Comparative Study of Static and Dynamic Analysis of RCC Structures under Indian Seismic Condition

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CHAPTER1

INTRODUCTION

GENERAL

One of the most damaging natural disasters that has a significant impact on both human lives and economic growth is an earthquake. Many multi-story reinforced cement concrete (RCC) structures have been built in earthquake-affected areas in recent years due to increasing urbanization and industrial growth. Due to the fact that a major portion of India is located inside several seismic zones as defined by Indian Standard codes, the country is extremely vulnerable to seismic activity. Buildings were severely damaged by previous earthquakes.
like the Nepal earthquake occur in 2015, and the Kashmir earthquake occur in 2005, underscoring the significance of earthquake-resistant structural design. In order to make the structure safe and occupants of the structure safe ,seismic analysis are necessary.

Because of its strength, durability, affordability, and adaptability to different architectural needs, reinforced cement concrete buildings are frequently utilized in contemporary construction. Although RCC buildings may successfully withstand vertical loads, they are exposed to additional lateral forces during earthquakes, which, if improperly built, may result in excessive displacement, cracking, instability, and even structural collapse. Stiffness, mass distribution, building geometry, height, soil condition, ductility, and structural configuration are some of the variables that affect a structure's seismic reaction. To comprehend how structures behave under earthquake stress circumstances, precise seismic analysis is also required.
The primary objective of seismic analysis is to evaluate the response of structures subjected to ground motion and to ensure that the building can safely withstand earthquake forces without significant structural failure. Over the years, different analysis procedures have been developed to estimate the seismic behavior of structures. Among these methods, static analysis and dynamic analysis are the most commonly used techniques in structural engineering practice.

Dynamic analysis methods provide a more realistic representation of structural behavior under seismic excitation by considering the vibration characteristics of buildings. These methods include R.S.A and THA. This analysis considers important parameters such as natural time period, mode shapes, damping, and inertia forces, which significantly influence the seismic response of structures.In this methods have become more practical and reliable for evaluating the performance of RCC buildings located in severe seismic zones.

Indian seismic design provisions are mainly governed by Bureau of Indian Standards through codes such as IS 1893 (Part 1): 2016, IS 456: 2000, and IS 13920: 2016. These standards provide guidelines for calculating seismic loads, designing earthquake-resistant structures, and ensuring ductile detailing of RCC members. The selection of an appropriateanalysismethodaccordingtothesecodeprovisionsplaysavitalrolein

Achieving safe and economical structural design.

In the present study, a comparative evaluation of Pushover and Time history analysis methods for RCC structures under Indian seismic conditions is carried out using ETABS software. The study aims to analyze and compare important structural response parameters obtained from both methods. The research also investigates the effectiveness and applicability of static and dynamic analysis approaches for multi-storey RCC buildings subjected to seismic loading. The findings of this study are expected to provide useful insights for structural engineers and researchers in understanding the seismic performance of RCC structures and selecting suitable analysis techniques for earthquake-resistant design.

1.2 Reinforced Cement Concrete(RCC) Structures

In Rcc structures we get the combination of the tensile strength of steel reinforcement with the compressive strength of concrete. Due to their affordability, durability, and structural efficiency, RCC constructions are frequently used for institutional, commercial, industrial, and residential buildings.RCC constructions must be carefully built to resist both lateral seismic forces and gravity loads in earthquake-prone areas. For RCC buildings to survive better during earthquakes, proper reinforcement detailing, ductile design, and sufficient stiffness are crucial..

1.3 Earthquake and Seismic Forces

An earthquake is a sudden ground vibration caused by the release of energy with in the earth's crust. The seismic waves generated during an earthquake create inertia forces in structures, causing lateral motion and structural deformation. The magnitude of seismic forces acting on a building depends on several factors such as seismic zone, soil condition, structural mass, height of the building, and dynamic properties of the structure. If these forces are not properly considered during design, severe structural damage or collapse may occur during seismic events.

The intensity and effect of seismic forces on a structure depend upon several parameters such as earthquake magnitude, distance from the epicenter,soil condition,structural mass,building height, and structural configuration. Tall and irregular structures are generally more vulnerable to seismic effects because of higher flexibility and complex dynamic behavior. Earthquake forces act rapidly and unpredictably, making seismic analysis one of the most critical aspects of structural engineering.

India is highly susceptible to earthquakes because a large portion of the country lies in different seismic zones defined by IS 1893 (Part 1): 2016 issued by Bureau of Indian Standards. According to the code, India is divided into Zone II, Zone III, Zone IV, and Zone V based on seismic intensity. Structures located in higher seismic zones experience larger earthquake forces and therefore require more detailed analysis and stronger earthquake-resistant design provisions.

During an earthquake, seismic forces generate storey displacement, storey drift, overturning moments, and base shear in buildings. If these forces exceed the structural capacity, severe cracking, instability, and collapse may occur. Hence, proper seismic analysis is necessary to estimate the behaviour of structures accurately and ensure the safety of occupants and infrastructure during earthquake events.

1.4 Static Analysis Method

Static analysis is one of the simplest and most commonly used methods for evaluating the seismic response of structures. In this method, the dynamic effects ofearthquake motionare represented by equivalent lateral static forces acting at different floor levels of the building. The equivalent static method assumes that the structure behaves mainly in its fundamental mode of vibration and that the seismic forces can be distributed along the height of the building based on its mass and stiffness characteristics.

Pushover analysis is a method used by structural engineers to evaluate how a building or structure will behave when subjected to earthquake forces.In simple terms,the structure is pushed sideways with a gradually increasing horizontal force on a computer model, and its response is observed at every step — until the target terrace displacement reach or collapses.

The analysis provides important structural response parameters.These results help engineers design structural components capable of resisting seismic loads safely. However, static analysis has certain limitations because it does not accurately capture higher mode effects,torsional behavior,and time-dependent dynamic characteristics of buildings.

For tall, irregular, or complex structures, static analysis may produce less accurate results.The equivalent static method remains an important preliminary and design-level analysis technique for many conventional RCC buildings.

1.5 Dynamic Analysis Method

Dynamic analysis is a more advanced and realistic approach for finding the behavior ofstructures under earthquake loading. Unlike static analysis, dynamic analysis considers the actual vibration behavior of structures by including parameters. Since earthquakes generate rapidly varying ground motion, the structural response also changes continuously with time. Dynamic analysis provides a more accurate estimation of this response.

Time history analysis, evaluates the structural response using actual or simulated earthquake ground motion records. It provides highly detailed information regarding displacement, acceleration, and force variation with time.

Dynamic analysis is especially important for high-rise buildings, irregular structures, and buildings located in severe seismic zones because such structures are significantly affected by higher mode participation and dynamic amplification effects. Compared to static analysis, dynamic analysis produces more realistic results.

With the advancement of computer technology and structural analysis software such as ETABS, dynamic analysis has become more practical and efficient for engineering applications. Although dynamic analysis requires greater computational effort and detailed modeling.

1.5 Indian Seismic Design Codes

The seismic analysis and design of RCC structures in India are governed by various standards developed by Bureau of Indian Standards. These codes provide guidelines and procedures for calculating seismic loads, designing earthquake-resistant structures, and ensuring structural safety under seismic conditions. The main goal of these codes is to minimize structural damage and prevent collapse during earthquakes.

