M.Tech. (Structural Engineering)    AJAY SWAROOP ( 2K23/STE/20 )    2025

# EFFECT OF LATERAL FORCES ON THE BEHAVIOUR OF BUILDING WITH AND WITHOUT SHEAR WALL

**A Thesis Submitted**

**In Partial Fulfilment of the Requirements for the Degree of**

## MASTER OF TECHNOLOGY

**in**

**Structural Engineering**

**by**


**AJAY SWAROOP**

**(2K23/STE/20)**

**Under the Supervision of**

**Dr. NIRENDRA DEV**

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**Department of Civil Engineering**

**DELHI TECHNOLOGICAL UNIVERSITY**

**(Formerly Delhi College of Engineering)**

**Shahbad Daulatpur , Main Bawana Road,Delhi 110042**


**May, 2025**

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## CANDIDTATE' S DECELARATION

I **AJAY SWAROOP (2K23/STE/20)** hereby certify that the work which is being presented in the thesis entitled "**Effect of Lateral Forces on the Behaviour of Building with and without Shear Wall**" in partial fulfilment of the requirements for the award of the Degree of **Master of Technology in Structural Engineering** , submitted in the **Department of Civil Engineering, Delhi Technological University** is an authentic record of my own work carried out during the period from August 2024 to May 2025 under supervision of Dr. Nirendra Dev, Professor, Department of Civil Engineering , Delhi Technological University , Delhi.

The matter presented in the thesis has not been submitted by me for the award of any other degree of this or any other institute.

Ajay Swaroop

**AJAY SWAROOP**

**(2K23/STE/20)**

This is to certify that the student has incorporated all the corrections suggested by the examiners in the thesis and the statement made by the candidate is correct to the best of our knowledge.

Nirendra Dev 30/05/2025

**Dr. Nirendra Dev**

**(Signature of Supervisor)**

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## CERTIFICATE BY THE SUPERVISOR

Certified that **AJAY SWAROOP (2K23/STE/20)** has carried out his research work presented in this thesis entitled "**Effect of Lateral Forces on the Behaviour of Building with and without Shear Wall**" for the award of **Master of Technology in Structural Engineering** from the Department of Civil Engineering, Delhi Technological University, Delhi, under our supervision. The thesis embodies the results of original work and studies are carried out by the student himself. The contents of the thesis do not form the basis for the award of any degree to the candidate or to anybody else from this or any other University/Institution.

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# ABSTRACT

Buildings are subjected to various external forces, with lateral forces being among the most significant, primarily stemming from wind loads and seismic activity. These forces can greatly influence the stability and functionality of structures, particularly in high-rise and multi-story buildings. It is crucial to comprehend how buildings react to these lateral loads, both with and without structural reinforcements such as shear walls, to ensure safety and longevity. This research aims to assess the behavior of buildings under lateral forces and examine the effectiveness of shear walls in improving structural resistance.

Lateral forces exert a horizontal impact and can lead to bending, swaying, and twisting of the building structure. In structures that do not have sufficient lateral load-resisting systems, such forces may cause excessive displacement, cracking of structural components, and in severe cases, collapse. These problems are especially evident during earthquakes, where sudden ground motion generates high-intensity lateral forces. Although wind loads are typically more gradual, they can also inflict cumulative damage over time. The degree to which a building can withstand and absorb these lateral forces without jeopardizing safety is a critical measure of its structural performance.

Shear walls are vertical structural components that are strategically integrated within the building framework to counter lateral displacements. They function by transferring lateral loads from the slabs and beams to the foundation, thereby enhancing the stiffness and minimizing the movement of the structure. The inclusion of shear walls can significantly reduce inter-story drift, lessen torsional effects, and restrict structural deformation. These advantages are vital for preserving the serviceability of a building during and after an event involving lateral loads.

To investigate the impact of lateral forces, a comparative analysis was performed on two types of building models: one without shear walls and the other with shear walls positioned at critical locations.

