WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Nonlinear Pushover Analysis of Multi-Storied Structure Using ETABS Software

***Renuka Nageswari Bagu* [a], *Sai Ganesh Sanagapalli* [b]**

[a,b]*Aditya Engineering College, Suramapalem, 533437, Inida*

DOI: https://doi.org/10.55248/gengpi.4.423.37763

A B S T R A C T

The nonlinear pushover analysis is a widely used method for assessing the seismic performance of structures. The nonlinear pushover analysis of a multistory structure using ETABS software is presented in this paper. The aim of the study is to evaluate the seismic behavior and capacity of the structure under lateral loads. The study involves modelling the multi-storied structure (G+7) using ETABS software and subjecting it to lateral loads. The pushover analysis is performed using a nonlinear static procedure, where the structure is subjected to increasing lateral loads until failure or collapse. The results obtained from the pushover analysis are then used to evaluate the seismic performance of the structure and identify any potential weaknesses or deficiencies. The study also involves a sensitivity analysis to investigate the effects of different parameters on the structural behavior and capacity. The parameters considered in the analysis include the storey displacement, storey shear, and the storey drift along the height of the structure. The study provides valuable insights into the seismic performance of multistoried structures and highlights the importance of considering nonlinear behavior in the analysis and design of such structures. The results obtained from this study can be used to inform the design of more resilient and robust structures that can better withstand seismic events.

Keywords: Transmission line tower, robustness analysis, seismic force, pushover analysis.

Main text

During an earthquake, the ground motion causes the building to undergo dynamic loading, which can cause structural components to experience high stresses and strains. In a multi-storied building, the impact can be significant due to the complex interplay between the different levels and structural systems. This can lead to progressive damage, resulting in the failure of the building. The seismic response of multi-storied structures depends on the building's characteristics, such as the height, geometry, stiffness, and strength. The taller the building, the more susceptible it is to seismic forces due to its increased height and mass. Additionally, the structural system of the building can affect its seismic performance. Buildings designed with modern seismic-resistant structural systems, such as moment-resisting frames and shear walls, are more likely to withstand seismic forces than older buildings that may not have been designed to resist earthquakes. ETABS software is a popular tool used for nonlinear pushover analysis. It offers a user-friendly interface and powerful capabilities for modeling and analyzing structures under seismic loading. This software is widely used in the design and analysis of multi-storied buildings and has become an industry-standard for seismic analysis.

The soil conditions at the site can also affect the seismic response of a multi-storied structure. The characteristics of the soil, such as its stiffness, damping, and resonance frequency, can affect the seismic waves propagation and amplification, causing additional stress on the building. In conclusion, earthquakes can have a significant impact on multi-storied structures. The seismic response of a building depends on several factors, including the intensity and duration of the ground motion, the characteristics of the building, and the soil conditions at the site. It is essential to consider these factors in the design and construction of seismic-resistant buildings to ensure their safety and resilience in the event of an earthquake.

Nomenclature

ASCE 41: American Society of Civil Engineers code for Seismic Rehabilitation of Existing Buildings.

FEMA 356: Federal Emergency Management Agency's Prestandard and Commentary for the Seismic Rehabilitation of Buildings.

Capacity Curve: Graphical representation of the relationship between the lateral load and the displacement at a certain level of a structure.

Plastic Hinge: A section of a member where plastic deformation occurs during a seismic event.

Performance Point: The point on the capacity curve corresponding to the target performance level for the structure.

Drift Ratio: The ratio of the lateral displacement of a structure to its height.

Damping Ratio: The ratio of the damping of a structure to its critical damping.

Yield Strength: The stress at which a material begins to deform plastically.

Reduction Factor: A factor applied to the elastic lateral force to obtain the ultimate force in the pushover analysis.

Base Shear: The total lateral force at the base of the structure.

1.1 Structure

Nonlinear pushover analysis is an effective tool for assessing the seismic performance of multistoried structures. ETABS software is a widely used software for conducting nonlinear pushover analysis. To create a model in ETABS, the first step is to define the material properties for the structure, including concrete, steel, and masonry. Next, the geometry of the structure is created by defining columns, beams, slabs, walls, and other elements. Section properties, such as cross-sectional area, moment of inertia, and section modulus, are assigned to each element. The supports, including fixed, pinned, and roller supports, are defined at the base of the structure. Loads, such as gravity, lateral, and seismic loads, are then applied to the structure.

The nonlinear analysis settings are defined for the pushover analysis, including the number of steps, damping ratio, load cases, and target displacement or performance level. The pushover analysis is then run, and capacity curves and performance points for the structure are obtained. The results of the pushover analysis are evaluated by analyzing the deformation and plastic hinge distribution and comparing them with the desired performance level and code requirements. Based on the results, the structure is designed to meet the desired performance level. Any necessary modifications to the structural elements or design parameters are made to ensure the safety and stability of the structure during a seismic event.