IS 1893 (Part 1): 2016 is the primary code used for earthquake-resistant design of structures in India. It specifies seismic zone factors, importance factors, response reduction factors, design spectra, and methods for calculating seismic loads. The code also providesguidelines for static and dynamic analysis procedures based on the type and height of the structure.

IS 456: 2000 provides the general provisions for the design of reinforced concrete structures, including material specifications, load combinations, durability requirements, and structural detailing. Another important code, IS 13920: 2016, deals with ductile detailing of reinforced concrete structures which is affected by seismic forces. Ductile detailing improves the energy absorption and deformation capacity of structural members during earthquakes.

The Indian seismic ensure safe and economical structural design. Proper implementation of these standards helps engineers design RCC buildings capable of resisting earthquake effects effectively while maintaining structural stability and occupant safety.

1.6 Need for Comparative Study

Different analysis methods produce different results depending on the structural configuration, height, stiffness, and seismic characteristics of the building. Therefore, a comparative study between static and dynamic analysis methods becomes necessary to understand the variation in structural response and evaluate the accuracy of different approaches.

Static analysis methods are simpler and faster but may not accurately represent the actual dynamic behavior of structures during earthquakes. Dynamic analysis methods provide more realistic results because they consider vibration characteristics and modal participation effects. However, dynamic analysis requires more computational effort and detailed modeling procedures. Comparing these methods helps engineers determine the suitability of each approach for different structural conditions.

In the present study, important seismic response parameters are compared using static and dynamic analysis methods.The comparison helps in understanding the influence of analysis techniques on structural performance under Indian seismic conditions. Such studies are useful for improving design accuracy, structural safety, and economy in earthquake-resistant construction.

1.7 Need for Nonlinear Static (Pushover) Analysis

Traditional linear static and linear dynamic methods of seismic analysis assume that the structure remains within the elastic range during earthquake loading. These methods distribute earthquake forces based on simplified assumptions and are unable to capture the actual sequence of member yielding, stiffness degradation, and redistribution of internal forces.

The primary advantage of pushover analysis lies in its ability to:

- Identify weak structural components,
- Estimate displacement demand and ductility capacity,
- Evaluate overall collapse mechanism of the structure.

This method provides a clear relationship between base shear and terrace displacement in the form of a capacity curve, which can be further used to determine performance points and assess whether the structure meets desired performance objectives. Hence, pushover analysis is particularly suitable for earthquake performance evaluation of RCC buildings under Indian seismic conditions.

1.8 Need for Performing Nonlinear TimeHistory Analysis

Nonlinear THA is required to accurately evaluate the seismic performance of RCC structures under actual earthquake ground motions. Conventional static analysis methods are often unable to represent the real dynamic behavior of buildings during severe seismic events because earthquake forces vary continuously with time. Therefore, performing nonlinear time historyanalysis becomes essential for understanding the realistic structuralresponse, especially for high-rise, irregular, and earthquake-resistant structures.

The primary need for nonlinear time history analysis arises from the requirement to study the behavior of structures beyond the elastic limit. During strong earthquakes, structuralmembers such as beams and columns may experience cracking, yielding, stiffness degradation, and plastic hinge formation. Linear analysis methods cannot accurately capture these nonlinear effects, whereas nonlinear THA considers both material and geometric nonlinearities, providing a more realistic simulation of structural behavior under seismic excitation.

Another important reason for performing nonlinear time history analysis is to evaluate important seismic response parameters and internal member forces at every instant of time during the earthquake. This method allows engineers to identify critical structural components, weak zones, and possible failure mechanisms within the building. It also helps in assessing the stability, ductility, and energy dissipation capacity of RCC structures under severe seismic loading.

Nonlinear THA is especially necessary for performance-based seismic design, where the actual performance level of the structure must be evaluated under different earthquake intensities. It is widely used for important structures such as hospitals, tall buildings, bridges, industrial facilities, and structures located in high seismic zones. The method enables engineers to verify whether the structure satisfies objectives like as Ls,io, and Cp during earthquake events.

With the advancement of computational techniques and structural analysis software such as ETABS, performing nonlinear time history analysis has become more practical and efficient. Although the method requires detailed modeling, earthquake records, and higher computational effort, it provides highly accurate and reliable results for seismic evaluation and earthquake-resistant structural design.

1.9 Indian Seismic Design Philosophy

India follows a zone-based seismic design approach as specified in IS 1893 (Part 1):2016, which categorizes the country into different seismic zones based on risk. The design philosophy adopted in Indian codes is primarily life-safety oriented, meaning that the structures should not collapse during major earthquakes but may suffer significant damage. While this approach ensures life protection, it does not necessarily guarantee immediate post-earthquake functionality.

In recent years, there has been a growing shift from conventional force-based design to **performance-based seismic design**, which aims to achieve targeted performance levels under different earthquake intensities. Pushover analysis plays a crucial role in this transition by enabling engineers to verify whether the designed structure satisfies the objectives.

1.6Objectives of the Present Study

The main goal of the present study is to finding the earthquake performance of multi-storey RCC structures under Indian seismic conditions by using advanced seismic analysis procedures such as PA and THA. The study aims to investigate the nonlinear and dynamic behavior of RCC buildings subjected to earthquake loading and to understand the structural response under different seismic conditions. Modern earthquake-resistant design requires accurate prediction Of structural behavior beyond the elastic range; therefore, advanced analysis techniques are necessary to evaluate the actual performance of structures during strong ground motion.

One of the primary objectives of this research is to model and analyze RCC buildings using ETABS software according to Indian Standard code provisions. The study focuses on performing nonlinear static pushover analysis to evaluate the strength, stiffness, ductility, and collapse performance of the structure. Pushover analysis helps in identifying weak zones, hinge formation, performance points, and failure mechanisms in buildings during seismic excitation.Through this analysis,the progressive behavior of the structure from the elastic stage to the inelastic stage can be studied effectively.

Another important objective of the study is to perform THA using earthquake ground motion records to examine the actual dynamic response of RCC structures under seismic loading. THA provides detailed information regarding variation of displacement ,acceleration, velocity, and internal forces with respect to time. This method helps in understanding the real-time behavior of structures during earthquakes and gives realistic results compared to conventional static methods.

The study also aims to compare important seismic response parameters and performance levels obtained from analysis. The comparison helps in evaluating the effectiveness, reliability, and applicability of these advanced seismic analysis methods for RCC buildings located in earthquake-prone regions of India.

Another goal of this research is to study the influence of seismic loading on the overall stability and performance of RCC structures. The investigation further aims to identify suitable seismic analysis procedures for achieving safe, economical, and earthquake-resistant structural design. The outcomes of the study are expected to assist structural engineers, researchers, and designers in understanding the nonlinear seismic behavior of RCC buildings and improving the performance-based design approach in structural engineering.

