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Linear and Nonlinear static analysis of G+11 RCC building using Etab software

[1]Ashish R. Kondekar, [2]Rutuja A. Deshpande, [3]Aishwarya Y. Mohite Patil, [4]Trupti Y. Pawar, [5]Sakshi G. Kanawade

[1]Assistant Professor, [2,3,4,5]Student

Department of Civil Engineering,

Sinhgad Institute of Technology and Science, Narhe, Pune-411041, India- 411041

Abstract

The paper deals with the performance of the RC frame structure to calculate the performance capacity of the RC frame. The existing rectangular-shaped RC structural frame is modeled in ETAB's software by considering dead load using IS 875: 1964 (Part-1) live load using IS 875:1964 (Part-2) and earthquake load using IS 1398:2002. The various combinations of loads were created using IS-456 and IS-1398. The frame performance is evaluated on the parameters like Bending moment, Shear force, axial force, and story drift for static elastic and inelastic conditions using ETAB respectively. The building is constructed in Ahmedabad and hence as per the IS, 1893:2002 seismic zone III and soft soil is considered for the performance analysis. The performance comparison of static elastic (Linear) and inelastic static performance (Non-Linear) is made in this research paper. The ETABS models of Linear and Nonlinear static system which is G+11 story, are considered for design & analysis. The results are compared and summarized based on different parameters like lateral story displacement, base shear, stored drift, time period, and shear lag. The present study aims to compare the performance of high-rise structures with Linear and Nonlinear static systems against gravity and lateral loading. Both systems are designed by using Indian standard codes and Special Publication of Handbooks by the Bureau of Indian Standards. We Analise and design dimensions of slab, beam, and column so that all are adequate. When we were doing linear and Nonlinear analysis, it was found that plastic hinges form in the safe zone. The pushover curves resulted strongly affected by the assumed lateral load distribution. The modal shape provided the best agreement with the average results of the Static analyses.

***Keywords* – Pushover, Seismic analysis, Linear static analysis, Nonlinear static analysis**

I. INTRODUCTION

In the past decade, strong earthquakes have occurred all over the world and caused the great economic loss. For instance, the Wenchuan earthquake of China in 2008 caused approximately 138.33 billion USD losses; the Tohoku earthquake of Japan in 2011 led to about 30 billion USD losses; the Nepal earthquake in 2015 induced 6 billion USD losses, and so on. Therefore, resilient cities and buildings under earthquakes have gradually become an important research focus in recent years. Resilience is firstly defined by Sustainability Committed which refers to the ability to suffer less damage and recover rapidly from adverse events. Specifically, buildings should be appropriately designed, so that the major functionality of buildings can be maintained and structure can be easily and rapidly repaired in a short time after severe earthquakes. However, the current earthquake design codes IS1893:1962(part I) and IS4326:1993(5th Revision) generally adopt the force-based seismic design strategy to prevent the structure from collapsing, while the resilience and sustainability of the structures are still not well considered. In strong earthquakes, plastic deformation and elastic behavior of structures are usually designed to dissipate seismic energy which would inevitably lead to an extensive response, permanent residual drift, and structural damage. In general, structural components that dissipate seismic energy are also part of the gravity-resisting system in most situations, so the repair or replacement of seismic force-resisting components after a strong earthquake is usually difficult and not viable. The damaged structural components sometimes have to be demolished even though they only suffer small or moderate damage. Hence the research and development of the earthquake-resistant structural system are now at the forefront of structural and earthquake engineering.

There are different methods of analysis that provide different degrees of accuracy. The analysis process can be categorized based on 3 factors: -The type of the externally applied load, the behavior of structure/ structural material, and the type of structural mode selected. Based on the type of external action and behavior of the structure, the analysis can be further classified as Linear static analysis, Linear dynamic analysis, non-linear static analysis, or non-linear dynamic analysis. Linear static analysis or equivalent static analysis can only be used for regular structures with limited height. 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 a higher mode of vibration and the actual distribution of forces in the elastic range in a better way. They represent an improvement over linear static analysis. The significant difference between linear static and dynamic analysis is the level of force and its distribution along with the height of the structure. Non-linear static analysis is an improvement over the linear static and dynamic analysis in the sense that it allows the inelastic behavior of the structure. The method still assumes a set of static incremental lateral loads over the height of the structure. The method is relatively simple to implement and provides information on the strength, deformation, and ductility of the structure and the distribution of demands. This permits the identification of the critical members likely to reach a limit state during the earthquake, to which attention should be given during the design and detailing process. But this method contains many limited assumptions, which neglect the variation of loading patterns, the influence of higher modes, and the effect of resonance.

