Analysis of Irregular Building using Response Spectrum Method in ETABS

Jwala S Manoj
PG Student,
Civil Engineering Department
Mangalam College Of Engineering
Ettumanoor, Kottayam, Kerala, India

Richu George Varghese
Assistant Professor,
Civil Engineering Department
Mangalam College Of Engineering
Ettumanoor, Kottayam, Kerala, India

***Abstract*—Irregularity in building is considered in the plan or as well as in the vertical irregularity of the building. In this paper, irregularity is said to be a building which is having irregularity in the plan of the building. Here an irregular building of G+11 is analyzed for the seismic behaviour. A case study of G+11 building resting on normal ground is being done. The analysis is done as per IS 1893-2016, IS 456-2000, IS 875 (part 3)-2015. The analysis and modelling is done by using ETABS 18 software. The seismic analysis is done by using Response Spectrum Analysis method. By this analysis the dynamic response properties like base shear, story deflection, story drift and story shear can be found out.**

Keywords*— Irregularity, Vertical Irregularity, Seismic Behaviour, ETABS 18, Response Spectrum Analysis, Dynamic Response, Base Shear, Story Deflection, Story Drift, Story Shear

I. INTRODUCTION

Earthquake is the sudden vibration of the earth which is caused by naturally or by manual causes. During the construction of building, the structural engineers are aiming to construct strong, seismic resistant and more regular building to avoid failures. But due to many reasons such as unavailability of land, the construction more regular building is not possible. Irregularity in building can be classified into two (as per IS 1893(part 1)-2016, Page 14) namely, Plan Irregularity and Vertical Irregularity.

A. Types of Plan Irregularity

Torsional Irregularity - A building is said to be torsionally irregular, when the maximum horizontal displacement of any floor in the direction of lateral force at one end of the floor is more than 1.5 times its minimum horizontal displacement at the far end of the same floor in that direction or the natural period corresponding to the fundamental torsional mode of oscillation is more than those of the first two translational mode of oscillation along each principal plan direction.

Re-entrant Corners - a building is said to be have a re-entrant corner in any plan direction, when its structural configuration has a projection of size greater than 15 percent of its overall plan in that direction.

Floor slabs having excessive cut-outs or openings – A building is said to have discontinuity in their in-plane stiffness, when floor slabs have cut-outs or openings of area more than 50 % of the full area of the floor slab.

Out-of-Plane Offsets in Vertical Elements – A building is said to have out -of-plane offset in vertical elements, when structural walls or frames are moved out of plane in any storey along the height of the building.

Non-Parallel Lateral Force System – A building is said to have non-parallel system when the vertically oriented structural systems resisting lateral forces are not oriented along the two principal orthogonal axes in plan.