CHAPTER 2

LITERATUREREVIEW

1. The study presents a detailed evaluation of reinforced concrete (RC) structures using NSPA to assess their seismic performance.The research investigates the influence of infill percentage, shear wall configuration, and soft-storey location on structural behavior. Results show that increasing infill enhances stiffness and base shear capacity, while shear walls—especially periphery types—provide maximum lateral resistance. Conversely, soft storeys at lower levels increase vulnerability to seismic damage, whereas mid-level soft storeys perform comparatively better. The study, based on FEMA 356 and ATC-40 guidelines, concludes that proper integration of infill and shear walls significantly improves seismic performance. However, further research considering dynamic analysis and local design codes, such as IS 1893:2016, is necessary for more realistic modeling and region-specific design recommendations

2. The reviewed study contributes to this body of knowledge by examining how the height at which a soft storey occurs influences the behaviour of an L-shaped RC building. Results indicate that soft storeys located near the base attract higher deformation and hinge activity, whereas shifting the soft

storey upward reduces time period and improves overall performance. This aligns with existing findings while providing additional insight into the effect of vertical soft storey placement.

One of the most critical irregularities affecting seismic performance is the presence ofa soft storey, where a sudden reduction in stiffness leads to excessive drift and concentration of damage.Previous research consistently shows that buildings with soft storeys are more vulnerable during earthquakes, especially when the soft storey is located at the lower levels. Studies using software such as ETABS confirm that such buildings undergo larger displacements and exhibit early hinge development in columns.

3. Recent research has focused extensively on the earthquake performance of reinforced concrete(RC) buildings using nonlinear analytical procedures, particularly pushover analysis. Several studies have examined how structural irregularities influence deformation patterns and overall seismic capacity. Ahmed and Raza (2014) explored various plan-irregular RC building configurations and reported that irregular geometries, such as diaphragm discontinuities and Y-shaped layouts, show reduced base shear capacity and higher displacement demands compared to regular plans. Their findings highlight the sensitivity of torsional irregularities to lateral loading. Similarly, Hamraj (2014) evaluated different unsymmetrical building plans of multiple heights and demonstrated that modeling strategies—whether including infill walls or replacing them with equivalent struts—significantly affect performance levels and the ability of buildings to achieve immediate occupancy under seismic loading.

4. The literature reviewed in this chapter is strictly limited to the study presented in the selected *Comparison–2 research paper*, which focuses on the comparative seismic performance evaluation of reinforced concrete (RCC) buildings using PA and NTHA. The study goal to examine the accuracy, reliability, and behavioral differences of these two nonlinear analysis methods when applied to RCC structures subjected to earthquake loading.

The research highlights the restriction of conventional linear static and dynamic analysis methods and establishes the necessity of nonlinear procedures for realistic prediction of structural behavior under strong seismic excitations.

5. R. Kavitha et al. (2022) have done seismic analysis and design of multilevel car parking structure using ETABS software. The structure was analysed under different load conditions as per Indian Standard, namely dead load, live load, wind load and earthquake load. RSA was adopted to determine the earthquake response of the building. The study highlighted the need for correct modelling, diaphragm action and moment resisting frames to enhance the seismic performance of RCC structures. The authors found that it is crucial to use the right analysis and design methods to guarantee the stability and safety of multistorey structures under earthquake loadings.

6. The study investigated seismic vulnerability of RC buildings with different irregularities in plan using pushover analysis. Rectangular, diaphragm discontinuity, and Y-shaped buildings were analyzed by using ETABS software. The study was based on the parameters such as capacity spectrum,plastic hinge

formation,lateral displacement etc.to evaluate seismic performance. The results revealed that irregular buildings are more vulnerable to seismic damages than regular buildings. In particular, the presence of openings in the structure led to larger values of displacement in the diaphragm discontinuity models. The study found that the regular building configuration gives better performance in earthquake situations.

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7. The study examine pushover analysis of medium-rise RCC frame buildings with and without vertical irregularity in ETABS software. The research compared the seismic performance of regular and irregular buildings based on guidelines provided by ATC-40 and FEMA-273. Structural behavior was evaluated through parameters. The results showed that the lateral load resistance and seismic performance of the vertically irregular buildings were lower than that of regular buildings. It was also noticed that the overall stability and earthquake resistance of RCC buildings were found to reduce significantly with the increase in irregularity.

CHAPTER3

RCCFRAMEDSTRUCTURE

A Reinforced Cement Concrete (RCC) framed structure is one of the most widely used structural systems in modern construction due to its strength, durability, flexibility, and economy. In this structuralsystem, the loads acting on the building are transferred through interconnected structural members. RCC framed structures are commonly used for residential buildings, commercial complexes, industrial buildings, and multi-storey structures because they provide better stabilityand resistance against both vertical and lateral loads. In earthquake-prone regions, RCC framed structures are preferred because they possess good rigidity, ductility, and load-carrying capacity, which are essential for resisting seismic forces.

The basic principle of an RCC framed structure is that the entire load of the building is carried by the structural frame rather than by load-bearing walls. The beams transfer the load from slabs to columns, while columns transfer the load to the foundation, which ultimately distributes the load safely to the soil. This load transfer mechanism makes RCC framed structures highly efficient for supporting heavy loads and large spans. The frame action between beams and columns provides structural continuity and improves the overall stiffness and stability of the building.

RCC framed structuresareparticularlyimportant inseismic-resistant constructionbecause theycan effectively resist lateral forces generated during earthquakes. During seismic excitation, the frame experiences horizontal displacement, inertia forces, bending moments, shear forces, and torsional effects. Proper design of beams, columns, and joints is necessary to ensure that the structure can absorb energy and [15] maintain stability during earthquake loading. The seismic behavior of RCC framed structures depends on factors such as building geometry, stiffness, mass distribution, reinforcement detailing, and ductility.

ASSUMTIONSINDESIGN

- Thep.s.fforloads istakenasΥ_f=1.5,accordingtoclause36.4ofIS 456-2000
- Asperclause36.4.2ofIS456-2000,thepartialsafetyfactorformaterials is1.5 for concrete and 1.15 for steel.
- Loadcombinationsareconsideredusingthepartialsafetyfactorsspecifiedinclause 36.4ofIS456-2000.

LOADCOMBINATIONFORLIMITSTATEOFCOLLAPSEASPER IS 456-2000

According to IS 456:2000 (Clause36.4.2), the following load combinations are considered for the Limit State of Collapse:

1. Combination of Dead Load (DL) andLive Load (LL)= 1.5(DL+LL) This combination isused when both dead load and live load act together.

2. Combination of DeadLoad (DL)an EarthquakeLoad (EL)=1.5(DL+EL) This is considered when seismic force acts along with dead load.

3. Combination of DeadLoad and LiveLoad and EarthquakeLoad= 1.2(DL+LL+EL) This combination is used when all loads act simultaneously.

4. Combination for Stability Check=0.9DL+1.5EL This load combination is used to check overturning, uplift, and stability of the structure.

3.3 DEAD LOAD,LIVE LOAD AS PER INDIAN STANDARD

In the study we take the Liveload as 2KN/M^2

CHAPTER4

DETAILS OF THE MODEL STUDIED

4.1 Structural Details:-

In the study ,the type of structure we used is Reinforced cement concrete Building. Our sample RCC building is G+5storey.The story height of the building is3m each The Bay length of the RCC Building is 5 m × 5 m in both directions.

Structural Elements

The cross section of column is taken to be 400mmx400mmand the beam cross section is Taken as 300mmx 500mm and depth of the beam is 500mm which includes the thickness

Of slab.
The thickness of slab is taken as125mm.

