modal properties of asymmetric-plan and elevation buildings during the linear and non-linear analysis and the application of the displacement based adaptive pushover procedure. Different single and multi-storied structures on plane and elevation are considered in this study. The nonlinear analysis is carried out for all the structures and is compared. Various modes subjected to different failures are located according to different zones, (Immediate occupancy (IO), Life Safety (LS) and Collapse Prevention (CP)).

SCOPE OF THE WORK

The scope of the present work has been finalized as follows:

- Numerical models generation of different structures in the SAP 2000 platform and subsequent linear and nonlinear time history analysis for different type of structures under different earthquake condition.
- Comparison of different responses like displacement, velocity and acceleration etc. and other parameters like acceleration and velocity at different level of the structures for

linear and nonlinear time history analysis.

- The proposed algorithms can also be used for other structures like space frames, space trusses, and bridge structures etc.
- Vulnerability of structures can be evaluated using parameter uncertainties of structure and earthquake excitation.
- Stochastic modeling of ground motion is performed using Kanai-Tajimi model and Hu-spectral model. However, this can be extended for other type of power spectral density function.
- Dynamic experimentation verification may also be using a unidirectional shaking table or with actuator for the different models having plan and elevation irregularities.
- Seismic vulnerability evaluation from the above analysis.

RESULTS AND DISCUSSION

DISCUSSION: In this, different RC framed of G+3 structures are considered with different asymmetric about the elevation like rectangular type, C type, L type and T type in plan keeping the frame spacing and overall dimension of the structure as unchanged. All the numerical models are analysed in SAP 2000 platform and taken the same top node 78. From the Table 5.24 to 5.27 it is observed that roof displacement are higher in El Centro and lower in Chi-Chi earthquake in case of nonlinear than linear one. Also it is found from table no 5.24 to 5.27 that displacements in case of nonlinear are significantly increased with respect to the linear one.

EXAMPLE-5(G+20)

To get the behaviour of the multi-storey structure under earthquake a G+20 storey structure is considered in this example. The grid dimensions and the material properties are kept unchanged.

