

Time History Analysis of Unsymmetrical Multistorey Building and Comparative Study of Displacement

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Abstract— As occurrence of earthquake is unpredictable, we need to adopt certain preventive measures to overcome the failures during an earthquake. The uncertainty in failure of structures during an earthquake has made it a necessity to consider the seismic forces while analyzing and designing a structure. Under earthquake the structure is subjected to static and dynamic action. The static and dynamic analysis can be performed with in the elastic range and inelastic range. This paper gives an overview about the pushover and linear dynamic analysis. A G+5 reinforced concrete University building which is asymmetric and the vertical geometrical and diaphragm discontinuity irregularities are considered for the analysis. The seismic analysis of a building is done by using pushover analysis and Time history analysis in ETABS software. The linear time history is done by taking the time. For time history analysis time history record of 2001 BHUJ Earth Quake, Gujarat are used. The displacement, drift and base shear results are compared and pushover curve, capacity curve and performance point is found for the building. From the obtained results for building with irregularities time history analysis gives the realistic and better results compared to the pushover analysis.

Keywords— Capacity Curve, Dynamic Analysis, Pushover Analysis, Static Analysis, Time History Analysis.

I INTRODUCTION

The earthquakes occur due to rapid release of stored **strain energy in the earth's crust**. The generated seismic waves due to earthquake travel through the soil to the ground surface of the earth. Structures are vulnerable to earthquake ground motion and due to the ground motion the structures will get damaged. As occurrence of earthquakes in India is increasing day by day the demand for seismic analysis is increasing. If structure is not constructed in earthquake prone areas the structure needs not to be analysed for the seismic analysis, the dead load and live load analysis is enough without considering the seismic forces. In order to strengthen and resist the buildings for future earthquakes, the structure should be analysed for seismic forces along with the gravity and live loads. The building is regular or irregular is described in terms of size and shape of the building, based on the arrangement of structural elements and mass. As building is asymmetry in plan and shape, there is a chance to have irregularities in the building. In this present work seismic behaviour of a G+5 storied RCC building having diaphragm discontinuity and vertical geometrical irregularity has been analysed under push over analysis and time history analysis. But as linear static and response spectrum analysis methods also comes under seismic analysis methods, the linear static and response spectrum analyses are also done for the structure to know the behaviour of structure under static and dynamic methods.

II OBJECTIVES

1. To study the seismic behaviour of irregular RC building (G+5) under pushover and time history analysis by using ETABS software.
2. To select a suitable procedure among push over analysis and time history analysis to evaluate buildings with plan irregularities under seismic loads.
3. To study and evaluate various seismic assessment parameters such as push over curve, capacity curve and identify the weak links, story drift.
4. To compare and discuss the maximum displacement, maximum drift and base shear results obtained by the push over and time history method.

III METHODOLOGY

The proposed irregular RC university building which is constructed at vadlamudi, near Guntur district, Andhra Pradesh is considered for the analysis. Proposed building is modelled and analysed with the help of ETABS software. The IS-456:2000 code is considered for RCC design and for seismic analysis IS-1893:2002 code book is taken. As building is situated near Guntur, the building comes under seismic Zone-III. The importance of the building is taken as 1.5. For response spectrum analysis, response spectrum curve is taken from the IS 1893:2002 code book. The seismic analysis of the structure is done under linear static analysis, response spectrum analysis, linear time history analysis and pushover analysis in ETABS software. The linear time history is done by taking the time history record of 2001 BHUJ Earth Quake, Gujarat. Building responses such as story displacement, story drift, and story shear and base shear results are found and compared with respect to the four seismic analysis methods. As the present work include only the time history and pushover analysis methods the conclusions were mainly focused on the time history and pushover analysis.

IV SEISMIC ANALYSIS

Based on external action applied and behaviour of the structure, the analysis can be performed by the following methods:

- a) Linear Static Analysis,
- b) Nonlinear Static Analysis,
- c) Linear Dynamic Analysis and
- d) Nonlinear Dynamic Analysis.