4.3 Material Properties

The grade of the concrete used to model the rcc structure is M25 and the grade of the steel used is Fe 415.

4.4 Masonry Infill Modeling

The Masonry infill modeled as an equivalent diagonal strut and the strut width is taken as 485 mm. The thickness of strut is Taken as 125 mm and the compressive strength masonry in fill is taken as 1 MPa.

4.5 Shear Wall Model

- Two common shear wall forms studied:
  - Parallel shear wall
  - Periphery shear wall
- Modeled using:
  - 10-inchwallthickness
- Shear walls considered with half bay length=2.5m

4.6 MODELLING AND ANALYSIS OF MODEL

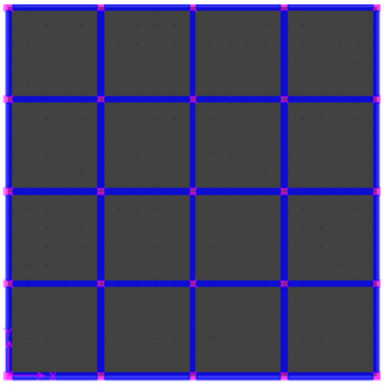


Fig4.1 Plan of the building

The structure is of G+5 Story building having bay length of 5m x 5m.In this structure shear wall is placed at corners and another case shear wall is placed at center.The infill walls we take it as a struts.

The column sizes are 400mmx 400mm

The beam size are 300mm x 500mm

The story height is 3m.
Moment M3 are assigned to beams and P-M2-M3 are assigned to columns at both ends.
The pushover analysis is performed in Xdirection and Ydirection.
The time history analysis are also performed in x direction andYdirection.

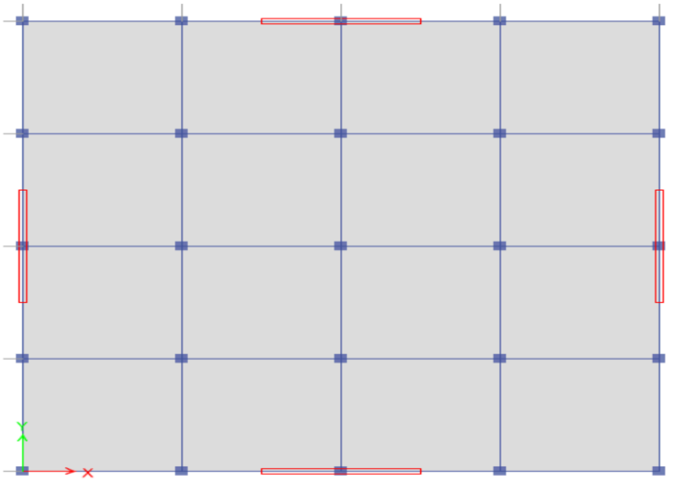
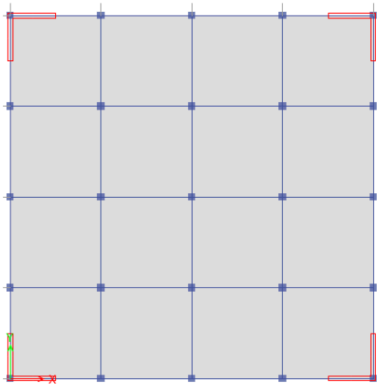
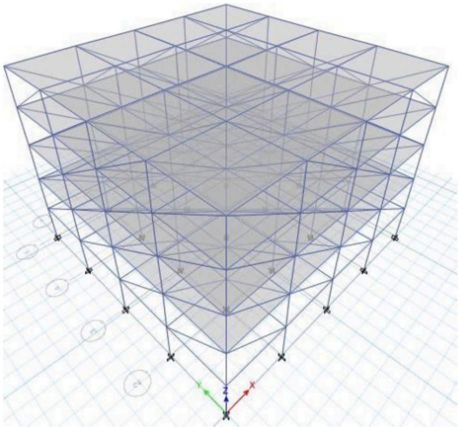


Fig1swatcenter



Swatcorner



Figurebuildingwithinfillwalls(strut)

CHAPTER 5

METHODOLOGY

5.1 RESEARCHMETHODOLOGY

This chapter describes the complete methodology adopted for carrying out the nonlinear static pushover analysis of RCC structures and time history analysis under Indian seismic conditions. The methodology includes selection of building models, determination of material properties, application of gravity and seismic loads as per Indian Standard codes, modeling procedures in ETABS software ,assignment of non linear hinge properties, and execution of PA and THA. The purpose of this methodology is to ensure realistic representation of structural behavior and accurate evaluation of seismic performance in terms of displacement, base shear, inter-storey drift, and performance levels.

5.2 Selection of Building Models

For the present study, typical multi storey RCC frame buildings are selected. The buildings are assumed to be located in a seismic region zone IV as defined by IS 1893 (Part 1):2016. The selected building represent commonly constructed residential or commercial RCC frame structures in India.

The following assumptions are made for the building models:

- Floor slabs act as rigid diaphragms.
- The foundation is assumed to be fixed at the base.

The buildings are modeled using ETABS software.

5.3 Material Properties

The material properties used for modeling the RCC structures are adopted as per IS456:2000.

5.3.1 Steel Properties

The Grade of reinforcing steel is taken as Fe415andYield strength is 415MPa.
Modulus of elasticity,is taken as2×10^5 MPa
These material properties are used for both linear and non linear modeling of the structure.

5.4 GEOMETRIC PROPERTY OF BUILDINGS

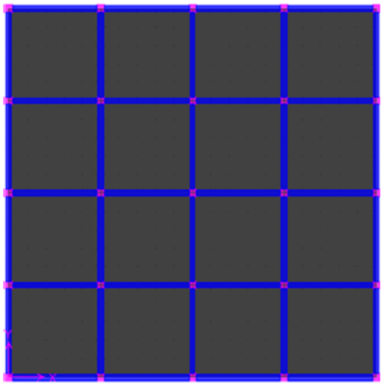


Fig 2 Typical plan of the building

5.5 Loading Details

The following types of loads are considered in the analysis:

5.5.1 DeadLoad(DL)

Dead load includes:

Selfweight of beams,columns,andslabs which is calculated by etabs software and Floor finishes.

5.5.2LiveLoad(LL)

Live load is applied as per IS875(Part2)depending on occupancy type(residentialor commercial). The live loads are taken as 2kN/m^2

5.5.3Seismic Load(EL)

Seismic loads are applied as per IS1893(Part1):2016.

Important seismic parameters considered: Seismic zone factor (Z), Importance factor (I), Response reduction factor (R) and soil type

5.6 Load Combinations

Load combinations are generated asperIS456:2000 and IS1893(Part 1):2016.

The load combinations are used for design verification before conducting push over analysis.

5.7 Modeling Procedure in ETABS

The modeling of RCC structures is carried out using ETABS software.The following steps are followed:

1. Definition of grid lines and storey levels
2. Assignment of material properties
3. Definition of frame and slab sections
4. Modeling of beams,columns,and slabs
5. Assignment of boundary conditions
6. Application of loads andload combinations
7. Linear analysis and design verification

After satisfactory completion of linear analysis and design, the model is converted into a nonlinear model for pushover analysis.