II. LITERATURE REVIEW AND SUMMARY

In this literature review, the publishers discussed the different PBPD structural system and their uses, but we studied these papers from our perspective to study the detailed concept of linear static and Non-linear static design methods. Papers give an idea about the methodology and design consideration for modeling and analyzing structures in ETABS and parameters which need to consider to compare the results of the analysis.

III. METHODOLOGY

For the study of Linear and Non-linear static analysis create models for these two structural analyses using ETABS software. For modeling Reinforced concrete structure having a G+11 story, the structure is considered with Gravity loads as per IS 875 (Part I) and (Part II) and Seismic loads as per IS 1893:2016. The floor height is kept constant at 3.5m and the size of the slab, column and beams are 150mm, 400*400 mm, and 300*550 mm respectively. The grade of concrete used is M30 and HYSD 500 Steel Rebar. After creating models for both the analysis models are analyzed for Static i.e., Equivalent static analysis and pushover analysis and results are compared with different parameters like Storey drift, Base shear, lateral story displacement, vertical displacement, etc. The conclusion and summary of the project are made from the comparison of the results of the models.

Type of Linear static analysis

1. Capacity based method -
2. Equivalent static method
3. Displacement based method
4. Energy-based method

Static analysis method steps:

1. Calculate seismic weight (W)
2. Determination of fundamental natural period (Ta)
3. Determine the Horizontal earthquake coefficient (Ah)
4. Determine Design base shear (Vb)
5. Vertical distribution of base shear (Qi)
6. Distribution of lateral forces to different lateral for eccentricity element.
7. Apply their lateral force along with their force and calculate response in the etc.

Gravity Load –

The simple structure in the above picture can be used to demonstrate how gravity loads move from the top of a structure to the ground.

1. A floor slab is designed to support the imposed gravity load.
2. This load travels from the floor slab to the beams that support it.
3. Upon reaching the beam, the load travels to the end of a beam, which is connected to a girder.
4. This girder is supporting the accumulated loads from the floor slab and beams and transmits the load to a connecting column.
5. The load then travels down the column to the foundation and is distributed to the ground.

Diaphragm

It is a horizontal or nearly horizontal system, which transmits lateral forces to the vertical resisting elements, for example, reinforced concrete floors and horizontal bracing systems.

Centre of mass

The point through which the resultant of the masses of a system acts. This point corresponds to the center of gravity of the masses of the system.

Centre of Stiffness

point through which the resultant the restoring forces of a system act or economic importance

(cl.no.6.4.2/table6/pg.no.18).

R = Response reduction factor depending on the perceived seismic damage performance of the structure characterized by ductile or brittle deformations which are shown in Table 3.2 **(IS456:2000, cl.no.6.4.2, Table7, pg.no.23).**

Sa/g = Average response acceleration coefficient.

The value of Sa/g is obtained from fig.3.3 from IS: 1893 (Part 1): 2016.

Seismic Base Shear

According to IS 1893 (Part-I): 2016, Clause 7.5.3 the total design lateral force or design seismic base shear (VB) along any principal direction is determined by

VB=Ah*W

Where,

Ah is the design horizontal acceleration spectrum

W is the seismic weight of the building

Design Horizontal Acceleration Spectrum Value

To determine the design of seismic forces, the country (India) is classified into four seismic zones (II, III, IV, and V). Previously, there were five zones, of which Zone I and II are merged into Zone II in the fifth revision the of code. According to IS 1893: 2016 (Part 1), Clause6.4.2 Design Horizontal Seismic Forces Coefficient Ah for a structure shall be determined by the following expression:

A_h = (z/2) *(I/R) *(sa/2g)

Where,

Z = Zone factor seismic intensity

R = Response reduction factor

I = Importance factor

Response spectrum factor:

Response spectrum analysis is a method to estimate the structural response to short, nondeterministic, transient dynamic events. Examples of such events are earthquakes and shocks. Since the exact time history of the load is not known, it is difficult to perform a time-dependent analysis.