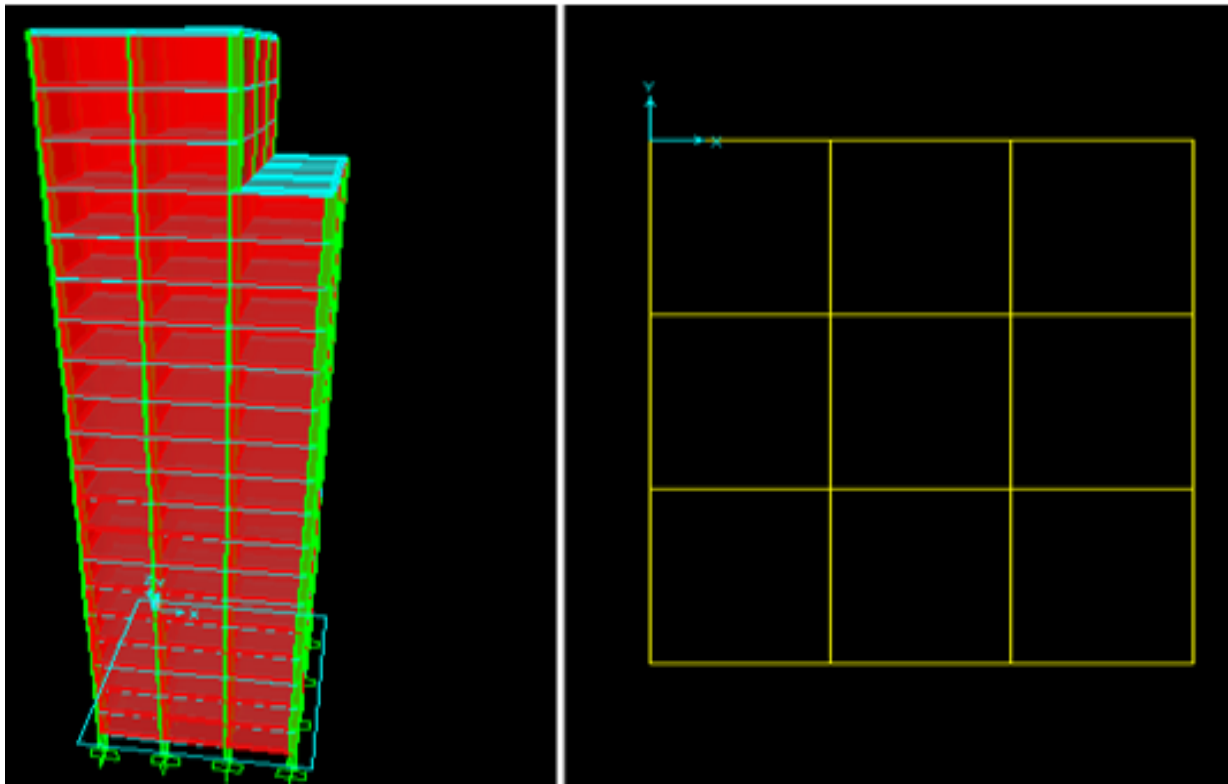


Fig.1: Plan (right) and Isometric View (left) of a G+20 (Rectangular Type) Structure