5.8 Nonlinear Hinge Properties

Nonlinear behavior of structural members is represented using plastic hinges as per FEMA356 guidelines.

5.8.1 Beam Hinges

M3 are assigned at both ends of beams at a distance of 0.1and 0.9 to simulate flexural yielding.

5.8.2 Column Hinges

P-M2-M3areassigned at both ends of columns at a distance of 0.1 and 0.9.

The hinge properties define the force–deformation behavior and classify the performance levels into: IO,LS, CP.

5.9 Pushover Load Pattern

PA is carried out by applying increasing lateral loads in a predefined pattern. In this study, the following lateral load patterns are considered: Uniform load pattern and First mode shape load pattern

The lateral loads are increased gradually while keeping gravity loads constant until target displacement or collapse condition is reached.

5.10 Pushover Analysis Procedure

The step-by-step pushover analysis procedure adopted in this study is as follows:

1. Apply full gravity load on the structure.
2. Assign non linear hinge properties to beams and columns.
3. Apply lateral loads incrementally in the chosen direction.
4. Monitor base shear and terrace displacement for at a target displacement of 600mm.
5. Track formation and progression of plastic hinges.
6. Continue the analysis until collapse mechanism or target displacement is achieved.

5.11 Performance Evaluation Criteria

1

The seismic performance of the RCC structures is evaluated based on the following parameters:

- Terrace displacement
- Plastic hinge distribution
- Global performance levels(IO,LS,CP)

The acceptance criteria for these parameters are adopted from FEMA356 andATC-40.

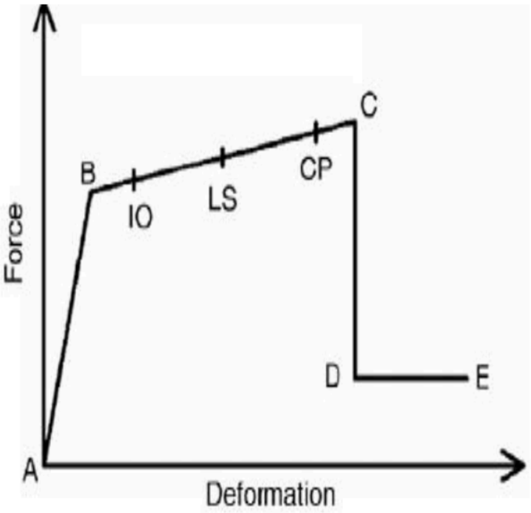


Fig5.11force deformation for push over analysis

5.12 Comparative Analysis Framework

For comparative evaluation, pushover analysis results of different building models such as SW at periphery,SW at center and building with infill walls are compared based on:

Maximum base shear resistance, Maximum Terrace displacement, Drift distribution along height, Sequence of plastic hinge formation and failure mechanism.

These comparisons help in identifying the most efficient and vulnerable structural configurations.

5.13 Limitations of the Methodology

The present methodology is subject to the following limitations:

1. Soil–structure interaction is not considered.
2. Foundation flexibility is ignored
3. Material degradation and cyclic loading effects are not explicitly modeled.

5.14 TIME HISTORY ANALYSIS methodology

THA is the most rigorous and realistic method of seismic analysis available to structural engineers. Unlike pushover analysis, which applies a slowly increasing static force, THA subjects the structural model to actual or simulated earthquake ground motion records — that is, the variation of ground acceleration with time — and computes the response of the structure at every instant during the earthquake.

1. Structural Modeling

A **three- dimensional RCC rigid-joint building model** was developed in **ETABS** to study seismic behavior under Indian earthquake loading conditions.

Building specifications considered are G+5 storey building and the storey height is3m each and bay spacing is 5mx5m. the beam size is 300 mm x500mm and coloumn size is 400mmx400mm And the slab thickness is 125mm.
The building was modeled as a regular moment-resisting RC frame.

2.MaterialProperties

The grade of concreteused is M25and the grade of steel used is Fe415.

3. AssignDamping Properties

Use**5%dampingratio**forreinforcedconcretestructuresascommonlyspecifiedbycodes

3. Select and Process Ground Motion Records

Select recorded accelerograms from databases such as **ELCENTRO.**

4. Apply Gravity Loads

Apply dead loads and a code-specified fraction of live loads statically be for the dynamic analysis This establishes the correct initial stress state in all members

5. Run the Dynamic Analysis

Input the scaled ground motion as a **time-varying base acceleration**

6. Extract Response Quantities

7. Post-Process the Results

8. Revise and Repeat if Required

CHAPTER6

MODELING AND ANALYSIS OF RCC STRUCTURES

6.1 INTRODUCTION‘

This chapter presents a brief description of the modeling and analysis of RCC structures with rigid joints carried out in ETABS software. The building models are generated based on typical Indian construction practice and are analyzed under gravity and seismic loading conditions as per the provisions of Indian Standard codes. The purpose of this chapter is to describe the modeling approach and analysis procedure adopted for the present study.

6.2 Description of Building Models

Three-dimensional models of multistorey RCC frame structures with rigid beam–column joints are developed. The buildings are assumed to be regular in plan with uniform storey height and bay spacing. All the structural components such as beams, columns, slabs, and rigid diaphragms are modeled accurately. The support conditions are assumed to be fixed at the base, and soil–structure interaction is neglected.

6.3 LoadApplication

Dead loads, live loads, and seismic loads are applied to the structures as per IS 875 and IS 1893 (Part 1):2016. The self-weight of the structure is automatically calculated by the software. Appropriate load combinations as specified by Indian codes are used for analysis and design verification.

6.4 Nonlinear Modeling

After completing linear static analysis and design, nonlinear hinge properties are assigned to beams and columns as per FEMA 356 guidelines.Moment hinges (M3)are assigned to beams, and P–M2–M3 interaction hinges are assigned to columns to simulate inelastic behavior during pushover analysis.

6.5 Pushover Analysis

Nonlinear static PHA was conducted by applying the lateral force progressively in the X and Y direction on the structure with the same gravity loading applied throughout the analysis. The lateral loading was incrementally applied in successive phases to observe the structural response in phases of growing seismic demand. The analysis was continued until the building's displacement was equal to the pre-defined target displacement or until a critical failure state was reached. The results obtained were used to draw the capacity curves, which assisted in the evaluation of the stiffness, strength and deformation capacity of the structure under nonlinear loading.

6.6 Time History analysis

After modeling of structure and adding the load cases of time history in X and Y Direction. We run the analysis of the model in Etabs of TH-X And TH-Y.

We are then get the behavior of the structure.

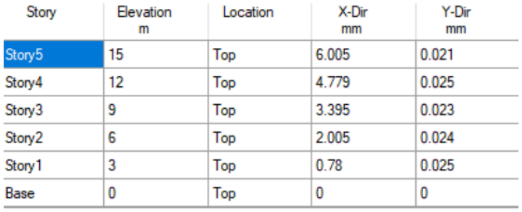
CHAPTER7

RESULT AND DISCUSSION

This chapter presents a brief discussion of the results obtained from the nonlinear static pushover analysis of RCC structures with rigid joints under Indian seismic conditions. The key parameters are evaluated. The results are used to assess and compare the overall seismic performance of the building models.

