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Time history analysis of asymmetric three: Dimensional building frames structure

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Abstract
After the advent of series of major earth quakes in and around India the codes of the land have been revised. In the urban areas depending upon the architectural needs and the cost of land it has become necessary to adopt high rise to very high rise buildings with regular to irregular orientation.
The present practice in seismic design is to adopt Response spectrum method of structural analysis. The code leaves the application of method of dynamic analysis making use of Time History Analysis concept to the discretion of the designer. In this context in the present project, a 1- storey building has been analyzed Time History Analysis making use of E-tabs.
A simplified nonlinear analysis procedure to predict earthquake responses of multi-story asymmetric buildings is presented and some examples are shown in this paper. In this procedure, the comparison of three multi-storied building i.e,
1. Symmetric structure.
2. Mass as-symmetric structure.
3. Stiffness as-symmetric structure.
In brief, In the symmetric structure, the mass, columns, beams which has same mass and sizes with floor to floor respectively has been analyzed by time history analysis. In the mass as-symmetric structure, the size of columns and beams are of same size but the loading of mass is different from span to span has been analyzed by time history analysis and in stiffness as-symmetric structure loading of mass is same from floor to floor but the size of column are different has been analyzed by time history analysis
A comparison of the three sets of results demonstrates both the capabilities and limitations of the proposed procedure with help of graphs.

Keywords: base shear, torsion, time history analysis of frame structure

1. Introduction
The primary purpose of all kinds of structural systems used in the building type of structures is to support gravity loads. The most common loads resulting from the effect of gravity are dead load, live load and snow load. Besides these vertical loads, buildings are also subjected to lateral loads caused by wind, blasting or earthquake. Lateral loads can develop high stresses, produce sway movement or cause vibration Therefore, it is very important for the structure to have sufficient strength against vertical loads together with adequate stiffness to resist lateral forces.
India is considered as one of the most disaster prone countries in the world. It has experienced several earthquakes in the past resulting in large number of deaths and severe property damage. The UNESCO had declared the nineties as the International Decade for Natural Disaster Reduction. Ironically, the previous decade also witnessed four earthquakes of magnitude 6.0 and above occurring in the Himalayas, Central India and the peninsular region resulting into approximately 10000 casualties and many more injuries. These figures would have been even higher, if these earthquakes had occurred in the neighbourhood of large urban centres, as was seen in the case of the Bhuj earthquake of January 2011. This earthquake alone accounted for more than 15000 lives in addition to having a crippling effect on the economy of the region. These disastrous consequences could have been avoided had the system been designed to withstand earthquake ground motion.
In terms of pure economic theory, earthquake causes two types of losses known as primary and secondary losses. A primary loss is an irrecoverable loss, which results in the loss of human life in earthquake. All other losses incurred due to an earthquake that can be recouped are termed as secondary losses.

2. Seismic design philosophy
The need for structural design against strong ground motion was first appreciated in the early decades of the 20th century after a series of catastrophic earthquake events throughout the world: San Francisco, California, 1908; Messina, Italy, 1908; Kanto, Japan, 1925; Napier, New Zealand, 1932 and Long Beach, California,1933, to mention but a few. Essentially, the first design codes prescribed specific detailing and construction rules against which the structure should be checked. In the absence of reliable measurement of ground motion intensity and lack of knowledge on Structural Dynamics, typically the magnitude of these forces was taken as 10% of the weight of the building.

3. Seismic zone map of India & recent earthquakes

Earthquakes have been occurring in the Indian sub continent from the time immemorial but reliable historical records are available for the last 200 years (Oldham, 1883). From the beginning of the 20th century, more than 700 earthquakes of magnitude 5 or more have been recorded and felt in India. The seismicity of India is divided into four groups, namely Himalayan region, Andaman Nicobar, Kutch Region, and Peninsular India.

The goal of seismic zoning is to delineate regions of probable intensity of ground motion in a country, for providing a guideline for provision of an adequate earthquake resistance in constructed facilities.

The first comprehensive seismic zoning map was developed by the Bureau of Indian Standards in 1962. Later in the subsequent years it was reviewed many times and thus a four zone seismic zoning map was adopted in Is 1893:2002. The map is based on expected intensity of ground shaking but does not consider the frequency of the occurrence.

Current seismic zoning map as per IS 1893-2002 says that around 60% (Zone V= 12%, Zone IV=18%, Zone III = 26% and Zone II 44%) of India is prone to moderate to major earthquakes. Accordingly, zone factors (z) are defined for each zone to arrive at the design seismic force acting on the structure. Zone II corresponds to intensity VI or lower and zone V corresponds to intensity IX or higher.