I = Importance factor is used to obtain the design seismic force depending on the functional use of the structure, characterized by hazardous consequences of its failure, its post-Earthquake functional need, historic value, or economic importance **(cl.no.6.4.2/table6/pg.no.18).**

R = Response reduction factor depending on the perceived seismic damage performance of the structure characterized by ductile or brittle deformations which are shown in Table 3.2 **(cl.no.6.4.2/Table7/pg.no.23).**

Sa/g = Average response acceleration coefficient (dimensionless value). The value of Sa/g is obtained from fig.3.3 from IS: 1893 (Part 1): 2016.

Seismic Weight:

The seismic weight of the whole building is the sum of the seismic weights of all the floors. The seismic weight of each floor is its full dead load plus the appropriate amount of imposed load, the latter being that part of the imposed loads that may reasonably be expected to be attached to the structure at the time of earthquake shaking. It includes the weight of permanent and movable partitions, permanent equipment, a part of the live load, etc. While computing the seismic weight of each floor, the weight of columns and walls in any story should be equally distributed to the floors above and below the story, and any weight supported in between stories should be distributed to the floors above and below in inverse proportion to its distance from the floor.

Seismic Weight = Full dead load + partial live load

Nonlinear static analysis -

A nonlinear analysis is an analysis where a nonlinear relation holds between applied forces and displacements. This is opposed to the linear static analysis, where the stiffness matrix remained constant. nonlinear static analysis is required for any static application in which the stiffness of the entire structure changes during the loading scenario. The simulation must be solved incrementally to account for the stiffness changes. Physical contacts allow stress transfer between structural components options including ANSYS, PERFORM-3D, SAP/ETABS, Staad-Pro, Open SEES, other programs like State DOT Bridge Software, Oasys/LS DYNA, GTStrudl, NASTRAN, and in-house software.

Types of Nonlinear static analysis methods: -

1. Pushover Analysis method
2. Geometric nonlinearities
3. Material nonlinearities
4. Contact nonlinearities

Pushover method

1) Pushover analysis is a static procedure that uses a simplified nonlinear technique to estimate seismic structural deformation.
2) PA is a nonlinear analysis procedure to estimate the strength capacity of a structure beyond its limit state up to its ultimate strength
3) It can help demonstrate how progressive failure in a building most probably occurs and identify the mode of final failure.
4) The method also predicts potential weak areas in the structure, by keeping track of the sequence of damages of every member in the structure.

As per IS1893-1:2016 Clause 7.7, the design base shear (VB) is distributed along the

3.3.7 Code Provisions: -

1. Code of practice for plain and reinforced concrete IS456:2000
2. Dead loads: - IS 875:1987 (Part-I)
3. Imposed loads: - IS 875:1987 (Part-II)
4. Seismic loads: - IS 1893:2016 (Part-I)
5. Ductile detailing: - IS 13920:2016

3.4 Types of Analysis

1) Static Equivalent Analysis (Linear Static Analysis)
2) Push Over Analysis (Non-linear Static Analysis)
3) Response Spectrum (Linear Dynamic Analysis)
4) Time History Analysis (Non-dynamic Analysis)

3.5 Load Case and Load Combination

All load cases and load combinations considered are as per the IS codes and listed below:

Load cases

1) DL: Dead load
2) LL: Live load
3) EQ: Earthquake load

degree of freedom system is expressed as the superposition of modal response, each modal response being determined from the spectral analysis of a single degree of freedom system, which is then combined to compare the total response. Modal analysis of the response history of structure to specified ground motion; however, the method is usually used in conjunction with a response spectrum.