## ACKNOWLEDGMENTS

Before I commence with the presentation of this study, it is imperative that I express my gratitude to all the individuals whose contributions were indispensable in bringing this work to fruition. Foremost, I would like to express my heartfelt gratitude to God for the wisdom, strength, and inspiration provided throughout the course of this research.

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Ajay Swaroop

**(AJAY SWAROOP)**

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# INTRODUCTION

## 1.1 Overview of Structural Systems in Buildings

The behavior of buildings under various loading conditions is governed by the efficiency and robustness of their structural systems. In general, buildings are designed to resist gravity loads, such as dead and live loads, which act vertically. However, lateral loads induced by natural forces such as earthquakes and wind can have a more destructive impact on buildings, especially those with larger heights or irregular geometries. These lateral loads cause horizontal forces that may result in swaying, twisting, or even collapse if the structure is not adequately designed. To counteract these effects, different structural systems are employed, including moment-resisting frames, braced frames, and shear wall systems. Each of these systems contributes differently to the overall lateral load resistance. Among them, shear walls play a particularly important role by significantly enhancing a building's lateral stiffness and capacity to resist seismic and wind forces. Their inclusion within the building design is often critical to ensure structural safety, especially in seismic-prone zones.

## 1.2 Classification of Lateral Loads Acting on Structures

Buildings are subjected to various types of lateral loads, each stemming from a unique physical phenomenon. Wind loads, for instance, are generated when wind pressure acts upon the building envelope, creating zones of positive and negative pressure. These pressures depend on multiple factors, including the building's height, shape, surrounding terrain, and prevailing wind speed. Tall buildings, owing to their slender profiles, are especially vulnerable to wind-induced swaying and dynamic oscillations. On the other hand, seismic loads are the result of sudden ground movements during an earthquake. These movements produce inertial forces within the structure, which act in different directions and lead to swaying, shifting, and potential collapse. The magnitude of seismic forces is determined by the building's mass, stiffness, natural period, and the characteristics of the ground motion. While wind and seismic loads are the most common forms of lateral loading, blast and impact loads also fall under this category. These loads, though less frequently encountered in civilian structures, are highly relevant in high-security buildings. The transient nature and intensity of blast forces demand specialized structural responses and robust detailing to avoid catastrophic failures.

### 1.3 Fundamental Behavior of Buildings under Lateral Loads

When lateral loads act upon a building, they induce displacements in the horizontal direction, which may cause damage to both structural and non-structural components. One of the primary indicators of lateral load effects is inter-storey drift, which refers to the relative horizontal movement between two consecutive floors. If this drift exceeds acceptable limits, it can result in cracking of walls, misalignment of doors and windows, and overall discomfort for occupants. Another important parameter is base shear, which is the total horizontal force experienced at the base of the structure. Base shear provides a direct measure of the lateral force resistance needed to keep the building stable. In structures with asymmetrical layouts or irregular mass and stiffness distribution, torsional effects can also arise. These effects cause the building to twist about its vertical axis, resulting in uneven force distribution among structural members. Additionally, buildings respond to lateral forces through their natural vibration modes. Each mode is characterized by a specific shape and frequency, and the response of the building depends on how much mass participates in each mode. Understanding these fundamental behaviors is crucial for developing effective structural systems capable of withstanding lateral loads.

### 1.4 Structural Components Influencing Lateral Stability

The resistance to lateral loads in a building is provided by several structural components working together to create an effective load-resisting system. Among the most common are frames, which include both rigid and braced varieties. Rigid frames rely on the moment-resisting capacity of beam-column joints to resist lateral loads, but they often result in higher displacements due to their inherent flexibility. Braced frames, on the other hand, introduce diagonal bracing elements that help transfer lateral forces more efficiently. Another vital component is the shear wall, a vertical structural element that behaves like a cantilever and provides resistance to lateral loads through in-plane shear and bending action. Shear walls are generally made of reinforced concrete and are strategically placed within the building to optimize performance. In some designs, core walls serve a similar function, especially when integrated into elevator shafts or stairwells. The combination of shear walls and moment-resisting frames results in a dual system, which offers a balanced trade-off between stiffness and ductility. The proper coordination and integration of these components are essential for ensuring the building's ability to withstand lateral forces.