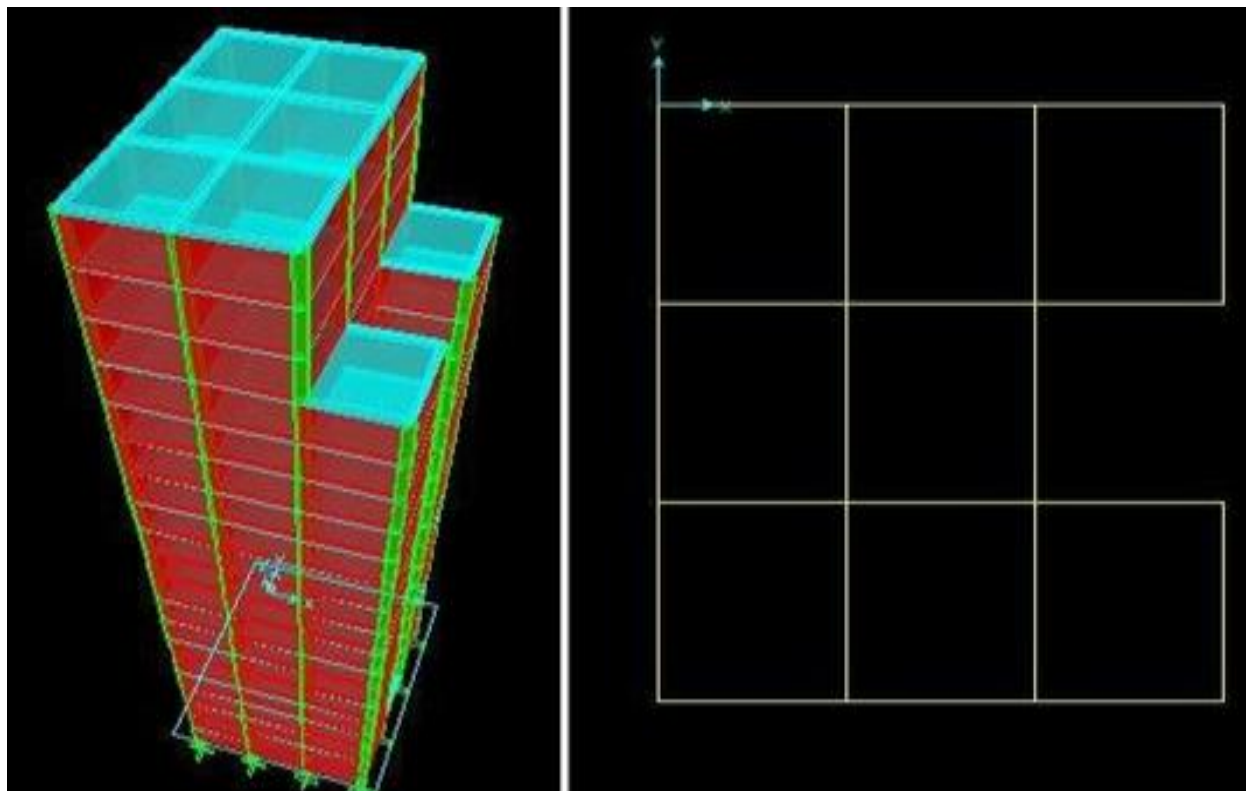


Fig.2: Plan (right) and Isometric View (left) of a G+20 (C Type) Structure

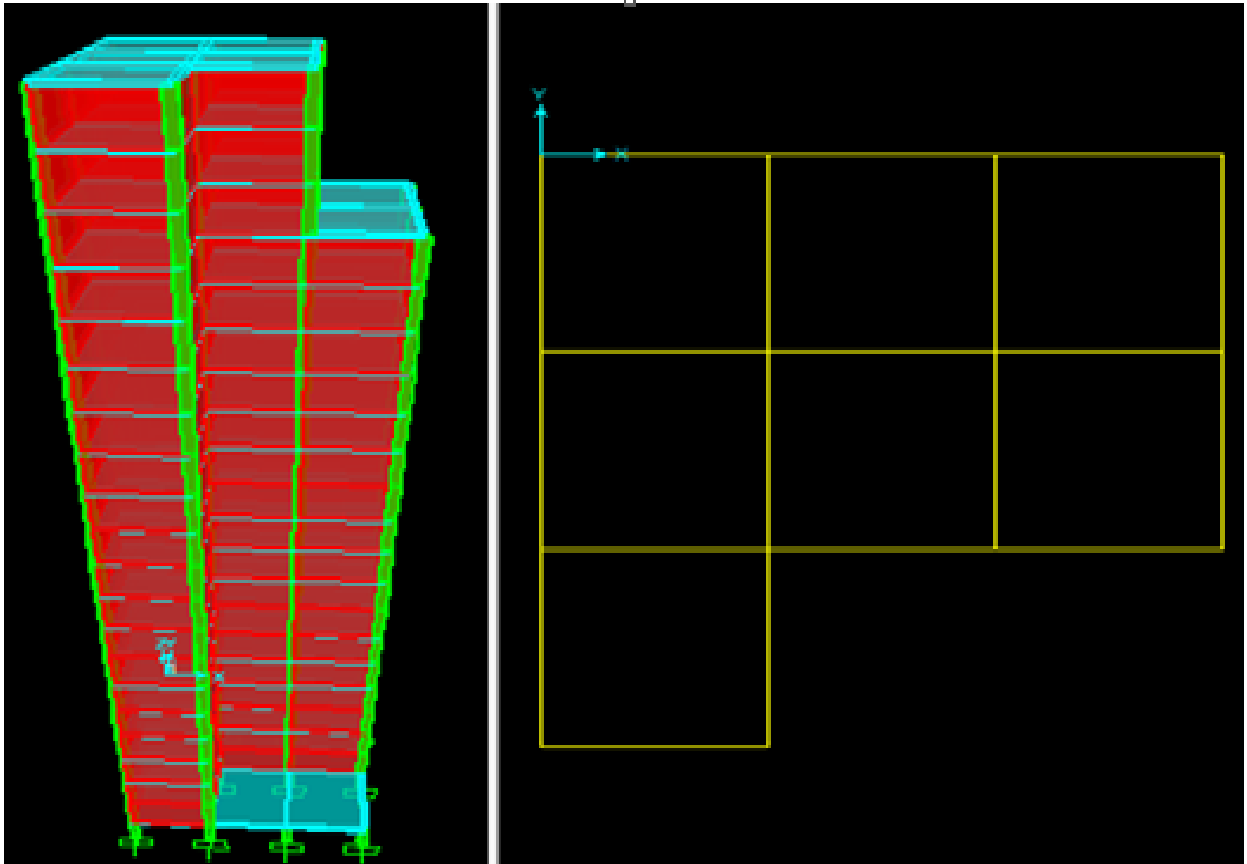


Fig.3: Plan (right) and Isometric View (left) of a G+20 (L Type) Structure

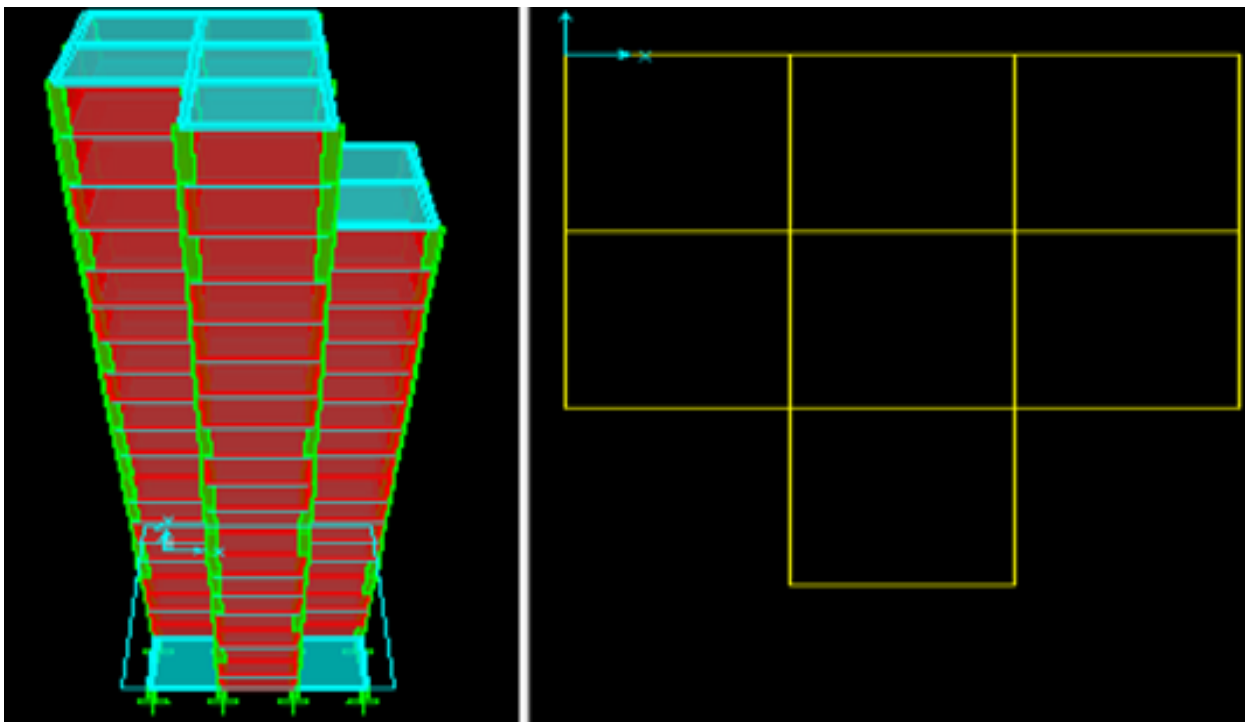


Fig.4: Plan (right) and Isometric View (left) of a G+20 (T Type) Structure

Table 1: Natural Frequencies and Eigen Values for the G+20 storey structure

Mode No	Rect.Type		CType		LType		TType	
	Nat. Freq	Eigen value	Nat. Freq	Eigen value	Nat. Freq	Eigen value	Nat. Freq	Eigen value
	Cylce/ sec	rad2/ sec2	Cylce/ sec	rad2/ sec2	Cylce/ sec	rad2/ sec2	Cylce/ sec	rad2/ sec2
1	1.09	47.73	1.11	48.85	1.02	41.39	1.08	46.2
2	1.15	52.54	1.15	53.07	1.19	56.73	1.11	48.71
3	2.26	201.86	2.23	196.71	2.33	214.58	2.37	222.23
4	3.36	446.04	3.39	455.07	3.3	430.4	3.31	433.64

Table 2: Properties of the Frame Members for structure G+20

Member	Length (m)	Breadth (m)	depth (m)	Mass density (Kg/m3)	Modulus of Elasticity (E)Gpa	Reinforcement bar size(mm)	
						Long. bar	Confinement bar
Beam	5/6	0.3	0.3	2500	21.7	8no of 25d	10d
Column	3	0.3	0.60	2500	21.7	10no of 25d	10d