Table no. 3.3 Parameters

Sr. No.	Parameters	Values
1	Grade Of Concrete	M 30
2	Grade Of Steel	Fe 500
3	Modulus of Elasticity of Steel	210 GPA
4	Modulus of Elasticity of Concrete	27000 MPA {as per IS 456:200, Cl.No.6.2.31}
5	Size Of Beam	350*600 mm
6	Size Of Column	600*600 mm
7	Thickness Of Slab	150 mm
8	Number Of Storey	G+11
9	Height Of Storey	3 .5m
10	Density Of Concrete	25kN/m^3
11	Location	Ahmedabad
12	Seismic Zone	III
13	Importance Factor	1
14	Response Reduction Factor	5 {SMRF}
15	Damping	5%
16	Site Condition	II
17	Seismic Zone Factor	0.16 (IS 1893:2016, Cl. No6.4.2)
18	Diaphragm	Rigid
19	Maximum Storey Displacement	H/500
20	Storey Drift Limitation	0.004h

Parameters to Comparison

a) Base shear
b) Lateral story displacement
c) Plastic hinges

ETABS

ETABS is an engineering software product that creates multi-story building analysis and design. Modeling tools and templates, code-based load prescriptions, analysis methods, and solution techniques, all coordinate with the grid-like geometry unique to this class of structure ETABS is the ultimate integrated software package for the structural analysis and design of buildings.

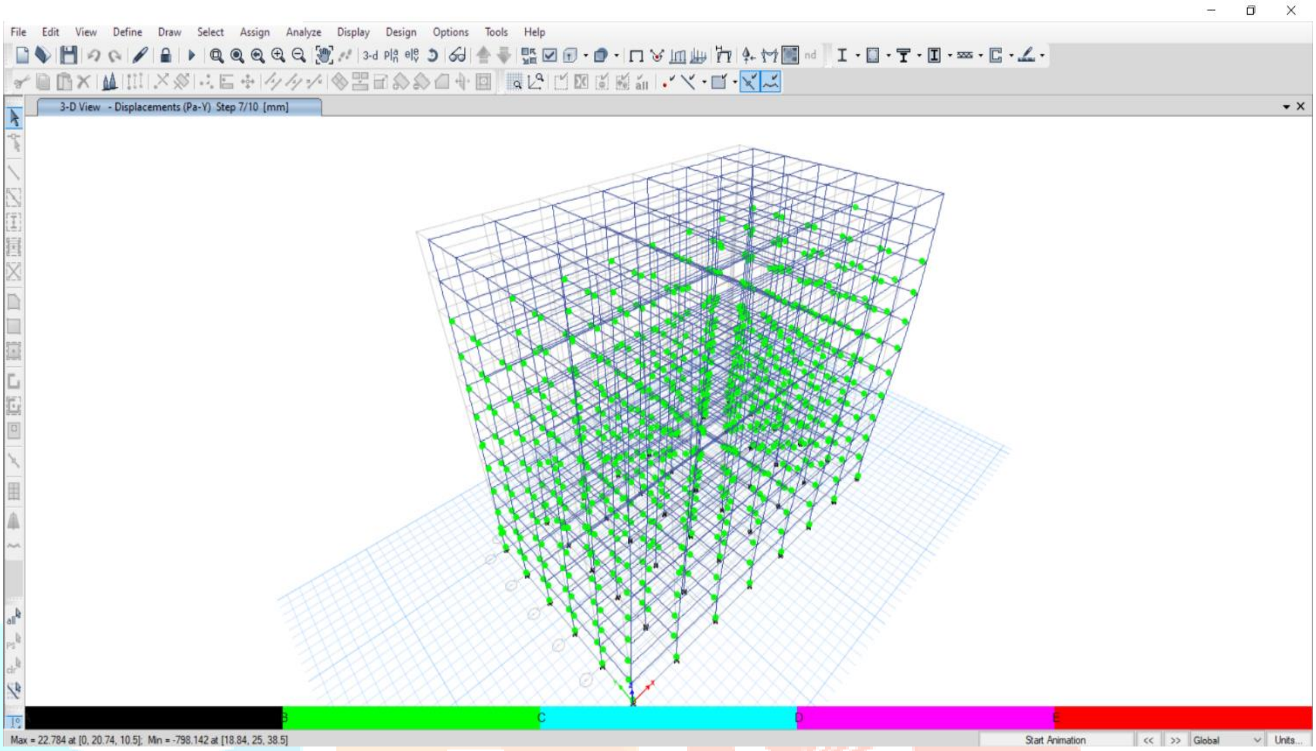
From the start of design conception through the production of schematic drawings, ETABS integrates every aspect of the engineering design process. ETABS offers advanced finite element analysis and designing tools for structural engineers. CAD drawings can be converted directly into ETABS models.