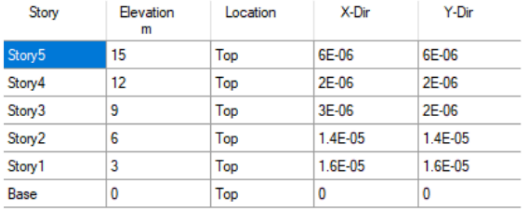
Plastic Hinge Formation

Plastic hinges initially form at the ends of beams, indicating a desirable ductile beam–sway mechanism. As the lateral load increases, hinges gradually develop in columns, especially at the lower storeys. The sequence of hinge formation provides insight into the expected failure mechanism of the structure.



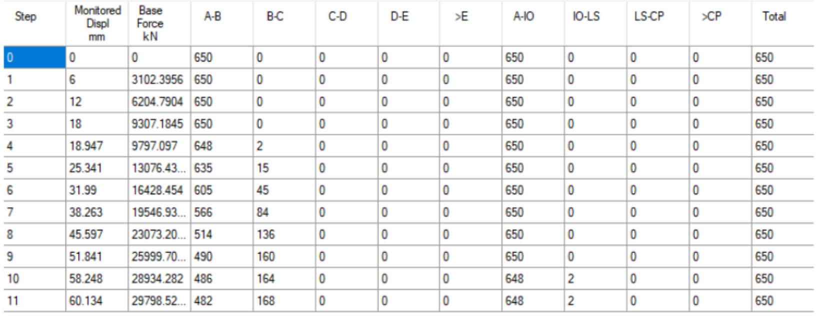
Story	Elevation m	Location	X-Dir mm	Y-Dir mm
Story5	15	Top	6.005	0.021
Story4	12	Top	4.779	0.025
Story3	9	Top	3.395	0.023
Story2	6	Top	2.005	0.024
Story1	3	Top	0.78	0.025
Base	0	Top	0	0

Figshowing storyresponseplot withshearwallatcenter



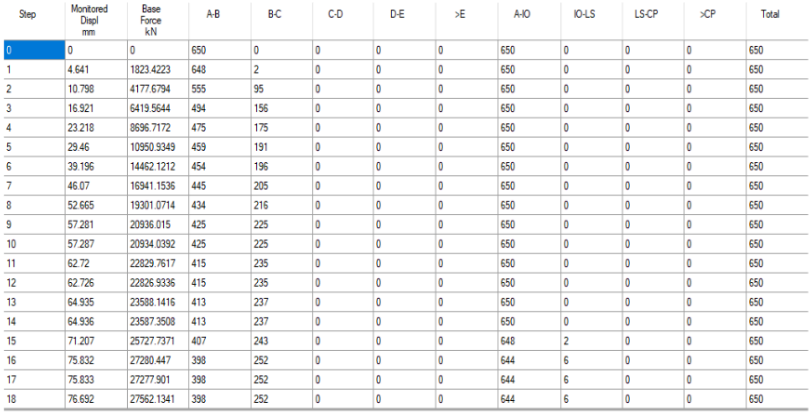
Story	Elevation m	Location	X-Dir	Y-Dir
Story5	15	Top	6E-06	6E-06
Story4	12	Top	2E-06	2E-06
Story3	9	Top	3E-06	2E-06
Story2	6	Top	1.4E-05	1.4E-05
Story1	3	Top	1.6E-05	1.6E-05
Base	0	Top	0	0

Figshowing storydriftofshearatcenter



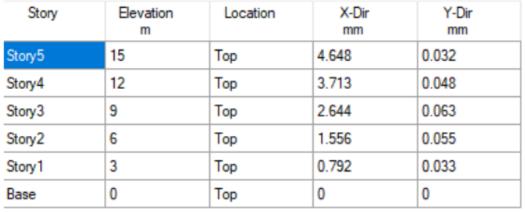
Step	Monitored Displ mm	Base Force kN	A-B	B-C	C-D	D-E	>E	A-IO	IO-LS	LS-CP	>CP	Total
0	0	0	650	0	0	0	0	650	0	0	0	650
1	6	3102.3956	650	0	0	0	0	650	0	0	0	650
2	12	6204.7904	650	0	0	0	0	650	0	0	0	650
3	18	9307.1845	650	0	0	0	0	650	0	0	0	650
4	18.947	9797.097	648	2	0	0	0	650	0	0	0	650
5	25.341	13076.43...	635	15	0	0	0	650	0	0	0	650
6	31.99	16428.454	605	45	0	0	0	650	0	0	0	650
7	38.263	19546.93...	566	84	0	0	0	650	0	0	0	650
8	45.597	23073.20...	514	136	0	0	0	650	0	0	0	650
9	51.841	25999.70...	490	160	0	0	0	650	0	0	0	650
10	58.248	28934.282	486	164	0	0	0	648	2	0	0	650
11	60.134	29798.52...	482	168	0	0	0	648	2	0	0	650

FigBaseshearwithdisplacementwithSWatcenter



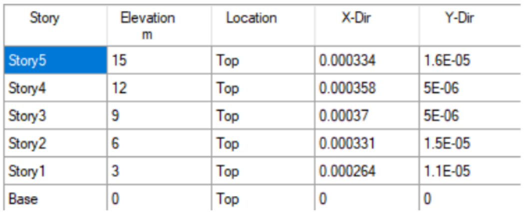
Step	Monitored Displ mm	Base Force kN	A-B	B-C	C-D	D-E	>E	A-IO	IO-LS	LS-CP	>CP	Total
0	0	0	650	0	0	0	0	650	0	0	0	650
1	4.641	1823.4223	648	2	0	0	0	650	0	0	0	650
2	10.798	4177.6794	555	95	0	0	0	650	0	0	0	650
3	16.921	6419.5644	494	156	0	0	0	650	0	0	0	650
4	23.218	8696.7172	475	175	0	0	0	650	0	0	0	650
5	29.46	10950.9349	459	191	0	0	0	650	0	0	0	650
6	39.196	14462.1212	454	196	0	0	0	650	0	0	0	650
7	46.07	16941.1536	445	205	0	0	0	650	0	0	0	650
8	52.665	19301.0714	434	216	0	0	0	650	0	0	0	650
9	57.281	20936.015	425	225	0	0	0	650	0	0	0	650
10	57.287	20934.0392	425	225	0	0	0	650	0	0	0	650
11	62.72	22829.7617	415	235	0	0	0	650	0	0	0	650
12	62.726	22826.9336	415	235	0	0	0	650	0	0	0	650
13	64.935	23588.1416	413	237	0	0	0	650	0	0	0	650
14	64.936	23587.3508	413	237	0	0	0	650	0	0	0	650
15	71.207	25727.7371	407	243	0	0	0	648	2	0	0	650
16	75.832	27280.447	398	252	0	0	0	644	6	0	0	650
17	75.833	27277.901	398	252	0	0	0	644	6	0	0	650
18	76.692	27562.1341	398	252	0	0	0	644	6	0	0	650