In most of the structures the linear static analysis is carried out by assuming lateral force is equivalent to the applied loading. The base shear distribution along the height of structure in terms of horizontal lateral force is according to the Code formula of IS 1893: 2002.

Nonlinear Static Analysis is also known as the push over analysis. In pushover analysis the magnitude of lateral loading is increased monotonically under permanent gravity **loads, until the structure's failure mode and weak links are** identified. Pushover analysis is done by controlling the force or displacement.

Linear dynamic analysis can be performed in two ways either by mode superposition method or response spectrum method and elastic time history method. This analysis will produce the effect of higher modes of vibration and the actual distribution of forces in the elastic range in a better way. In the Response spectrum method peak response of structure during an earthquake is obtained directly from the earthquake response, but this is quite accurate for structural design applications.

Time history analysis is the study of the dynamic response of the structure at every addition of time, when its base is exposed to a particular ground motion. Thus, for tall structures, structures with torsional asymmetries, or no orthogonal frameworks, a dynamic method is needed. The nonlinear time history of the analysis of the building under strong ground motion brings out the regions of weakness and ductility demand in the structure. This is the rational method available for assessing building performance.

V. MODELLING AND ANALYSIS

Six-story reinforced concrete university building which is constructed at Vadlamudi near Guntur District, Andhra Pradesh is considered for the seismic analysis to know the actual behaviour and response of the irregular structure under seismic forces. The plan at each storey varies slightly. In that case the centre of mass of each floor does not coincide with centre of gravity of the building. Fig .1 shows the finished view of the building.



Fig.1 The finished view of the building

TABLE I. GRAVITY LOADS

Gravity Loads	Value
Live Load	2.0kN/m ²
Live Load Roof	1.5kN/m ²
Wall load(230mm-4mHt)	17.48kN/m
Parapet wall load (230mm)	8.74kN/m

TABLE II. SIZES OF STRUCTURAL ELEMENTS

Structural Element	Cross section (mm x mm)
Beam 1,2,	400 x 650, 350 x 600
Beam 3,4	230 x 500, 300 x 550
Beam 5,6	450 x 700, 230 x 500
Column 1,2	600 x 900, 450 x 750
Column 3,4	300 x 750, 600 x 750
Column 5,6	380 x 750, 230 x 770
Column 7,8	230 x 600, 300 x 600
Column 9,10	450 x 600, 600 x 600
Column 11,12	300 x 750, 750 x 750
Slab	200mm

TABLE III EARTH QUAKE PERAMETERS (IS 1893-2002)

Parameters	Code Provisions
Type of Structure	RCC
Nature of Building	University Building
Damping of Concrete	5%
Importance Factor	1.5
Response Reduction Factor	5
Seismic Zone	III