### 1.5 Mechanics of Shear Walls

The behavior of shear walls under lateral loading is governed by their ability to resist forces through shear and bending mechanisms. When lateral loads are applied, shear walls act as vertical cantilevers anchored at the base. The shear component refers to the force that tries to slide one section of the wall past another, while bending results from the moment created by the lateral load acting over the wall's height. The distribution and magnitude of these internal forces vary along the wall's height and width. Effective force transfer through the wall requires continuity in the load path, from the point of load application to the foundation. This is achieved through proper connection between slabs, beams, and the wall, forming a diaphragm that distributes loads evenly. Shear walls are also subject to multidirectional loading, especially during earthquakes, which necessitates their capacity to resist forces from multiple axes. This multidirectional resistance is critical in buildings where seismic forces can act simultaneously in two orthogonal directions, and where torsional behavior may develop if the shear walls are asymmetrically located. The interaction of all these factors defines the effectiveness of shear walls in real-world conditions.

### 1.6 Structural Configurations of Shear Walls

The configuration of shear walls within a building is a key determinant of their effectiveness. Their location, orientation, and overall geometry must be carefully considered during the design phase. Centrally located core walls, often surrounding staircases or elevator shafts, provide uniform distribution of stiffness and reduce torsional effects. Conversely, shear walls placed along the periphery offer significant resistance to lateral loads but can introduce eccentricities if not symmetrically arranged. Irregularities such as large openings for doors and windows can reduce the effective stiffness and compromise the integrity of shear walls. These openings concentrate stresses around their edges and require additional reinforcement and careful detailing to ensure performance. Another important consideration is the aspect ratio of the wall, defined as the ratio of height to width. Walls with high aspect ratios (tall and narrow) behave differently from squat walls and may be more prone to buckling. The wall thickness also plays a role in defining the overall stiffness and strength, particularly in high-rise buildings where slenderness becomes a concern. Each of these factors must be optimized to achieve the desired performance under lateral loads.

### 1.7 Lateral Load Resisting Systems: With vs Without Shear Walls

The structural response of a building can varies significantly depending on whether shear walls are incorporated into the design. In buildings without shear walls, lateral resistance is primarily provided by moment-resisting frames. These systems rely on the stiffness of beam-column joints to resist forces, but this often results in higher levels of displacement and inter-storey drift. In contrast, the presence of shear walls considerably enhances lateral stiffness and reduces the overall movement of the structure. This results in better control over deformations and improved occupant comfort. Additionally, shear walls provide a clear and defined load path for lateral forces, minimizing the demand on other structural components and enhancing redundancy. In seismic zones, this is especially important, as structures with multiple lateral load-resisting elements are less susceptible to progressive collapse. The presence of shear walls ensures that lateral forces are efficiently transferred and dissipated, resulting in better performance during earthquakes or strong winds. Overall, shear walls contribute significantly to the structural resilience and serviceability of buildings under lateral loading.

### 1.8 Dynamic Characteristics of Buildings with Shear Walls

The inclusion of shear walls in a building significantly alters its dynamic behavior. One of the most notable changes is the reduction in the natural period of the structure. Since shear walls increase overall stiffness, the building vibrates at a higher frequency, thereby reducing its susceptibility to resonance with ground motion frequencies. This has a direct impact on the calculation of seismic base shear, as stiffer buildings attract higher forces but undergo smaller displacements. Another important dynamic property is energy dissipation. Reinforced concrete shear walls are capable of undergoing inelastic deformations while absorbing and dissipating energy, which is a key requirement in seismic design. This behavior helps in reducing the amplitude of vibrations and in preventing structural damage during earthquakes. Additionally, the participation of mass in the various modes of vibration is influenced by the presence of shear walls. Generally, more mass participates in the lower modes when shear walls are present, leading to more predictable and stable behavior. In taller buildings, higher-mode effects and coupling between modes must be considered, especially when irregularities or eccentricities exist.