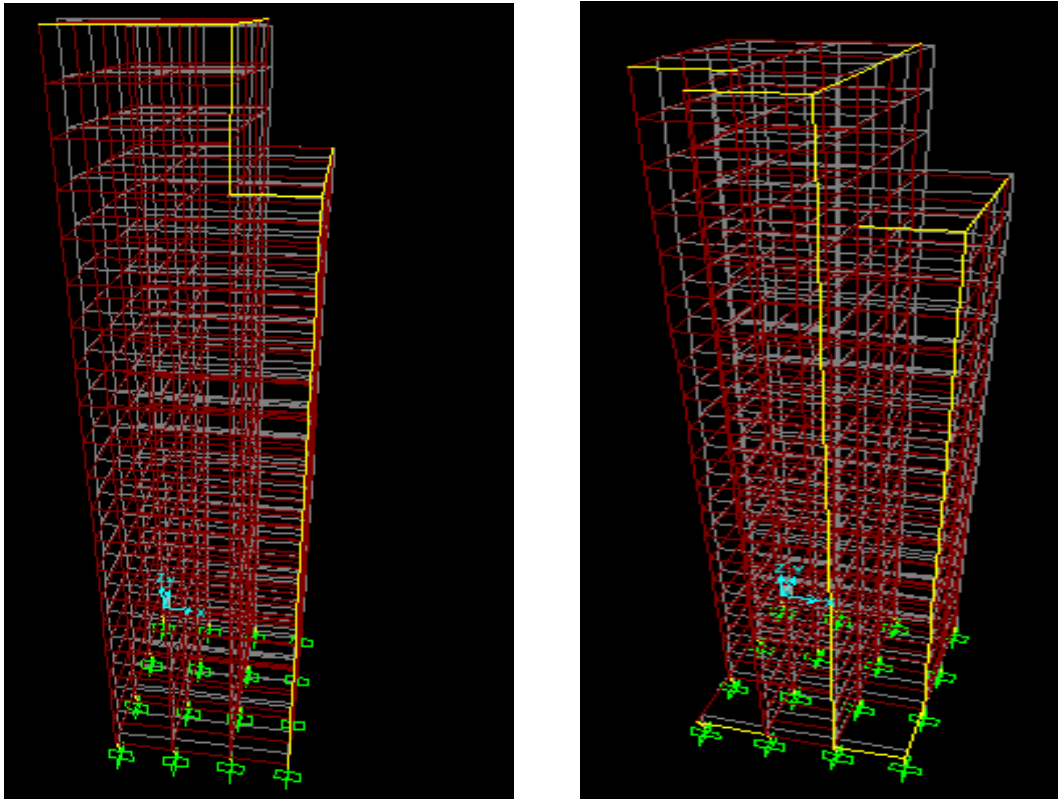


Fig.5: First Mode shapes for the Rect. Type (left) and L type structure (right)