TABLE IV. TIME HISTORY CCONSIDERED FOR STUDY

Earthquake	Date	Magnitude	P. G. V. (m/sec)
BHUJ GUJARATH	2001	7.8	1.5

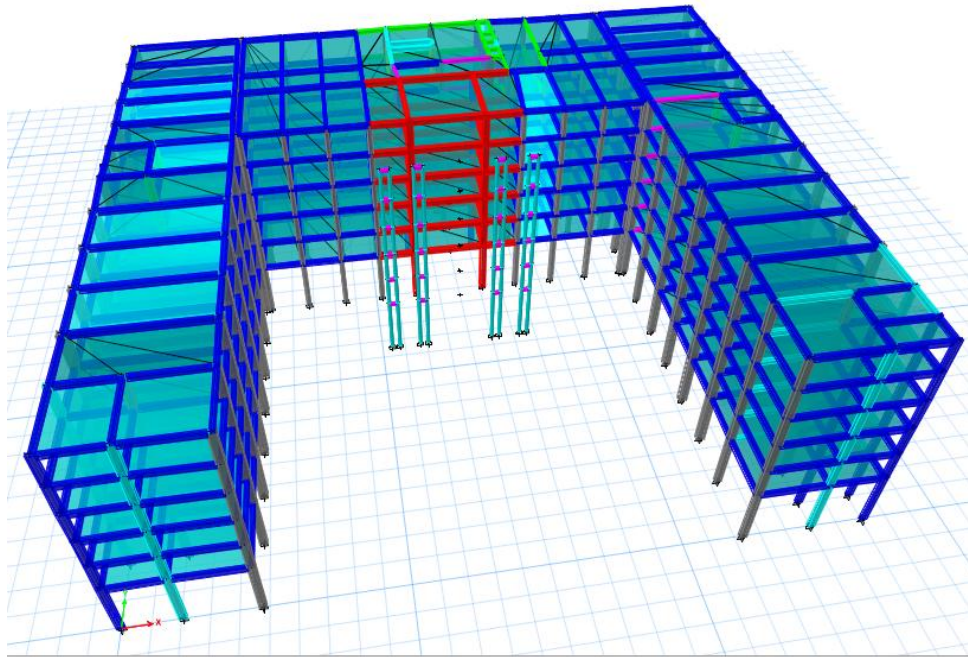


FIG 2 THREE-DIMENSIONAL RENDERED VIEW OF THE BUILDING MODEL IN ETABS

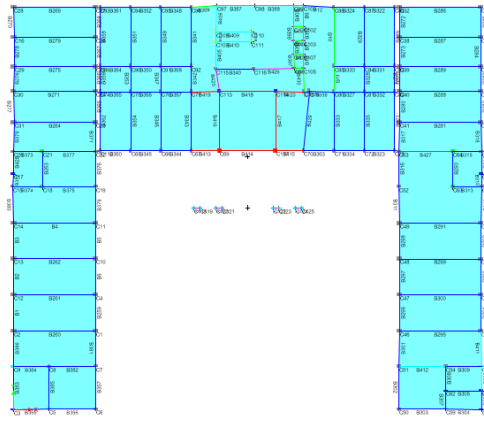


FIG.3 PLAN VIEW AT SECOND FLOOR LEVEL

The distribution of lateral forces is done by considering the load path from rigid diaphragms (i.e. whole one floor slab is assumed to be rigid and act as a rigid body to transfer the lateral loads to the vertical elements).

VI. RESULTS AND DISCUSSION

THE MAXIMUM STORY DISPLACEMENTS AND DRIFT OF THE BUILDING FOR STATIC LINEAR ANALYSIS, RESPONSE SPECTRUM ANALYSIS, TIME HISTORY ANALYSIS AND STATIC PUSHOVER ANALYSIS ARE COLLECTED. THE BASE SHEAR IS TAKEN FOR STATIC LINEAR ANALYSIS, RESPONSE SPECTRUM ANALYSIS, TIME HISTORY ANALYSIS AND STATIC PUSHOVER ANALYSIS. PUSH OVER CURVE IS DRAWN BASED ON THE OBTAINED RESULTS.

The maximum story displacement is 73.96mm for pushover analysis, when the applied earthquake force in X direction. The story displacement is less for equivalent static and linear time history analysis compared to the response spectrum analysis. Up to the linear state the pushover displacement results are of the similar as the other analysis methods like linear static and response spectrum but the building can take the displacement of 156.2mm in non linear state, and then above the maximum displacement the building will be failed. In pushover analysis the capacity of the building for the displacement will be known but in linear time history the maximum displacement cannot be known but the exact behaviour and response of the structure will be known for the given past earthquake ground motion records.