HINGE

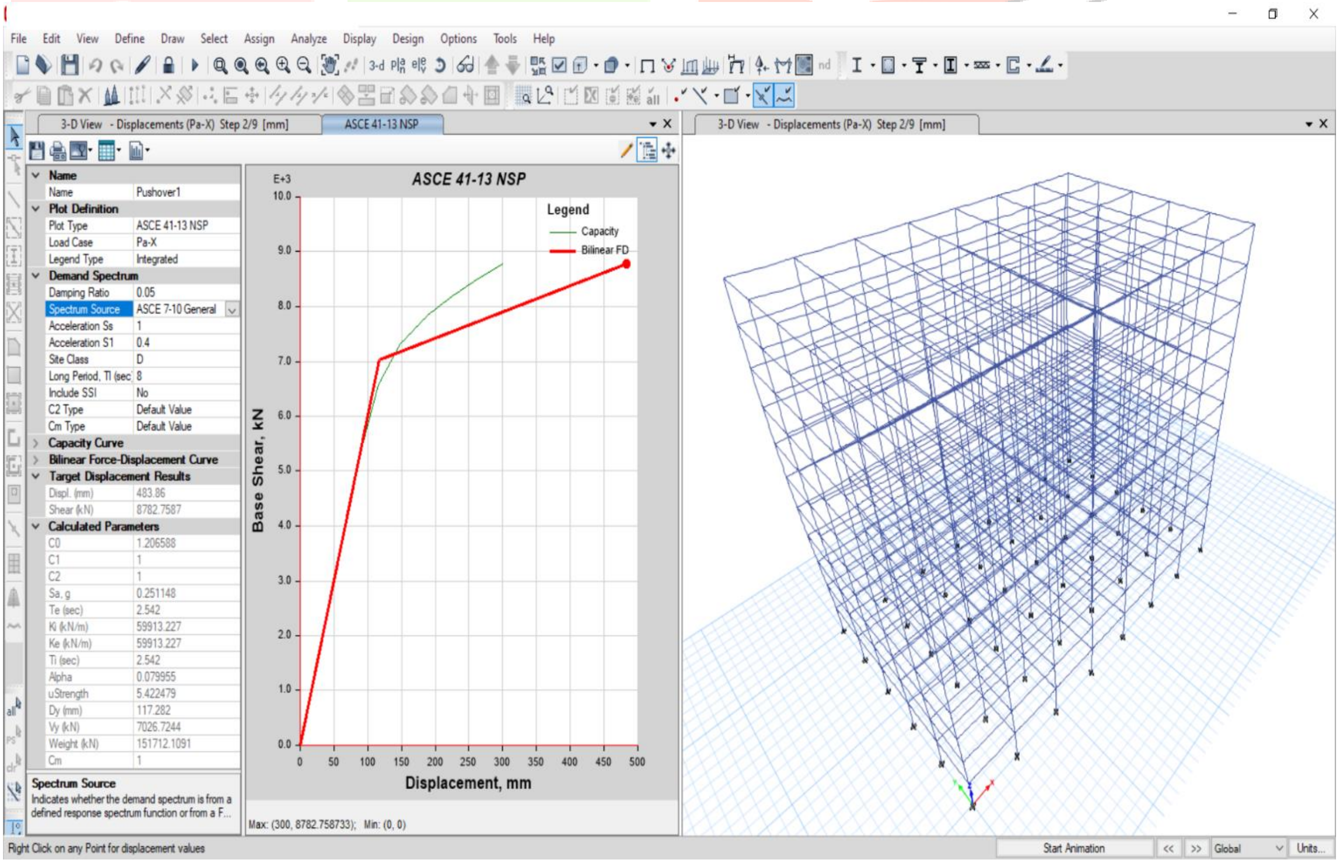
The point of elastic action of the structure member is called a plastic hinge. In this state structural member starts losing strength to come back to their previous position. We assign hinge-s to the model for observing the structural behavior of sequential loss of strength in the different performance levels of the structure due to seismic effect.