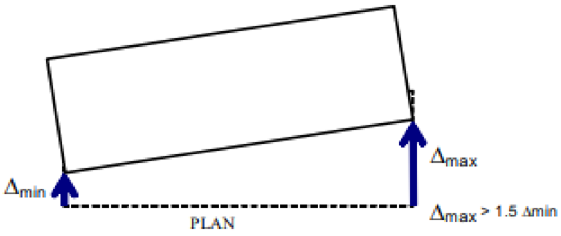

Fig. 1 Torsional Irregularity

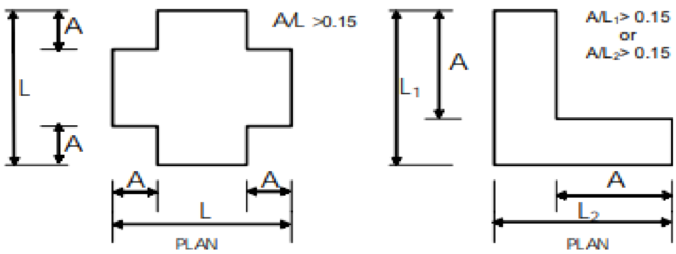

Fig 2. Re-entrant Corners

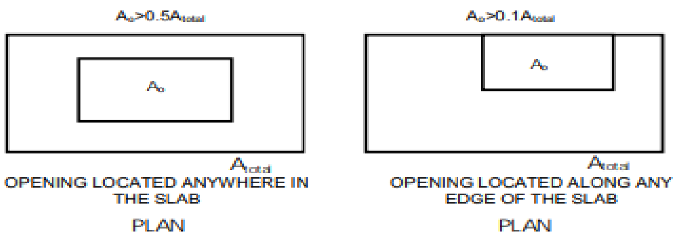

Fig 3. Floor slabs having excessive cut-outs or openings

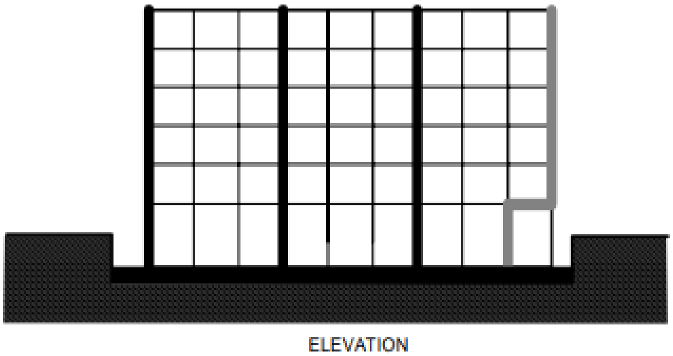

Fig 4. Out-of-Plane Offsets in Vertical Elements

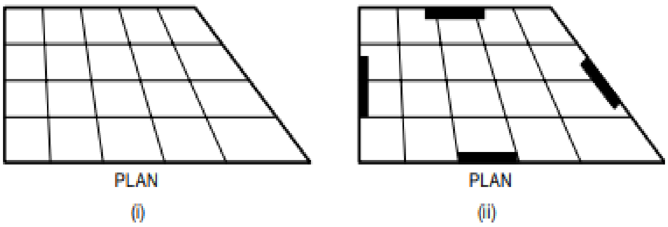

Fig 5. Non-Parallel Lateral Force System

(i) Moment frame building and

(ii) Moment frame building with structural walls

B. *Types of Vertical Irregularity*

Stiffness Irregularity (Soft Storey)- A soft storey is a storey whose lateral stiffness is less than that of the storey above.

Mass Irregularity – Mass irregularity shall be considered to exist, when the seismic weight (as per 7.7) of any floor is more than 150 percent of that of the floors below.

Vertical Geometric Irregularity – When the horizontal dimension of the lateral force resisting system in any storey is more than 125 percent of the storey below.

In-Plane Discontinuity in vertical Elements Resisting Lateral Force – In Plane offset of the lateral force resisting elements is greater than 20 percent of the plan length of those elements.

Strength Irregularity (Weak Storey) – A weak storey is a storey whose lateral strength is less than that of the storey above.

Floating or Stub columns – Such columns are likely to cause concentrated damage in the structure.

Irregular Modes of oscillation in two principal plan directions – Abuilding is said to have lateral storey irregularity in a principal plan direction.