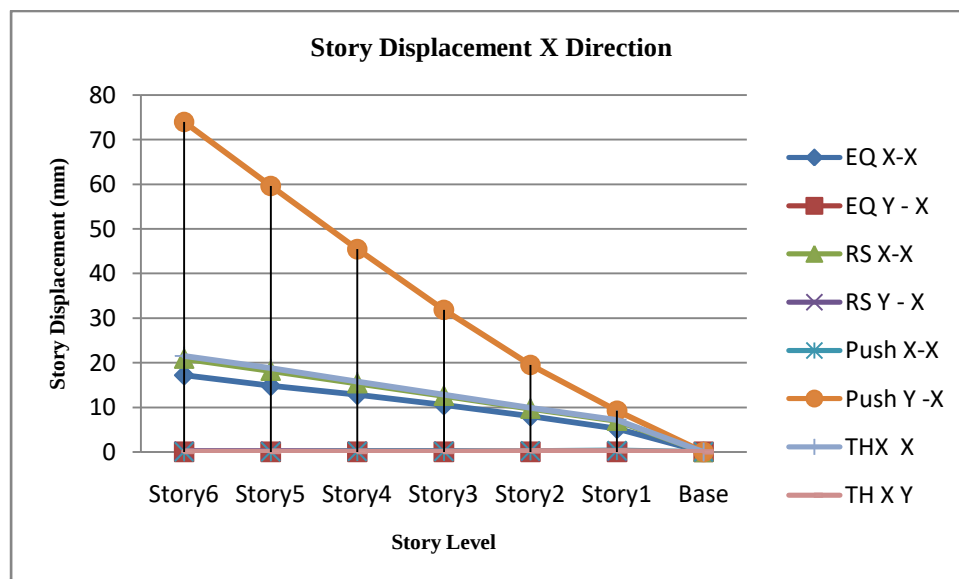


Fig.4 Story Displacement in X-Direction

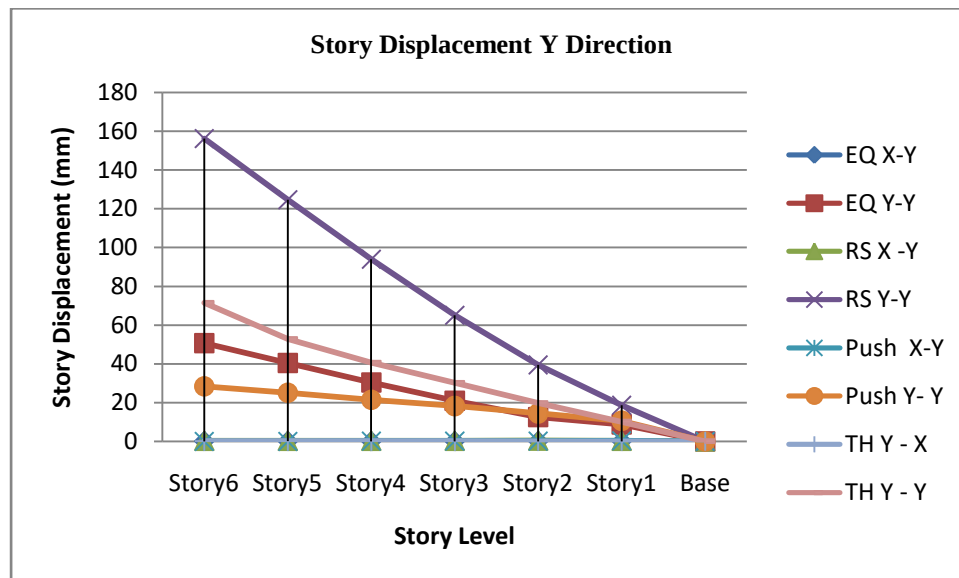


Fig.5 Story Displacement in Y-Direction

The maximum story drift is 0.0358 for Push over analysis, when the push min is applied in X- direction is 0.001396. The maximum story drift is less for linear static analysis compared to the response spectrum analysis and time history analysis. The linear static method is unable to find the proper drift and behaviour of the structure under seismic forces for an irregular structure. Up to the linear state the pushover drift results are of the similar as the other analysis methods like linear static and response spectrum but in non linear state the building can take the drift of 0.00467mm, and then above the maximum drift the building will be failed. In pushover analysis the maximum capacity of the building for the drift will be known but in linear time history the maximum drift that a building can take cannot be known but the exact behaviour and response of the structure will be known for the given past earthquake ground records.