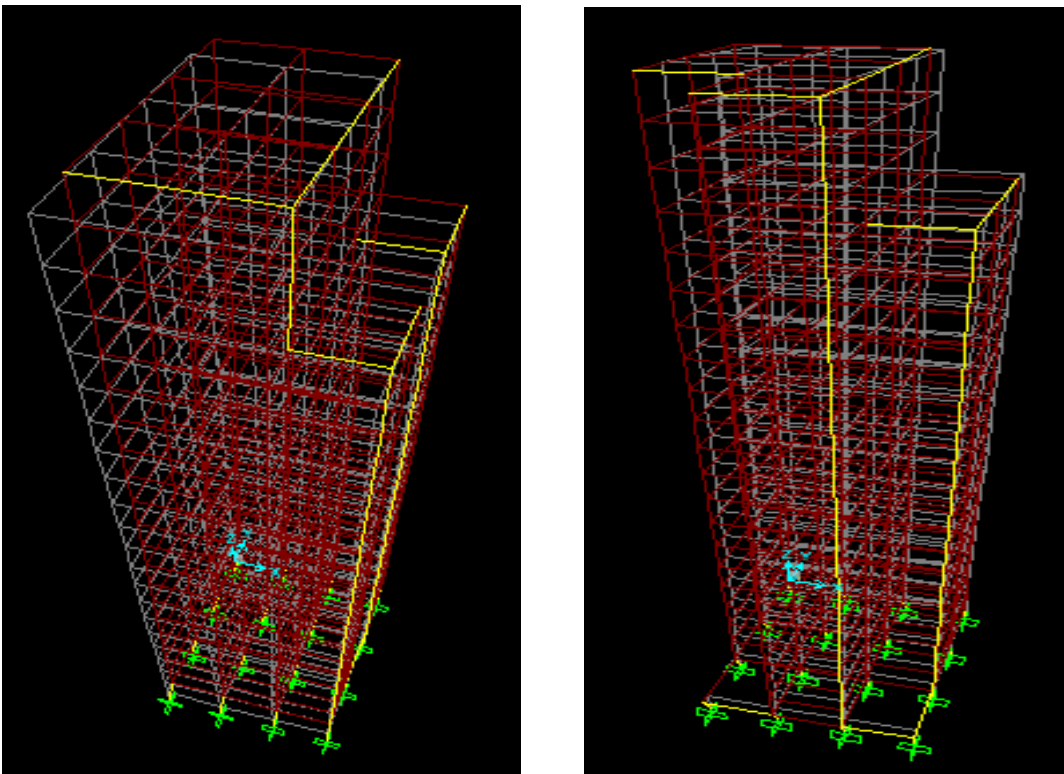


Fig. 6: First Mode shapes for the C type (left) and T types tructure (right)

Table 3: Comparison of maximum roof displacement of G+20 (Without Plan Irregularity) structure for Linear and Nonlinear Time History analysis

TimeHistory Functions	Max Roof Displ. For LinearTH Analysis(m)	Max Roof DisplacementFor Non Linear TH Analysis(m)	Corresponding Node as per SAP 2000 Model
AltadenaTH	0.024931	0.034537	350
ElCentroTH	0.125769	0.215962	350
ImperialValleyTH	0.02453	0.033064	350
Barkot(India)TH	0.019112	0.039588	350
Chamba(India)TH	0.021691	0.031986	350
Chamoli(India)TH	0.02567	0.043853	350
Chi-Chi(Taiwan)	0.000013	0.000019	350
Gangtok(India)TH	0.01185	0.013411	350
Malda(India)TH	0.014437	0.018617	350
Northridge(California)TH	0.021798	0.027538	350
Nahanni(Canada)TH	0.001993	0.004718	350
Siliguri(India) TH	0.003345	0.004584	350
UdhamSinghNagar(India)TH	0.016629	0.029113	350

Table 4: Comparison of maximum roof displacement of G+20 (C-Type) structures for Linear and Nonlinear Time History analysis

TimeHistory Functions	Max Roof Displ. For LinearTH Analysis(m)	Max Roof DisplacementFor Non Linear TH Analysis(m)	Corresponding Node as per SAP 2000 Model
AltadenaTH	0.025037	0.035298	350
ElCentroTH	0.123674	0.211681	350
ImperialValleyTH	0.024164	0.032065	350
Barkot(India) TH	0.019107	0.039141	350
Chamba(India)TH	0.021334	0.03152	350

Chamoli(India)TH	0.025368	0.043277	350
Chi-Chi(Taiwan)	0.000013	0.000018	350
Gangtok(India)TH	0.011674	0.013246	350
Malda(India)TH	0.014451	0.018309	350
Northridge(California)TH	0.021658	0.027416	350
Nahanni(Canada)TH	0.001955	0.00471	350
Siliguri(India) TH	0.003307	0.004687	350
UdhamSinghNagar(India)TH	0.016861	0.029707	350

Table 5: Comparison of maximum roof displacement of G+20 (L-Type) structures for Linear and Nonlinear Time History analysis