Zone II has lowest danger or risk while Zone - V has highest hazards.

Since damage controlled limit state has been accepted, the zone factor, z has been reduced to half (z/2) of Maximum Considered Earthquake (MCE) for Design Basis Earthquake (DBE).

Structures are explicitly designed for DBE and maximum considered earthquake is taken care of through over strength and ductility provisions.

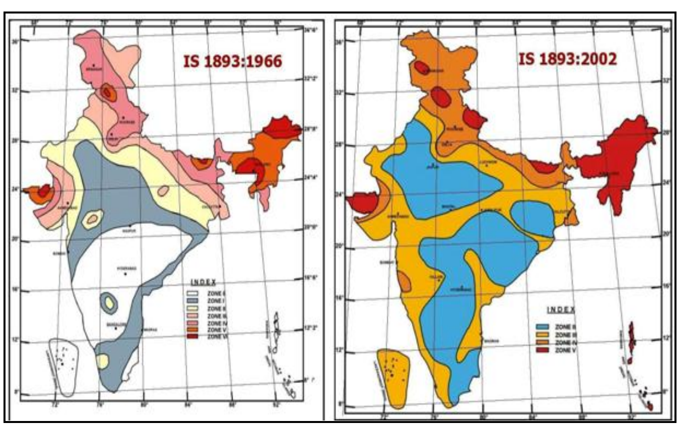

Fig 1: Seismic zoning maps of India I.S. 1893:1966 and IS1893:2002

4. Objective of study

To compare the following aspects of the buildings.
Lateral Displacements at joints.
Base shear- in X direction and in Y-direction
Torsion
Velocity

5. Overview of time history analysis

During early days, analysis was taken up using approximate methods such as cantilever methods and portal methods. With the advancement of computer, methods based on stiffness approach were used to perform the analysis due to lateral loads. The Dynamics analysis is performed by mode superposition method. The present practice in seismic design is to adopt Response spectrum method of structural analysis. The code leaves the application of method of dynamic analysis making use of time history analysis concept to the discretion of the designer. However designing structures making use of time history analysis is desirable when the structure has irregular shape.

6. Methodology

Structures on the earth are generally subjected to two type of load: Static and Dynamic. Static Loads are constant with time while dynamic loads are time varying. In general the majority of civil engineering structures are designed with the assumption that all applied loads are static. The effect of dynamic load is not considered because the structure is rarely subjected to dynamic loading; more so, its consideration in analysis make the solution more complicated and time consuming. This feature of neglecting the dynamic loads becomes the cause of disaster sometimes, especially in the case of earthquakes. The best and the recent example of this category is the Bhuj earthquake of January 26, 2001, which claimed more than 15000 lives and left many homeless and did huge damage in the region in all aspects. Now a days there is a growing interest in the process of designing Civil engineering structures capable to withstand dynamic loads, particularly the earthquake induced load.

7. Analysis of building structure

In the present work, a 40-storied reinforced concrete frame building situated in Hyderabad city which falls in Zone II, is taken for the purpose of study. The plan area of building is 54x54m and 3.0m as height of typical storey. It consists of 9 bays in X-direction and 9 bays in Y-direction. The total height of the building is 120.2m along parapet wall. The building is considered as a Special Moment Resisting Frame. The plan of building is shown in fig. 1 and the front elevation along x-z axis is shown in Fig n the elevation along y-z axis is shown in Fig. 2. As the structure is regular and relatively simple, the identification of the differences in results can be known in easy and can be discuss.