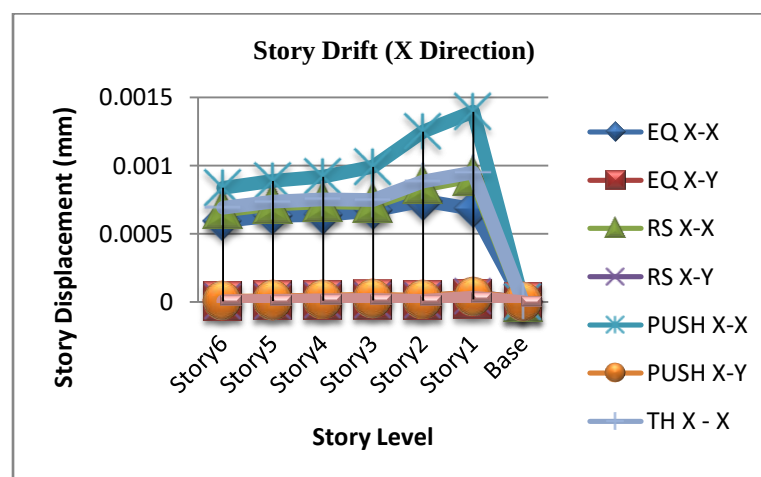


Fig.6 Story Drift in X-Direction

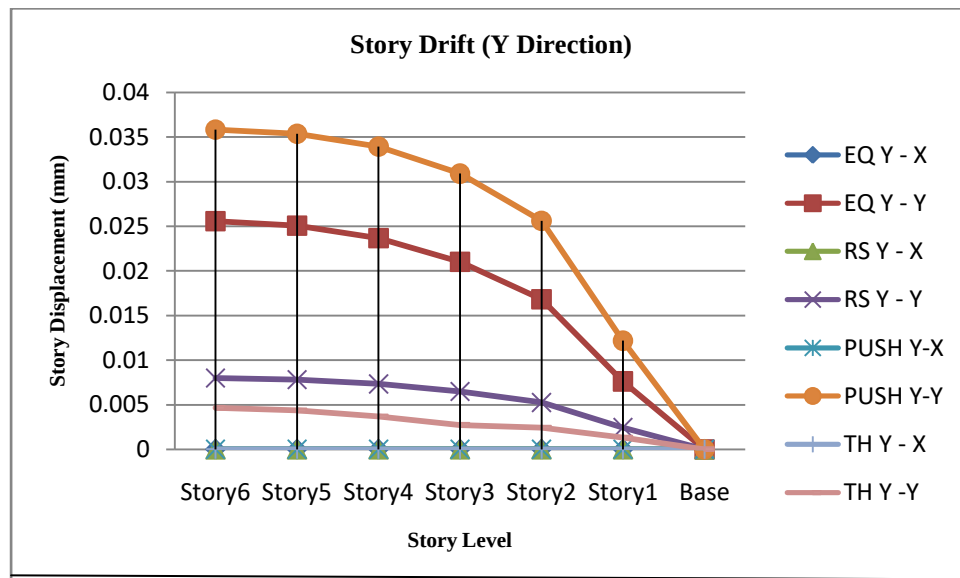


Fig.7 Story Drift in Y-Direction

The base shear is the sum of the story shear from the top story to the base. When the lateral force is applied on the building it will get distributed through the horizontal diaphragm to the vertical elements. The force due to the earthquake load distribution in linear static method in X direction is 3563.0589kN and in Y direction 3684.73kN

TABLE V. Base Shear Results Comparison

Type of Analysis	Base Shear (kN)
EQ-X	3563.0589
EQ-Y	3684.73
RS-X Max	4462.6256
RS-Y Max	4613.3557
TH-X	5954.825
TH-Y	2682.247
PUSH-UX	7650.98
PUSH-UX Max	10627.763

In case of response spectrum analysis when the response spectrum function is applied in X direction is 4462.6256kN and in Y direction 4613.3557kN. In linear time history analysis the bhuj earth quake time history record in X direction is considered the base shear is 5954.825kN and when bhuj earth quake time history record in Y direction is considered the base shear is 2682.247kN. The pushover analysis is applied in X direction due to gravity force in X direction is 7650.98kN up to the elastic behaviour of the structure. The maximum base shear in X direction is 10627.763kN.