FIGshowingBASESHEaRWITHSWATCORNER



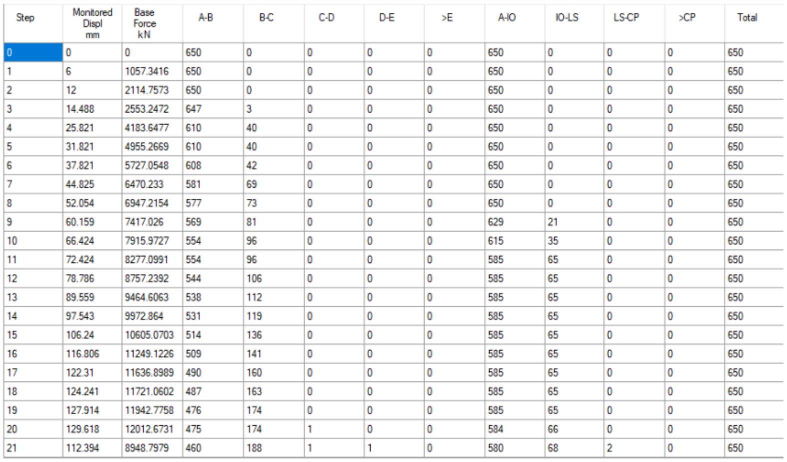
Story	Elevation m	Location	X-Dir mm	Y-Dir mm
Story5	15	Top	4.648	0.032
Story4	12	Top	3.713	0.048
Story3	9	Top	2.644	0.063
Story2	6	Top	1.556	0.055
Story1	3	Top	0.792	0.033
Base	0	Top	0	0

FIGSTOREYRESPONSEPLOT WITHSWATCORNER



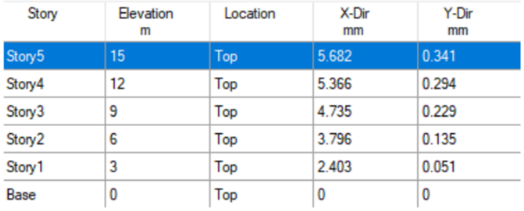
Story	Elevation m	Location	X-Dir	Y-Dir
Story5	15	Top	0.000334	1.6E-05
Story4	12	Top	0.000358	5E-06
Story3	9	Top	0.00037	5E-06
Story2	6	Top	0.000331	1.5E-05
Story1	3	Top	0.000264	1.1E-05
Base	0	Top	0	0

FIGSTOREYDRIFTWITHSWAtCORNER



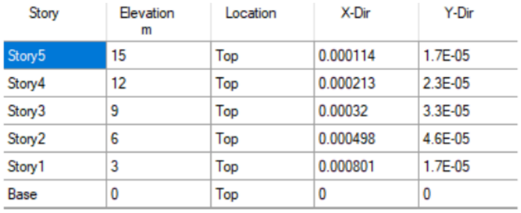
Step	Monitored Displ mm	Base Force kN	A-B	B-C	C-D	D-E	>E	A-IO	IO-LS	LS-CP	>CP	Total
0	0	0	650	0	0	0	0	650	0	0	0	650
1	6	1057.3416	650	0	0	0	0	650	0	0	0	650
2	12	2114.7573	650	0	0	0	0	650	0	0	0	650
3	14.488	2553.2472	647	3	0	0	0	650	0	0	0	650
4	25.821	4183.6477	610	40	0	0	0	650	0	0	0	650
5	31.821	4955.2669	610	40	0	0	0	650	0	0	0	650
6	37.821	5727.0548	608	42	0	0	0	650	0	0	0	650
7	44.825	6470.233	581	69	0	0	0	650	0	0	0	650
8	52.054	6947.2154	577	73	0	0	0	650	0	0	0	650
9	60.159	7417.026	569	81	0	0	0	629	21	0	0	650
10	66.424	7915.9727	554	96	0	0	0	615	35	0	0	650
11	72.424	8277.0991	554	96	0	0	0	585	65	0	0	650
12	78.786	8757.2392	544	106	0	0	0	585	65	0	0	650
13	89.559	9464.6063	538	112	0	0	0	585	65	0	0	650
14	97.543	9972.864	531	119	0	0	0	585	65	0	0	650
15	106.24	10605.0703	514	136	0	0	0	585	65	0	0	650
16	116.806	11249.1226	509	141	0	0	0	585	65	0	0	650
17	122.31	11636.8989	490	160	0	0	0	585	65	0	0	650
18	124.241	11721.0602	487	163	0	0	0	585	65	0	0	650
19	127.914	11942.7758	476	174	0	0	0	585	65	0	0	650
20	129.618	12012.6731	475	174	1	0	0	584	66	0	0	650
21	112.394	8948.7979	460	188	1	1	0	580	68	2	0	650

BASESHEARVSDISPLACEMENTWITHINFILLWALLS



Story	Elevation m	Location	X-Dir mm	Y-Dir mm
Story5	15	Top	5.682	0.341
Story4	12	Top	5.366	0.294
Story3	9	Top	4.735	0.229
Story2	6	Top	3.796	0.135
Story1	3	Top	2.403	0.051
Base	0	Top	0	0

STORYRESPONSEPLOTWITHINFILLWALLS



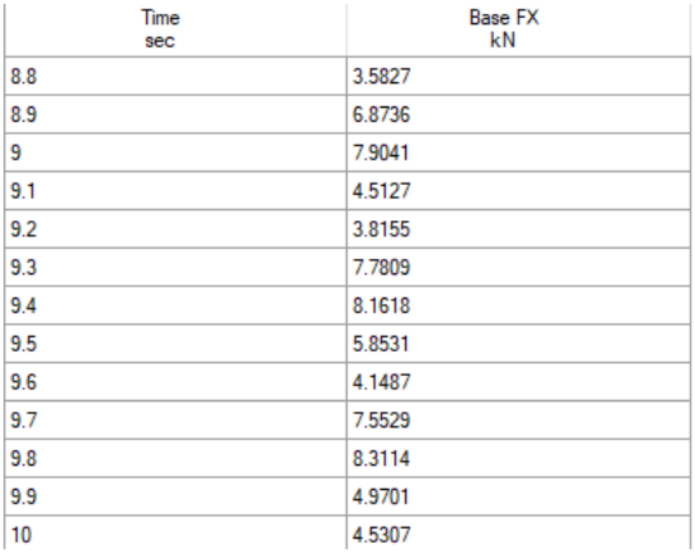
Story	Elevation m	Location	X-Dir	Y-Dir
Story5	15	Top	0.000114	1.7E-05
Story4	12	Top	0.000213	2.3E-05
Story3	9	Top	0.00032	3.3E-05
Story2	6	Top	0.000498	4.6E-05
Story1	3	Top	0.000801	1.7E-05
Base	0	Top	0	0

STORYDRIFTWITHINFILLWALLS

The result of all the observation table is that in the story response plot the shear wall at corner have least story displacement which shows that the position of shear wall at corner is best to reduce the storey displacement .

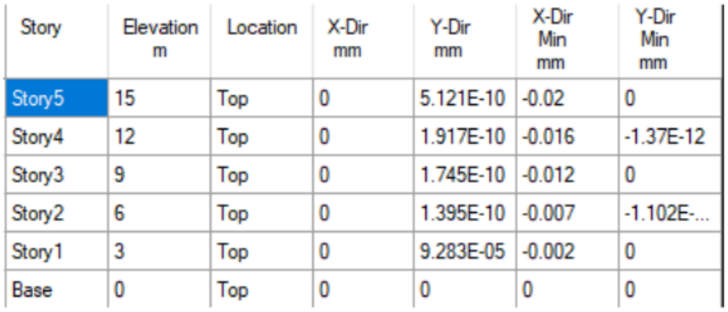
Plastic hinges initially form at the ends of beams, indicating a desirable ductile beam–sway mechanism. As the lateral load increases, hinges gradually develop in columns, especially at the lower storeys. The sequence of hinge formation provides insight into the expected failure mechanism of the structure.