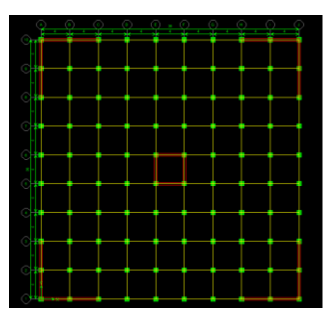

Fig 2: Plan of Model-1, Symmetric structure in regular shape

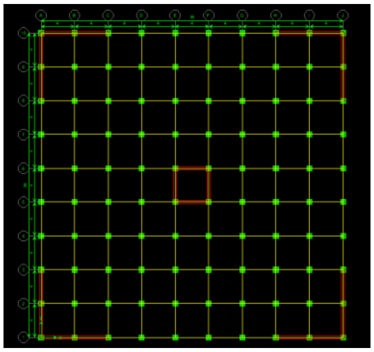

Fig 3: Plan of Model-2, Mass as-symmetric structure in irregular shape

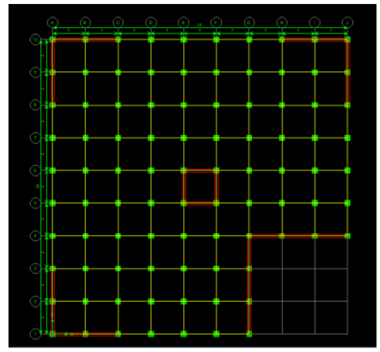

Fig 4: Plan of Model-3, Stiffness as-symmetric structure in irregular shape

Table 1: General data collection and condition assessment of the building

1.	**Plan size**	**54x54m**	**54X54**	**54X54**
2.	Building height	120.2	120.2	120.2
3.	Number of stories above ground	40	40	40
4.	Type of structure	RC frame	RC frame	RC frame
5.	Open ground storey	Yes	Yes	Yes
6.	Falling hazards	Parapet wall	Parapet wall	Parapet wall
7.	Type of building	Regular frame with open ground storey	Regular frame with open ground storey	Regular frame with open ground storey
8.	Beam sizes	450x600mm	450x600mm	450x600mm
9.	Column sizes	600x600mm 800x800mm 1200x1200mm	600x600mm 800x800mm 1200x1200mm	600x600mm 800x800mm 1200x1200mm
10.	Mass load	Loads are different from span to span.	All loads are same from floor to floor	All loads are same from floor to floor
10.	Grade of concrete used	M40	M40	M40
11.	Software used	E-TABS vs. 9.6	E-TABSvs. 9.6	E-TABS vs. 9.6

8. Results and discussions

The results of the analytical investigations are presented in the Tables. The results are also shown graphically in the Figures.

Displacement at point 1: After modeling and analyzing the structure, the displacements at the joints in the structure were checked out. In this chapter, joints of the extreme columns of comparison of three buildings are checked for displacement and they are compared.

Table 2: Time vs. Displacement at joint 1 in the buildings: The table below shows the Displacement values with respect to time for 25 S at joint 1 in the buildings.

Symmetric structure		**Mass asymmetric structure**		**Stiffness asymmetric structure**	
Modal 1		**Modal 2**		**Modal 3**	
Time (s)	**Displacement(m)**	**Time (s)**	**Displacement(m)**	**Time (s)**	**Displacement(m)**
0	0	0	0	0	0
0.5	0.05649	0.5	0.05694	0.5	0.06234
1	0.23801	1	0.23835	1	0.20453
1.5	-0.44854	1.5	-0.4551	1.5	-0.52741
2	-0.80456	2	-0.81025	2	-0.61664
2.5	1.71084	2.5	1.71939	2.5	1.70457
3	1.57213	3	1.58278	3	1.14549
3.5	-0.89258	3.5	-0.92028	3.5	-1.12474
4	-1.51255	4	-1.51988	4	-1.13344
4.5	-0.31635	4.5	-0.26322	4.5	0.25161
5	1.26578	5	1.27211	5	1.00768
5.5	1.16505	5.5	1.11844	5.5	0.47629
6	-0.70882	6	-0.73018	6	-0.75162
6.5	-1.25662	6.5	-1.23454	6.5	-0.72998
7	-0.08748	7	-0.03804	7	0.33892
7.5	1.031	7.5	1.03099	7.5	0.76463
8	0.67772	8	0.61099	8	-0.03023
8.5	-0.52866	8.5	-0.54757	8.5	-0.53318

9	-0.91925	9	-0.86099	9	-0.17684
9.5	0.00324	9.5	0.04368	9.5	0.24891
10	0.79759	10	0.76903	10	0.2463
10.5	0.38925	10.5	0.32765	10.5	-0.03884
11	-0.4978	11	-0.5041	11	-0.21899
11.5	-0.62484	11.5	-0.55657	11.5	-0.12247
12	0.11958	12	0.15701	12	0.11908
12.5	0.60867	12.5	0.55586	12.5	0.17088
13	0.22944	13	0.16849	13	0.0098
13.5	-0.40913	13.5	-0.38862	13.5	-0.12122
14	-0.42545	14	-0.35477	14	-0.08991
14.5	0.16001	14.5	0.17756	14.5	0.05192
15	0.45959	15	0.39761	15	0.11459
15.5	0.09468	15.5	0.04453	15.5	0.04217
16	-0.35842	16	-0.3222	16	-0.08527
16.5	-0.28713	16.5	-0.21947	16.5	-0.13536
17	0.16605	17	0.16616	17	0.01661
17.5	0.33371	17.5	0.26757	17.5	0.15462
18	0.03507	18	-6.25E-04	18	0.05936
18.5	-0.2915	18.5	-0.2449	18.5	-0.14259
19	-0.18109	19	-0.12151	19	-0.11491
19.5	0.16127	19.5	0.14665	19.5	0.07732
20	0.23794	20	0.17255	20	0.13173
20.5	-3.18E-04	20.5	-0.02002	20.5	0.01342
21	-0.2177	21	-0.1653	21	-0.122
21.5	-0.11862	21.5	-0.0724	21.5	-0.0829
22	0.13674	22	0.11128	22	0.08249
22.5	0.16454	22.5	0.10681	22.5	0.11146
23	-0.02284	23	-0.02959	23	-0.02139
23.5	-0.16965	23.5	-0.11766	23.5	-0.12391
24	-0.06714	24	-0.03313	24	-0.02816
24.5	0.10902	24.5	0.07718	24.5	0.09148
25	0.13281	25	0.08393	25	0.07962