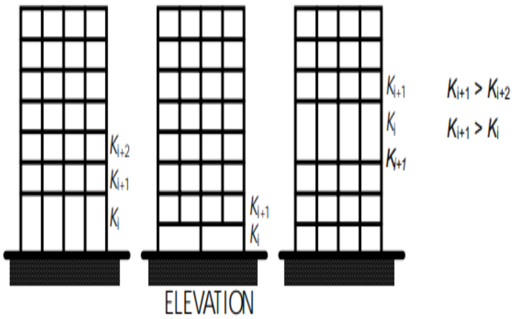

Fig 6. Stiffness Irregularity

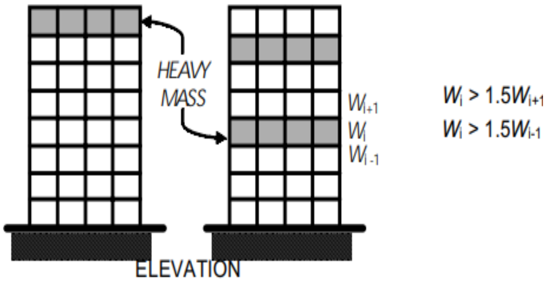

Fig 7. Mass Irregularity

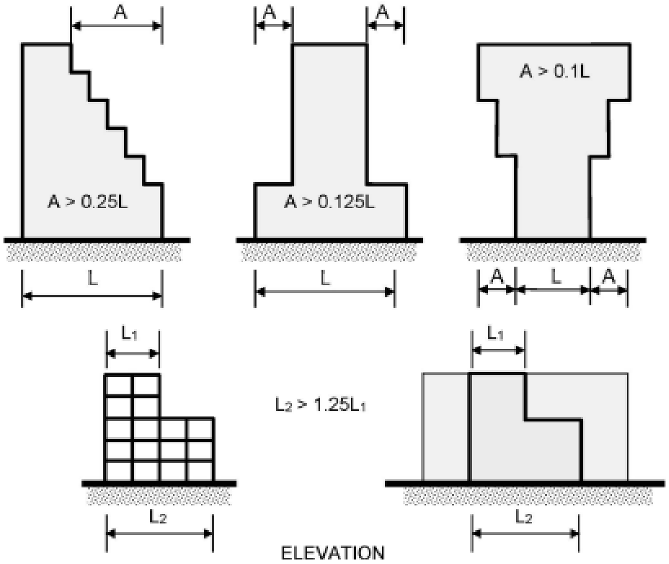

Fig 8. Vertical Geometric Irregularity

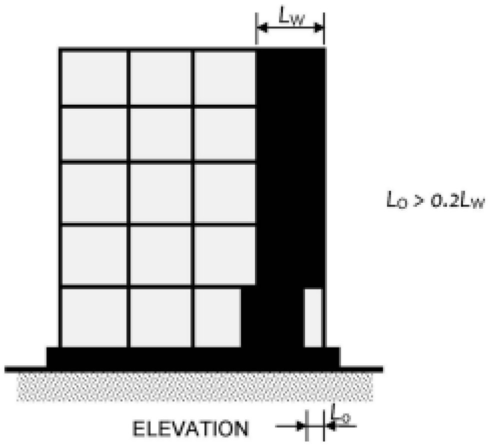

Fig 9. In-Plane Discontinuity in vertical Elements Resisting Lateral Force

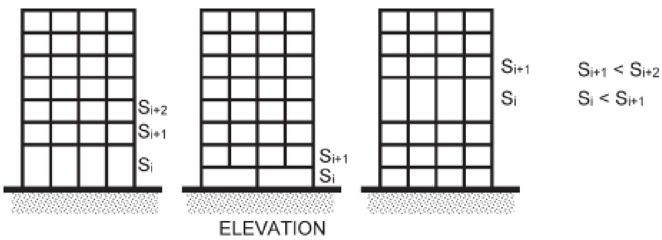

Fig 10. Strength Irregularity

(The above data is taken from IS 1893: 2016 – part 1 for the preparation of the paper).

II. LITERATURE REVIEW

Ravikumar C M et al., (2012) has conducted different seismic analysis approaches using Equivalent static method, Response Spectrum Analysis & Pushover analysis. And seismic analysis of buildings with two types of irregularities in the building models namely plan irregularity with geometric and diaphragm discontinuity and vertical irregularity with a setback type on sloping ground. The performances of all the models except the building models on the sloping ground lies in between the safety of life. It suggested that such buildings resting on sloping ground are more vulnerable to earthquake than the other types of the models.

Rahul Ghosh & Debbarma., (2017) has conducted different seismic analysis approaches using Equivalent static force method, response spectrum method and time history method. The responses have been noted for open ground storeyed setback building and has suggested to relieve soft storey effect by using three techniques. The techniques used are infill wall, reinforced concrete-filled steel tube column (RCFSTC) and shear wall.

Kolasani Rajasekhar & Maganti Janardhana, (2019) has studied the behavior of an RC framed building resting on plain ground and resting on the sloping ground including the effect of infill wall stiffness and compared the dynamic response of buildings resting on sloping ground as well as plain ground.