IV. RESULTS AND DISCUSSION

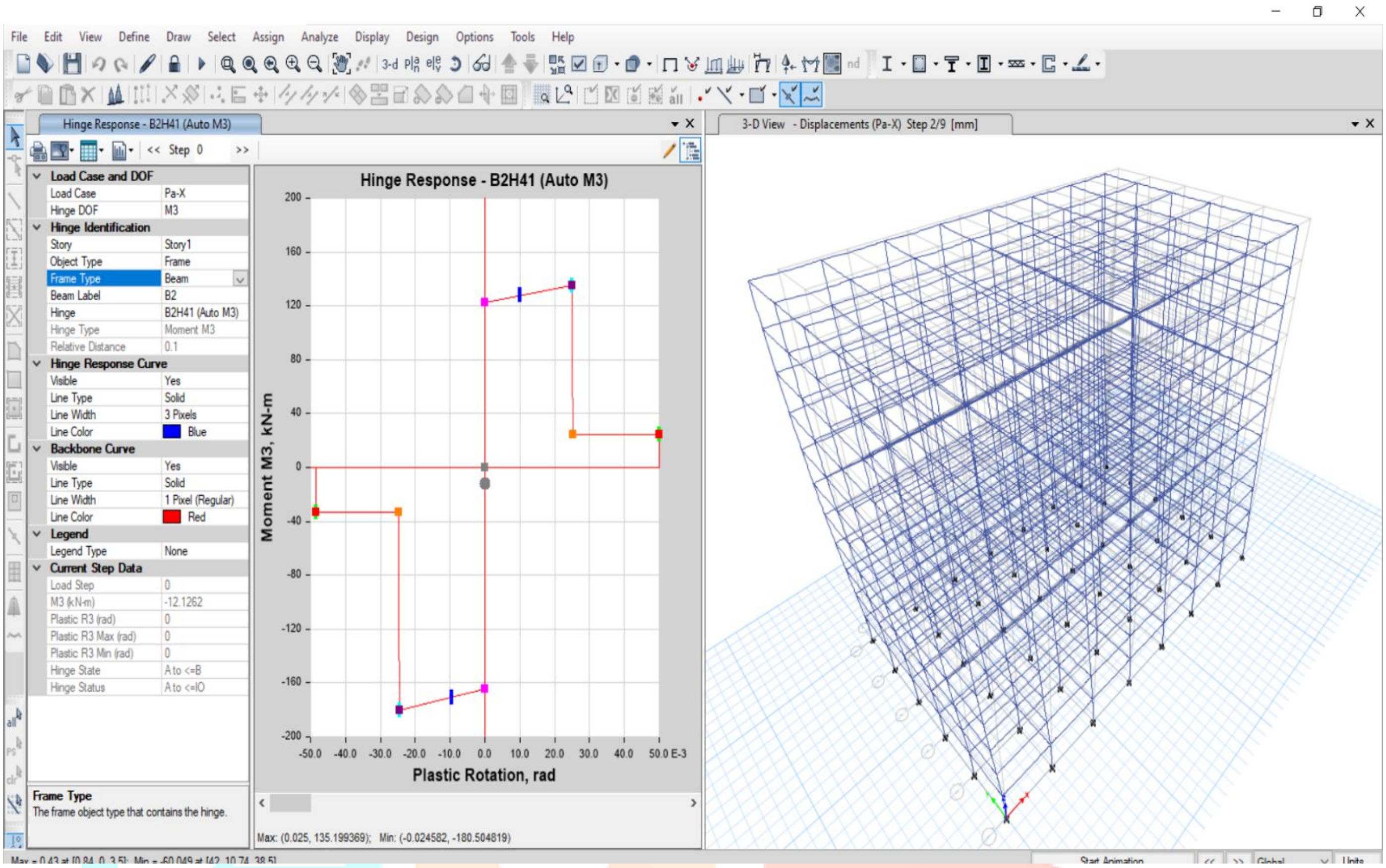
The next step is to review the hinge formation at the performance point. One can see the individual stage of each hinge at its location. The decision depends on whether the most severely yielded hinge is formed in the beams or the column, whether they are concentrated in a particular story denoting soft story, and so on. After running analysis see deform the shape of push along X direction & Y Direction and observer what hinge are forming and here our design structure starts to fail. Display pushover curve-1st Base shear vs Displacement see how the base shear drops as the hinges form and reach the different stages. Plot ATC 40 Capacity spectrum> Capacity Curve in green>and demand curve in blue.