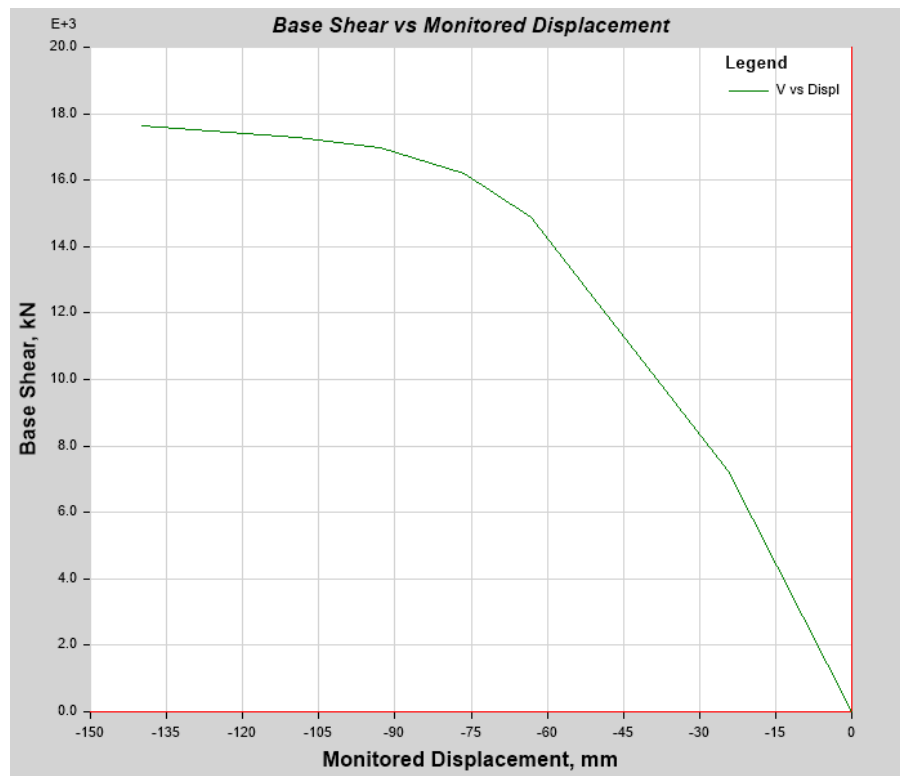


Fig.8 Push over Curve of the Building

The seismic performance of a building can be evaluated in terms of pushover curve, performance point, plastic hinge formation etc. The base shear vs. roof displacement curve (Fig. 8) is obtained from the pushover analysis of the building from which the maximum base shear capacity of structure can be obtained..

The plastic hinges are formed up to the linear state are from site class A-B. The plastic hinges formed are the final step where the building will get collapsed. Very few of the plastic hinges were formed from immediate occupancy to life safety. One beam is between the site classes C-D. One beam is at collapse state that is from site classes E-F. In Fig.9 the single demand point is shown.