The above table shows the variation of displacement values at the interval of 0.5 second in the three different types of structures i.e., symmetric structure to asymmetric structure. It is observed that there is minor change in the displacement values.

Table 3: shows the maximum displacement with respect to time for three types of the buildings.

Structures	Maximum displacement At point IN (M)	Time(S)
Model-1	1.7	2.5
Model-2	2.36	11
Model-3	0.54	2.5

The maximum displacement with respect to time when compared with 3 types of buildings is 2.36m at 11s in Model-2.

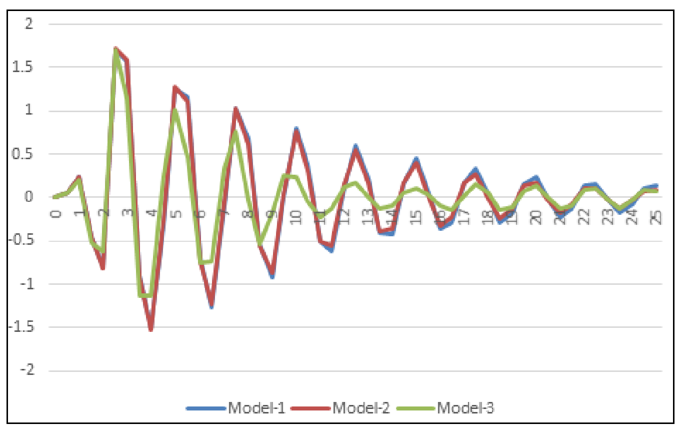

Fig 5: Graph showing Time vs. displacement at joint no.1 in the buildings

Table 4: shows the Maximum Velocity with respect to time for three types of the buildings

Structure	Maximum velocity(mph)	Time(s)
Model-1	5.2	4.5
Model-2	8.88	4.5
Model-3	2.62	2

The maximum Velocity with respect to time when compared With 3 types of buildings is 8.88mph at 4.5s in Model-2.

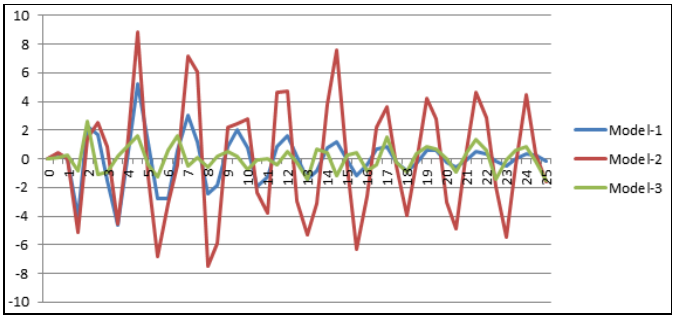

Fig 6: Graph showing Time vs. velocity at joint: 1 in buildings

Table 5: Shows the beam moment 3-3 with respect to time for three types of the buildings

Structure	Beam moment 3-3 At b148	Time(s)
Model-1	3.57 x 10^2	2
Model-2	8.68 x 10^2	17.5
Model-3	2.18 x 10^{11}	12

The maximum Beam moment 3-3 with respect to time when compared with 3 types of buildings is 8.68x10^2 at 17.5s in Model-2.