G Ajay & A.Gouthami, (2019) has conducted the seismic performance of reinforced concrete regular and vertical irregular frame with and without a shear wall on sloping and surface ground with the help of Response spectrum analysis and Time history analysis. They also compared the results obtained by both the approaches to determine the reaction of regular and vertical irregular frame configurations.

Apurva Arjun Gaikwad & Atul B. Pujari., (2019) has carried out Response Spectrum analysis and Time History analysis on Low, Medium, and high rise building on the different types of sloping ground as well as plain ground. And they compared the results in terms of dynamic response in different sloping conditions.

Das et al., (2020) has evaluated the seismic behaviour of various type of irregular structure which is having irredularity in plan and vertical irregularity. A large number of failures have occurred due to the presence of asymmetry and irregularity in structures due to the effect of past earthquakes. This study provide a critical review on the seismic behavior of structures with asymmetry and irregularity conditions of a building.

Anirudh Raajan et al., (2021) has studied the effect of irregularity of mass at every storey for 3 different zones (zone III, zone IV, zone V) and studied the Storey Drift and Storey displacement in different seismic zones at different storey of the building.

Anjeet Singh Chauhan & Rajiv Banerjee., (2021) has studied the structure irregularities which are considered as one of the main fundamentals of the failure of the structure. The structures are having different irregularities such as vertical, mass, stiffness, diaphragm, strength, torsional irregularity, etc. For the analysis of the irregular type of structures, it is very important to carry out dynamic analysis to find out the maximum dynamic response of the building. Hence, it is very difficult to get the time history record for all the places, so, it is appropriate to use Response Spectrum Analysis instead of using dynamic response analysis. The analysis and modeling of the Stepback building are carried out with the help of Etabs software as per IS 1893:2016 to compare the building based on their dynamic response properties like mode Period, Base Shear, Story deflection, Story drift, and story shear and also to evaluate the irregularities of structure on the sloping ground.

From the study of the literatures, it is revealed that many studies have been done on the seismic behaviour of the building. But less studies have been done on the seismic analysis of irregular building using ETABS software.

III. OBJECTIVE OF STUDY

- To understand the seismic behaviour of a G +11 irregular building in a seismic zone V as per IS 1893:2016.
- To study the sturtural behaviour of the building under seismic loads.
- To study the Response Spectrum Analysis of the irregular building using ETABS software.
- To find out the seismic responses such as base shear, storey displacement, storey drift and storey shear of the irregular building.

IV. SCOPE OF STUDY

This paper is focused on the seismic analysis of an irregular building which of G+11. The seismic analysis is done by using Response Spectrum Analysis method of dynamic analysis. This analysis is done in ETABS-18 software. All the loads and conditions are taken as per IS 1893:2016. In this irregular building mostly plan irregularity is being considered. The entire modelling, analysis and design are carried out using ETABS software itself. The plan of the irregular building is drawn in AutoCAD software and the imported to the ETABS software.

V. A CASE STUDY

In this case study a G+11 irregular building is being modelled and analysed using the ETABS software. The plan of the irregular building is drawn in AutoCAD software and the imported to the ETABS software. In this paper, irregularity is mainly considered in the plan irregularity of the structure. The seismic analysis is carried out by Response Spectrum Analysis method.

The Geometric Properties of the irregular building being analysed is given in the table below:

Table 1. Geometric Properties

Sl.No.	Parameter	Values
1	Building Type & Dimension	Commercial & (20 m x 40 m)
2	Length in the X direction	20 m
3	Length in the Y direction	40 m
4	No. of bays in X direction @ 5m each	4
5	No. of bays in Y direction @ 5m	8

	each	
6	Depth of Slab	150 mm
7	Size of Column	450 mm x 700 mm
8	Size of Beam	300 mm x 400 mm
9	Height of Floor	3.6 m
10	No. of Storey	G+11
11	Loads types	As per IS 875 Part-1 & 2
12	Dead Load	Self-weight
13	Roof Live Load	1.5 KN/m² (Clause 4.1, Table 2)
14	Floor Live Load	3 KN/m²
15	Material Property	As Per IS 456:2000
16	Grade of Concrete	M 30
17	Grade of Rebar	Fe 415
18	Concrete Density	25 KN/m³
19	Seismic Parameter	As per IS 1893 (Part-1):2016
20	Zone	V (Table No. 2)
21	Zone factor (Z)	0.36 (Clause 6.4.2, Table 3)
22	Importance Factor (I)	1.2 (Clause 7.2.3, Table 8)
23	Soil type	Type II (stiff Soil)
24	Response Reduction Factor (R)	5 (SMRF) (Clause 7.2.6, Table 9)
25	Damping Ratio	5% (Clause 7.2.4)
26	Earthquake Load	As per IS 1893 (part-1):2016