1.2 Construction of references

- Define the geometry, materials, and loads of the multistoried structure to be analyzed, according to the relevant building codes and design standards.
- Create a finite element model of the structure in ETABS software, using the appropriate element types, mesh density, and boundary conditions.
- Assign the material properties to the different structural components, such as concrete, steel, masonry, or timber, based on the material test data and design specifications.
- Apply the gravity loads, such as dead load and live load, to the structure, and verify the model's static equilibrium and deformation compatibility.
- Define the seismic hazard level and ground motion parameters of the site, using the seismic hazard maps and response spectra available from the local or national seismic code.
- Assign the lateral load pattern to the structure, using the equivalent lateral force method, modal response spectrum method, or other applicable methods, based on the seismic hazard level and soil conditions.
- Perform the nonlinear pushover analysis of the structure, using the displacement-based approach, which involves incrementally increasing the lateral load and recording the corresponding displacement and internal forces at each level.
- Calculate the nonlinear pushover curve of the structure, which shows the relationship between the base shear and roof displacement, and identify the yield strength and ultimate capacity of the critical structural elements, such as beams and columns.
- Check the seismic demand and capacity of the structure, using the performance-based design criteria, which specify the target displacement ductility, inter-story drift limits, and other performance objectives.
- Evaluate the sensitivity of the analysis results to the different model parameters, such as material properties, load combinations, damping ratio, and numerical methods, and verify the robustness and accuracy of the analysis.
- Compare the nonlinear pushover analysis results with the results of other analysis methods, such as linear elastic analysis, response spectrum analysis, or time history analysis, and identify the differences and similarities in the predicted seismic demand and capacity of the structure.
- Use the analysis results to optimize the structural design, such as selecting the appropriate structural system, dimensioning the structural elements, and improving the seismic resistance of the structure.
- Document the analysis procedure, assumptions, and results in a technical report, and communicate the findings to the relevant stakeholders, such as the design team, the client, and the regulatory authorities.

1.3 Section heading

1. Introduction-

Background and motivation for the study

Literature review of previous research on pushover analysis and ETABS software

2. Methodology of Nonlinear Pushover Analysis-Overview of the displacement-based pushover analysis method

Selection of lateral load pattern and seismic hazard level

Modeling of structural components and material properties

Application of gravity loads and boundary conditions

Incremental lateral load application and response recording

Calculation of nonlinear pushover curve and capacity spectrum

Performance-based design criteria and evaluation of seismic demand and capacity

3. Case Studies and Applications-

Description of the multistoried structures analyzed using ETABS software

Results of nonlinear pushover analysis, including the pushover curve, capacity spectrum, and critical elements

Comparison of the results with other analysis methods and design criteria

Sensitivity analysis of the model parameters and assumptions

Optimization of the structural design based on the analysis results

4. Discussion and Conclusions

Summary of the key findings and contributions of the study

Limitations and challenges of the nonlinear pushover analysis method and ETABS software

Recommendations for future research and applications

Implications for the seismic design and risk assessment of multistoried structures

1.4 Footnotes

- The nonlinear pushover analysis is a simplified method for predicting the seismic response of structures and may not capture all the nonlinear behavior and interaction effects of the components.
- The ETABS software is a widely used finite element analysis tool for designing and analyzing buildings and other structures, but its accuracy and reliability depend on the quality of the input data, modeling assumptions, and numerical methods.
- The selection of the lateral load pattern and seismic hazard level can significantly affect the analysis results and should be based on the site-specific seismicity and soil conditions.
- The performance-based design criteria provide a more realistic and flexible approach for designing earthquake-resistant structures, but their implementation requires a good understanding of the structural behavior, earthquake engineering principles, and risk management concepts.
- The sensitivity analysis and model validation are essential steps in the nonlinear pushover analysis to ensure the credibility and confidence of the analysis results and should be performed by experienced and qualified engineers.
- The nonlinear pushover analysis can be used for designing new structures, evaluating existing structures, retrofitting vulnerable structures, and assessing the seismic risk of a portfolio of buildings.

2. Illustrations

Schematic diagram of the multistoried structure to be analyzed, showing the different building components such as beams, columns, slabs, and walls.

Finite element model of the structure in ETABS software, showing the different nodes, elements, and boundary conditions.

Nonlinear pushover curve for the structure, showing the relationship between the base shear and roof displacement.

Plastic hinge formation in critical structural elements, such as beams and columns, indicating the yield strength and ultimate capacity of these elements.

Seismic hazard map of the site, showing the different levels of ground motion intensity and probability of occurrence.

Comparison of the nonlinear pushover analysis results with the seismic code provisions or performance-based design criteria, showing the level of seismic demand and capacity of the structure.

Sensitivity analysis of the different model parameters, such as material properties, load combinations, and damping ratio, showing the effect on the structure's seismic response and performance.

3D visualization of the structure's response during the earthquake, showing the distribution of displacements, accelerations, and stresses in different parts of the structure.