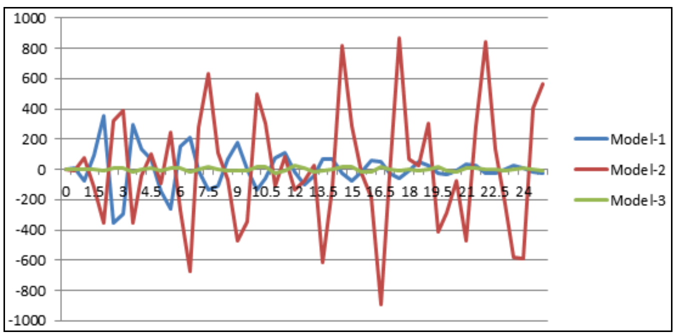

Fig 7: Graph showing Time vs. beam moment for three types of the buildings at joint: 1 in buildings

Table 6: It shows the maximum base shear-X vs. time for three types of the buildings

Structure	Base shear-x for whole structure kn	Time(s)
Model-1	8.6x10^5	4
Model-2	1.82x10^6	4
Model-3	4x10^5	21

The maximum Base Shear-X with respect to time when compared with 3 types of buildings is 1.82x10^6 at 4s in Model-2.

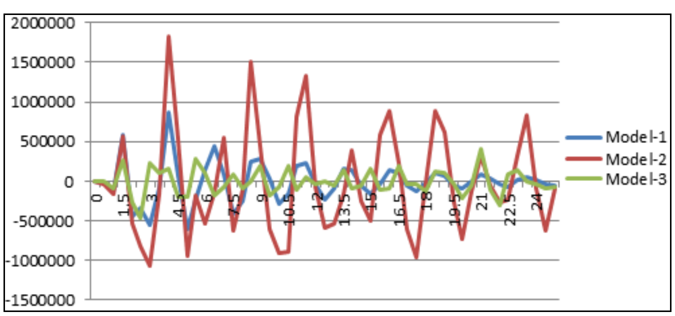

Fig 8: Graph shows maximum Base Shear-X with vs time at joint: 1 in buildings

Table 7: shows the maximum base Moment-y vs time for three types of the buildings

Structure	Base moment-y for whole building	Time(S)
Model-1	5.1x10^7	4
Model-2	7.1x10^7	4
Model-3	1.5x10^7	3.5

The maximum Base Moment-Y with respect to time when compared with 3 types of buildings is 7.1x10^7 m at 4s in Model-2.

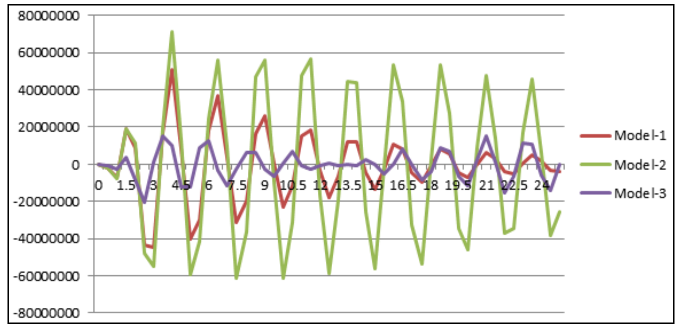

Fig 8: The maximum Base Moment-Y vs time at joint: 1 in buildings

9. Conclusions

In modern construction we encounter buildings, which exhibit some degree of plan asymmetric. This asymmetry can be caused by an uneven distribution of strength, stiffness and or mass. In addition these structures stiffness and or mass these structures are supposed to be affected by accidental eccentricity.

Single storey stiffness asymmetric buildings oscillate predominantly in the first mode than the mass asymmetric building and the symmetric building.

The comparison of results for the maximum displacement, velocity, acceleration, torsion obtains from the time history analysis of single storey asymmetric building; show that the proposed procedure can estimate the response of multi-storey building model satisfactory.

It has been observed that the lateral displacements, more in stiffness asymmetric structure. It has been noticed that the displacement values for building with symmetric structure is less by 30% and mass asymmetric structure is less by 77% when compared to building with stiffness asymmetric structure.

The maximum velocity, is more in stiffness asymmetric structure. It has been noticed that the maximum velocity values in symmetric structure is less by 23% and in mass asymmetric structure is less by 75% when compared to building with stiffness asymmetric structure.

The base shear is more in symmetric structure when compared to other two structures. It has been noticed that the base shear in stiffness asymmetric structure is less by 28% and in mass asymmetric structure is less by 47% when compared to building with symmetric structure.

The maximum torsion, is more in stiffness asymmetric structure. It has been noticed that the maximum torsion values in symmetric structure is less by 33% and in mass asymmetric structure is less by 77% when compared to building with stiffness asymmetric structure.

The case studies show that the procedure leads to good estimates of the trends of building response us for asymmetric buildings. The results deteriorate for the mass asymmetric and stiffness asymmetric structure.

10. Scope of further study

- Rigorous time history analysis with direct integration method can be applied for tall structures.
- Non linear time history analysis can be adapted to the buildings with irregular shape.

11. References

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