A. Modelling of the building

The modelling of a G+11 irregular building is being done using the ETABS software. The geometrical properties of the irregular building being analysed is given in the above table of Table 1. The structural material under consideration is to be isotropic and homogenous. The joint between the irregular building elements is considered by using a diaphragm as constraints. The Response Spectrum Analysis has been carried out for fixed base.

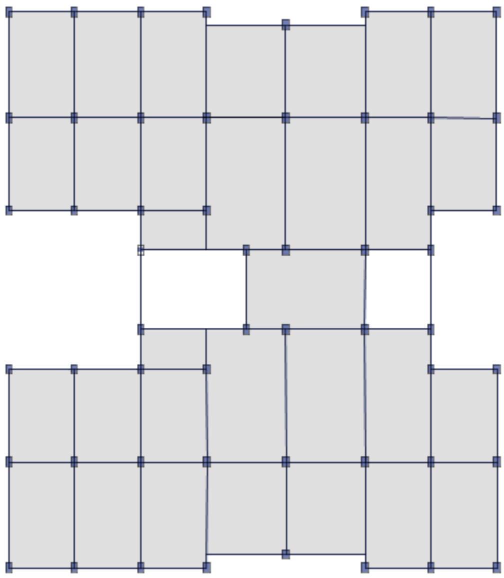

Fig 11. Plan View of the irregular building being analysed

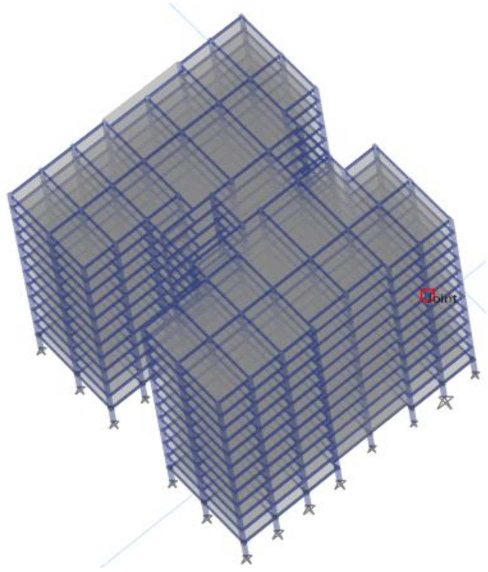

Fig 12. Modelling of the G+11 building

B. Response Spectrum Analysis

The analysis of the structure can be done using two methods: Response Spectrum and Time History Methods (as per IS 1893:2016). In this study, Response Spectrum method is being used for the analysis. This method consists of obtaining the total response of the building by superimposing the response in various modes. The important parameters used for the analysis are Seismic zone V, zone factor-0.36, importance factor-1.2, damping ratio-0.05, response reduction factor-5.

VI. Results And Discussion

An irregular building of G+11 has been analyzed for seismic load with irregularities. The seismic load was applied in X and Y directions. The response spectrum analysis results has been discussed in the below sections.

A. Reponse Spectrum in X-direction

The dynamic response of the irregular building for story shear, storey displacement and storey drift are analysed here. The storey shear, storey displacement and storey drift in X-direction is being analysed below:

1. Story shear in X-direction
   After dynamic analysis story shear has been evaluated using ETABS.

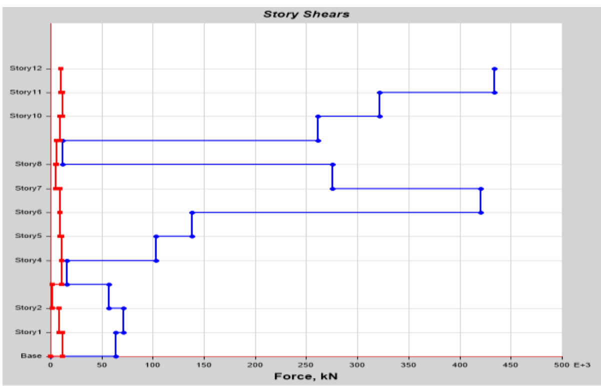

Fig 12. Story shear in X-direction

The maximum storey shear value is obtained at storey 11 and value is 433417 kN.