TimeHistory Functions	Max Roof Displ. For LinearTH Analysis(m)	Max Roof DisplacementFor Non Linear TH Analysis(m)	Corresponding Node as per SAP 2000 Model
AltadenaTH	0.024619	0.035275	350
ElCentroTH	0.092358	0.153373	350
ImperialValleyTH	0.025133	0.02559	350
Barkot(India)TH	0.018901	0.030938	350
Chamba(India)TH	0.019356	0.027753	350
Chamoli(India)TH	0.01855	0.030826	350
Chi-Chi(Taiwan)	0.000012	0.000015	350
Gangtok(India)TH	0.012009	0.013629	350
Malda(India)TH	0.017309	0.023727	350
Northridge(California)TH	0.020897	0.026606	350
Nahanni(Canada)TH	0.001526	0.002261	350
Siliguri(India) TH	0.002551	0.003905	350
UdhamSinghNagar(India)TH	0.014996	0.023234	350

Table 6: Comparison of maximum roof displacement of G+20 (T-Type) structures for Linear and Nonlinear Time History analysis

TimeHistory Functions	Max Roof Displ. For LinearTH Analysis(m)	Max Roof DisplacementFor Non Linear TH Analysis(m)	Corresponding Node as per SAP 2000 Model
AltadenaTH	0.024217	0.031624	350
ElCentroTH	0.137822	0.225536	350
ImperialValleyTH	0.026952	0.041845	350
Barkot(India)TH	0.022582	0.042973	350
Chamba(India)TH	0.024211	0.035877	350
Chamoli(India)TH	0.025414	0.040246	350
Chi-Chi(Taiwan)	0.000015	0.000021	350
Gangtok(India)TH	0.013052	0.015148	350
Malda(India)TH	0.015295	0.020216	350
Northridge(California)TH	0.022301	0.028446	350
Nahanni(Canada)TH	0.002199	0.004584	350
Siliguri(India) TH	0.003402	0.006029	350
UdhamSinghNagar(India)TH	0.01408	0.022466	350

Table 7: Comparison of maximum Power Spectral Density function of G+20 structures for Time History analysis

STRUCTURE TYPE	PSDHUSOFT1	PSDHUTAJIMI 1	Corresponding Node as per SAP 2000 Model
NORMALTYPE	0.00939	0.075019	350
CTYPE	0.010169	0.081267	350
LTYPE	0.011543	0.092309	350
T TYPE	0.005992	0.047816	350

DISCUSSION: In this, different RC framed of G+3 structures are considered with different asymmetric about the elevation like rectangular type, C type, L type and T type in plan keeping the frame spacing and overall dimension of the structure as unchanged. All the numerical models are analysed in SAP 2000 platform and taken the same top node 350. From the Table 5.30 to 5.33 it is observed that roof displacement are higher in El Centro and lower in Chi-Chi earthquake in case of nonlinear than linear one. Also it is found from table no 5.30 to 5.33 that displacements in case of nonlinear are significantly increased with respect to the linear one. It is also observed that in case of L type in elevation the PSD responses are higher than others.

CONCLUSION

For the vulnerability assessment of different structures few different structural models are prepared in the SAP 2000 platform and the linear and nonlinear time history analysis is performed using different known earthquakes like Altadena, EL CENTRO, NORTHRIDGE, IMPERIAL VALLEY, CHI-CHI, NAHANNI AND SIKKIM etc. in the different structural model variation occurs in the geometry and also the material. Observing the results it can be concluded that

1. Responses like roof displacement increases in a significant manner for the most of the structures if nonlinearity is incorporated in the time history analysis. However, magnitudes of responses are different for different structures and also for different strong motions. Generally it is observed that more irregularity increases the top displacements more.
2. Responses like roof displacement and velocity or acceleration at several nodes are higher for a structure having asymmetry in plan in compare with the same structure having symmetry in plan. So for earthquake vulnerability it is always preferable to construct structures symmetrical as far as possible.
3. Structural time period and natural frequencies varies if the plan and elevation irregularity are incorporated.
4. Study on behaviour of structures under Earthquake is an important part for the structural analysis and design. Time history analysis is a suitable method for performing dynamic analysis for earthquake.

Top nodes of a structure experience different displacement under different earthquake and also the displacement increases in case of nonlinear analysis with respect to the linear one.

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