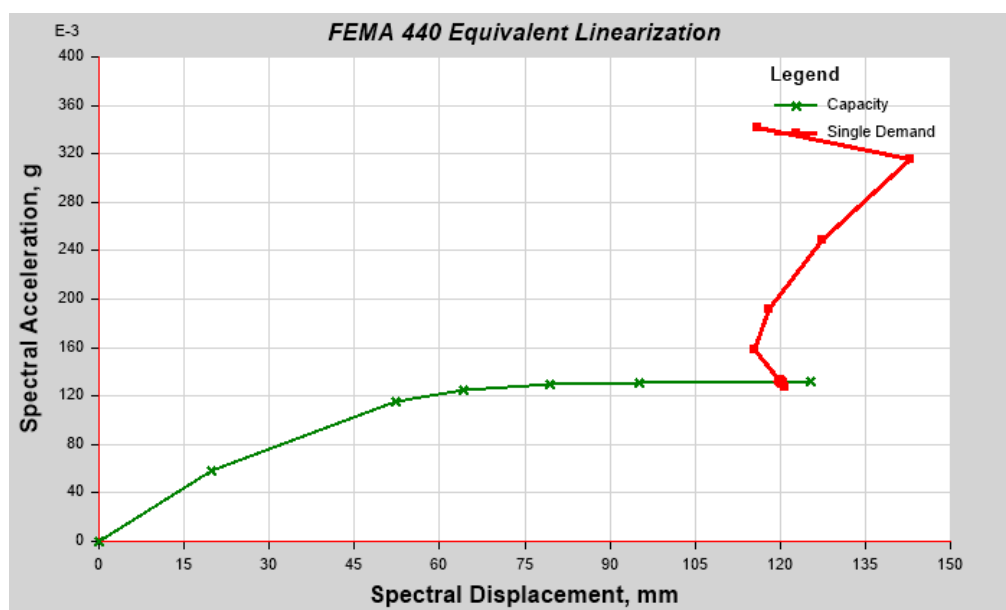


Fig 9.Push over plot for FEMA 440

VII. CONCLUSIONS

The response and behaviour of the G+5 irregular RC university building is investigated under linear static analysis, response spectrum analysis, linear time history analysis and push over analysis. From the results obtained in this present work was completed, the following conclusions were given:

1. As centre of mass and centre of stiffness is not coinciding and due to irregularities in the building, the story drift is changing from floor to floor.
2. The time history analysis is giving the proper story shear results compared to the linear static and response spectrum for the give ground data.
3. As time history analysis is done up to the linear state of the building the displacement and drift results obtained by the time history gives the exact behaviour of a structure when the building is exposed to earthquake forces.
4. For important building the time history analysis predicts the response and exact behaviour of the structure more accurately up to the linear state.
5. Up to the linear state the pushover displacement and the drift results are of the same as the other analysis methods like linear static and response spectrum but the building can take the displacement of 252.6mm at maximum step of 1384 then above the maximum displacement the building will be failed.
6. In pushover analysis the capacity of the building for the displacement will be known but in linear time history the maximum displacement cannot be known but the exact behaviour and response of the structure will be known for the given past earthquake ground records.

It can be summarized that the response of the building under linear static analysis, response spectrum analysis, linear time history analysis and push over analysis is different as the type of external action and behaviour of the structure that we apply for the analysis. From the above study it is found that the time history analysis gives the higher degree of accuracy compared to the other analysis method and from the push over analysis the maximum capacity of the structure for the displacement can be known

REFERENCES

- [1] **Gururaj B. Katti, Basavraj S. Balagopal**, “**Seismic Analysis of Multi-Storeyed RCC Buildings Due to Mass Irregularity by Time History Analysis**”, International Journal of Engineering Research & Technology, Volume 03, Issue 07, July 2014.
- [2] IS 1893(Part 1): 2002. “**Criteria for Earthquake Resistant Design of Structures,**” **Bureau of Indian Standards**, New Delhi, 2002.
- [3] **Ms. Nivedita N. Raut& Ms. Swati D. Ambadkar**, “**Pushover Analysis of Multi-storeyed Building**”, Global Journal of Researches in Engineering Civil and Structural Engineering, Volume 13, Issue 4, Versions 1.0, Year 2013.
- [4] **T. Mahdi and V. Soltangharaie**, “**Static and Dynamic Analyses of Asymmetric Reinforced Concrete Frames**”, **The 15th World Conference on Earthquake Engineering**, Paper No.4735, Year 2012.
- [5] Bahador Bagheri, Krishna Nivedita. A, Ehsan Salimi **Firoozabad** , “**Comparative Damage Assessment of Irregular Building Based on Static and Dynamic analysis**”, International Journal of Civil and Structural Engineering, Volume 3, Issue 3, March 2013.

- [6] **Sohrab Youldash**, “**Seismic Behavior of Reinforced Concrete Buildings Under Varying Frequency Contents**”
M.Tech Thesis, School of Civil Engineering, National Institute of Technology, Rourkela, Odisha, May 2014.
- [7] Arunava Das and Priyabrata Guha, “**Comparative Study of the Static and Dynamic Seismic Analysis of RC regular and irregular frame structures**”, International Journal of Scientific and Engineered Research, Volume 7, Issue 4, 2016.

TEXT BOOKS

- [8] Pankaj A garwal and Manish Srikhade, “**Earthquake Resistant Design of Structures**”, **PHI learning Private** Limited, New Delhi, (2012).

WEBSITES

- [9] www.nptel.ac.in.
- [10] www.wikipedia.com