2. Storey Displacement in X-direction

The storey displacement has been evaluated using this analysis. The maximum storey dispalcement is obtained at storey 12 and the value is 3.789E+19 mm.

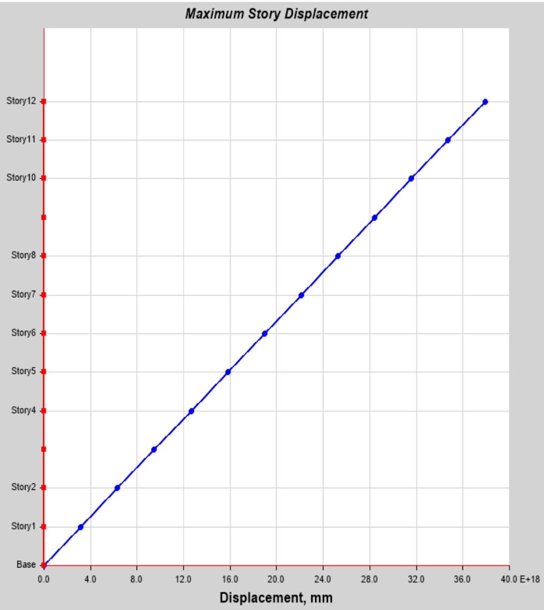

Fig 13. Storey Displacement in X-direction

3. Storey drift in X-direction

Storey drift is the relative displacement between floors above or below the storey considered. It is being calculated using ETABS software. In the X-direction, the maximum value obtained is 8.772E+14 at storey 12.

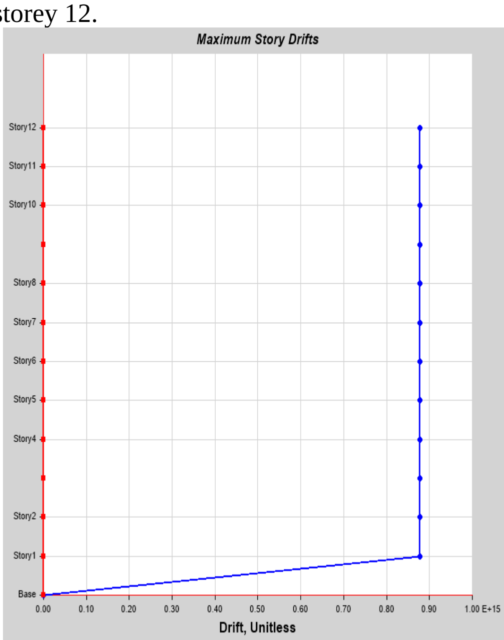

Fig 14. Storey drift in X-direction

B. *Reponse Spectrum in Y-direction*

The dynamic response of the irregular building for story shear, storey displacement and storey drift are analysed here. The storey shear, storey displacement and storey drift in Y-direction is being analysed below:

1. Story shear in Y-direction

After dynamic analysis story shear has been evaluated using ETABS. The maximum storey shear value is obtained at storey 7 and value is 203509 kN.