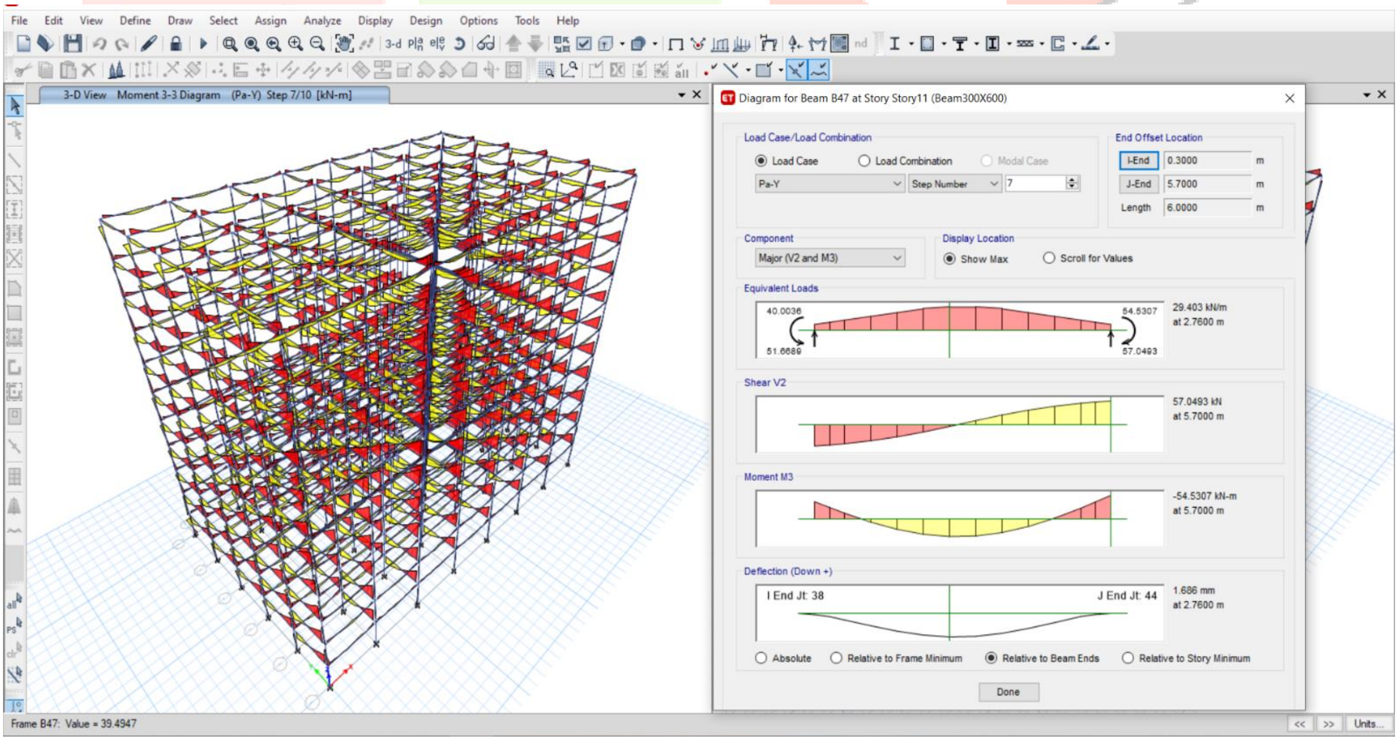
Graph No.1 Plastic Hinges formation



Graph No.2 Base Shear v/s Displacement curve



Graph No.3 Plastic Hinges curve



Graph No.4 Shear forces & BM

CONCLUSION

1. We Analise and design dimensions of slab, beam, and column that all are adequate.
2. When we were doing linear and Nonlinear analysis, it was found that plastic hinges form in the safe zone.
3. The pushover curves resulted strongly affected by the assumed lateral load distribution. The modal shape provided the best agreement with the average results of the Static analyses.

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WEBOLOGY

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4. **Web 4https://images.app.goo.gl/5QhhhUpb5Bu8L1rv5**
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6. **Web 6https://images.app.goo.gl/mxixud7C7vLZv4ds8**