Comparison of the nonlinear pushover analysis results with the results of other analysis methods, such as linear elastic analysis, response spectrum analysis, or time history analysis, showing the differences in the predicted seismic demand and capacity of the structure.

Convergence study of the nonlinear pushover analysis, showing the effect of the number of load increments, convergence criteria, and numerical methods on the accuracy and efficiency of the analysis results.

3. Equations

- Nonlinear static analysis equation:

$F = K u$

where F is the applied nodal forces, K is the stiffness matrix, and u is the nodal displacement vector.

- Pushover analysis equation: $V = P \sin(\pi Dr/Dmax)$

where V is the applied base shear, P is the lateral load pattern, Dr is the displacement at each level, and Dmax is the maximum displacement.

- Plastic hinge formation equation:

$Mpl = My + cRy$

where Mpl is the plastic moment capacity, My is the yield moment capacity, c is the overstrength factor, and Ry is the ductility ratio.

- Capacity spectrum method equation:

$Sa(T) = Cs\ S(T) / R$

where Sa(T) is the spectral acceleration at a period T, Cs is the design spectral acceleration coefficient, S(T) is the response spectrum, and R is the system response reduction factor.

- Performance point equation:

$CDP = RSP / RSA$

where CDP is the capacity design point, RSP is the response spectrum point, and RSA is the nonlinear pushover analysis point.

- Ductility demand equation:

$\mu = \Delta y / \Delta p$

where μ is the ductility demand, Δy is the yield displacement, and Δp is the peak displacement.

- Displacement ductility factor equation:

$\mu f = \Delta f / \Delta y$

where μf is the displacement ductility factor, and Δf is the displacement at the failure state.

Description of the ETABS model, including geometry, materials, and boundary conditions.

Details of the seismic hazard and lateral load pattern used in the analysis.

Tables or figures showing the input data and analysis results, such as member sizes, element properties, load combinations, and deformation profiles.

Code provisions and design criteria used in the analysis, such as ASCE 7, ACI 318, or AISC specifications.

Comparison of the pushover analysis results with other methods, such as dynamic analysis, response spectrum analysis, or time history analysis.

Sensitivity analysis of the model parameters, such as stiffness, strength, damping, or boundary conditions.

Model validation and verification using experimental or field data, such as shake table tests or earthquake damage surveys.

Additional discussion of the design implications and practical considerations, such as detailing requirements, construction methods, or cost estimates.

List of the ETABS commands or scripts used in the analysis, and instructions for replicating the analysis or modifying the model.

Glossary of technical terms and abbreviations used in the paper.

Acknowledgements

It is with immense pleasure that we would like to express our indebted gratitude to our project guide Mr.B. Maheswara Rao, Assistant Professor who has guided us a lot and encouraged us in every step of the project work, his valuable moral support and guidance throughout the project helped us to a greater extent. Our deepest thanks to our HOD Dr. B. Ramamohana Reddy, M.Tech., Ph.D, Associate Professor for inspiring us all the way and for arranging all the facilities and resources needed for our project. We wish to thank our project coordinator Dr. S. Govindarajan, Professor in CE for his support and suggestions during our project work. We owe our sincere gratitude to Dr.M.Sreenivasa Reddy, Principal for providing a great support and for giving us the opportunity of doing the project. We are thankful to our College Management for providing all the facilities in time to us for completion of our project. Not to forget, Faculty, Lab Technicians, non-teaching staff, and our friends who have directly or indirectly helped and supported us in completing our project in time.

With Sincere Regards,

Renuka NageswariBagu

Sai Ganesh Sanagapalli

References

- G. S. Saisaran, V. Yogendra Durga Prasad, T. Venkat Das (2016) “Push Over Analysis for Concrete Structures at Sesimic Zone-3 using Etabs Software” International Journal of Engineering Research & Technology.
- S. Tippu Sultan, D. Thrimurthi Naik (2020) “Seismic Response Study and Pushover Analysis of Multi-storied reinforced concrete building” International Journal of Advanced Research in Science & Technology.
- Jadhav, S., & Kulkarni, P. (2018). Nonlinear Pushover Analysis of a Multistory Building Using ETABS. International Journal of Engineering Research and Development, 14(8), 26-32.
- Nagare, G. V., &Sontakke, S. S. (2020). Nonlinear Static Analysis (Pushover Analysis) of Multistory Structures using ETABS. ResearchGate.
- Suryawanshi, P. R., & Jadhav, S. V. (2018). Nonlinear Pushover Analysis of a Multistoreyed RCC Building using ETABS. International Journal of Innovative Research in Science, Engineering and Technology, 7(4), 166-174.
- Abadi, A., &Vahidkhah, K. (2021). Evaluation of Seismic Performance of Steel Moment Frames Using Nonlinear Static Analysis. Journal of Performance of Constructed Facilities, 35(2), 04020142.
- Iqbal, M. A., &Akter, F. (2019). Nonlinear Static Pushover Analysis of a Reinforced Concrete Building in Bangladesh. International Journal of Civil Engineering and Technology, 10(3), 155-166.