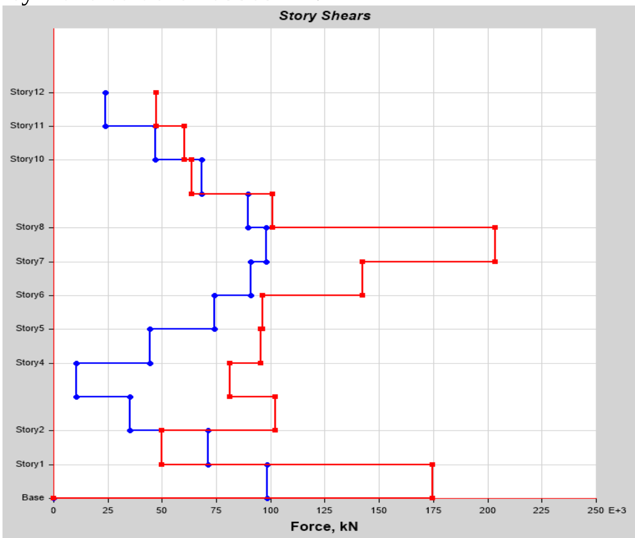

Fig 15. Story shear in Y-direction

2. Storey Displacement in Y-direction

The storey displacement has been evaluated using this analysis. The maximum storey dispalcement is obtained at storey 12 and the value is 1.491E+16 mm.

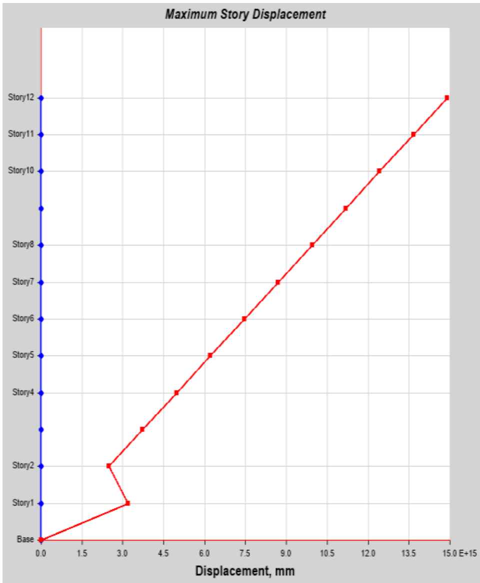

Fig 16. Storey Displacement in Y-direction

3. Storey drift in Y-direction

Storey drift is the relative displacement between floors above or below the storey considered. It is being calculated using ETABS software. In the Y-direction, the maximum value obtained is 8.878E+11 at storey 1.

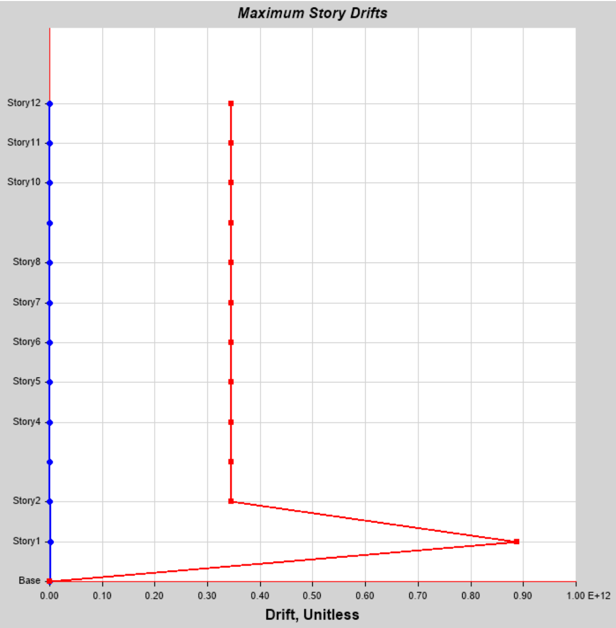

Fig 17. Storey drift in Y-direction

VII. CONCLUSIONS

- According to Eurocode-8, the maximum allowable displacement is calculated as:

  H/250

  Where H is the height of the storey above ground level.

  From the above calculation the maximum allowable displacement obtained is 0.1872 mm, which within the limit. Hence, the irregular building analysed is safe against storey displacement.
- As per IS 1893:2016(part1) (Cl-7.11.1), Storey drift in any case shall not exceed 0.004 times of storey height which is equal to the value 0.1872, which is within the limit of the value obtained. Therefore the building is safe against the storey drift.

The above points show that the irregular building of G+11 analysed in this study is safe against the seismic behaviour and under the conditions applied.

ACKNOWLEDGMENT

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