RESULT OF TIME HISTORY ANALYSIS



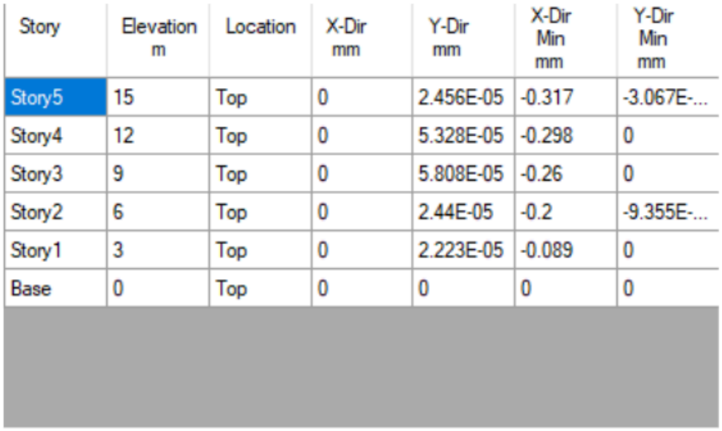
Time sec	Base FX kN
8.8	3.5827
8.9	6.8736
9	7.9041
9.1	4.5127
9.2	3.8155
9.3	7.7809
9.4	8.1618
9.5	5.8531
9.6	4.1487
9.7	7.5529
9.8	8.3114
9.9	4.9701
10	4.5307

TIMEHISTORYPLOT,ATSWATCORNER



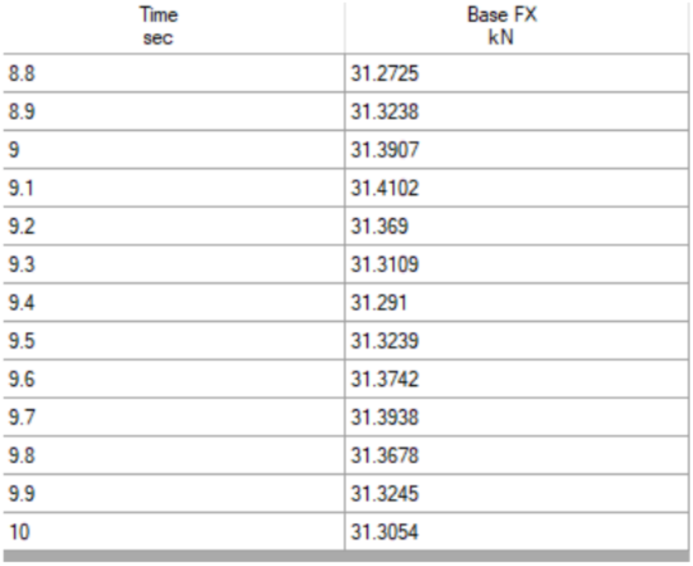
Story	Elevation m	Location	X-Dir mm	Y-Dir mm	X-Dir Min mm	Y-Dir Min mm
Story5	15	Top	0	5.121E-10	-0.02	0
Story4	12	Top	0	1.917E-10	-0.016	-1.37E-12
Story3	9	Top	0	1.745E-10	-0.012	0
Story2	6	Top	0	1.395E-10	-0.007	-1.102E-...
Story1	3	Top	0	9.283E-05	-0.002	0
Base	0	Top	0	0	0	0

Storyresponseplot(swat corner)



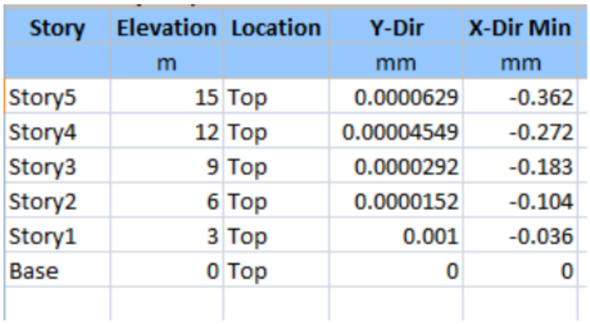
Story	Elevation m	Location	X-Dir mm	Y-Dir mm	X-Dir Min mm	Y-Dir Min mm
Story5	15	Top	0	2.456E-05	-0.317	-3.067E-...
Story4	12	Top	0	5.328E-05	-0.298	0
Story3	9	Top	0	5.808E-05	-0.26	0
Story2	6	Top	0	2.44E-05	-0.2	-9.355E-...
Story1	3	Top	0	2.223E-05	-0.089	0
Base	0	Top	0	0	0	0

STORYRESPONSEPLOT(INFILLWALL)



Time sec	Base FX kN
8.8	31.2725
8.9	31.3238
9	31.3907
9.1	31.4102
9.2	31.369
9.3	31.3109
9.4	31.291
9.5	31.3239
9.6	31.3742
9.7	31.3938
9.8	31.3678
9.9	31.3245
10	31.3054

TIMEHISTORYPLOT(INFILLWALL)



Story	Elevation	Location	Y-Dir	X-Dir Min
	m		mm	mm
Story5	15	Top	0.0000629	-0.362
Story4	12	Top	0.00004549	-0.272
Story3	9	Top	0.0000292	-0.183
Story2	6	Top	0.0000152	-0.104
Story1	3	Top	0.001	-0.036
Base	0	Top	0	0

Fig story response plot (sw at center)

The comparative study of THA clearly shows that structural configuration significantly affects dynamic seismic performance.

- SW at corner showed the least storey displacement and betterstability and it provide good seismic resistance.
- Infill wallmodelshowedmoderateimprovementinstiffnessandseismicresistance.
- SW at center performed better than a simple RCC frame but was less efficient than corner sw placement.

The reduction in displacement in the corner shear wall model confirms that proper shear wall positioning plays a critical role in resisting earthquake-induced lateral forces.Corner shear walls also help reduce torsional irregularity and improve force transfer.

From the TH response,it is evident that dynamic analysis provides a more realistic representation of structural behavior compared to static methods because it captures variation of base shear, displacement, and internal response with time.

Thus,the corner sw arrangement was found to be the most effective configuration for seismic resistance under Indian seismic loading conditions.

CHAPTER 8

CONCLUSION

This study aimed at investigating the seismic response of a G+5 reinforced concrete (RCC) building through PA and THA using ETABS program.

The aim of this study was to compare different structural arrangement like sw at corners, SW at central and RCC frame with in fill wall to find out how effective each of the searrangement is in resisting earthquake forces.

The results indicated the significant influence of the lateral load resisting elements on the overall stability and behaviour of the structured during earthquakes. The model with sw at the corners was best suited structurally of all the models investigated. This configuration resulted in better lateral stiffness, lesser storey displacement and drift and control of the torsion effects due to earthquake loading.

Comparative Study of Static and Dynamic Analysis of RCC Structures under Indian Seismic Condition

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