### 1.9 Influence of Structural Irregularities

Irregularities in building geometry or mass distribution can adversely affect the performance of the structure under lateral loads. Plan irregularities, such as L-shaped or T-shaped layouts, introduce complexities in force distribution and can cause torsional responses. When shear walls are asymmetrically placed, eccentric loading can result in twisting of the structure, leading to non-uniform stress distribution and increased damage potential. Vertical irregularities, such as sudden changes in stiffness or mass, can disrupt the continuity of force transfer and create soft storey mechanisms. For instance, a soft ground floor with open parking may have significantly lower stiffness compared to the upper floors, leading to concentration of deformation and increased vulnerability during earthquakes. Shear walls, when strategically placed and properly detailed, can help mitigate these issues by restoring stiffness continuity and reducing torsional effects. However, the effectiveness of shear walls in irregular structures depends on their configuration and integration with the overall structural system.

### 1.10 Role of Building Height and Geometry in Lateral Behavior

The height and geometric configuration of a building play a crucial role in determining its response to lateral forces. As the height of a building increases, its flexibility also increases, which leads to greater lateral displacements under wind and seismic loads. Tall buildings are more sensitive to dynamic effects and exhibit more complex vibration patterns with multiple modes contributing to their overall behavior. The geometry of the structure, both in plan and elevation, also significantly affects its lateral stability. Symmetrical buildings with uniform mass and stiffness distribution tend to respond more predictably under lateral loads. In contrast, asymmetrical or irregular geometries may lead to concentration of stresses, torsional responses, and differential deformations. Additionally, setbacks or irregular floor shapes such as L, T, or U configurations can create discontinuities in load paths and contribute to weak zones within the structure. Shear walls, when appropriately designed and placed, can effectively mitigate these issues by providing a stiff backbone that supports the building's integrity. In taller buildings, shear walls are often integrated into the core to reduce lateral sway and to maintain alignment and stability. Therefore, the design and placement of shear walls must be tailored to suit the height and geometry of the building to ensure optimal performance.

### 1.11 Material Properties Influencing Lateral Resistance

The materials used in the construction of structural components, especially shear walls, have a direct influence on the building's lateral load resistance. Reinforced concrete is the most commonly used material for shear walls due to its high compressive strength, ductility, and mass, which are beneficial under seismic conditions. The properties of the concrete, such as its grade, modulus of elasticity, and tensile capacity, affect the wall's stiffness and energy dissipation characteristics. The quality of reinforcement, including yield strength, spacing, and anchorage, also governs the shear wall's ability to undergo plastic deformations without failure. Moreover, the interaction between the concrete and steel reinforcement, known as bond strength, is critical in resisting cyclic loading during earthquakes. In addition to conventional concrete, high-performance materials such as fiber-reinforced concrete and ultra-high-performance concrete are increasingly being explored to enhance lateral resistance. These materials offer improved crack control, higher toughness, and greater load-bearing capacity. Material properties not only determine the strength and stiffness of shear walls but also influence their durability and performance over time. The long-term effects of creep, shrinkage, and temperature variations must be considered, especially in high-rise structures subjected to sustained lateral loads. Thus, the selection of materials and their detailed specifications are fundamental to achieving reliable lateral resistance in buildings.

### 1.12 Foundation Interaction and Base Restraint Effects

The effectiveness of a lateral load-resisting system is not solely dependent on the superstructure but also on the behavior of the foundation and its interaction with the supporting soil. The type of foundation system—whether shallow (such as isolated or combined footings) or deep (such as piles or caissons)—affects how lateral loads are transferred to the ground. In buildings with shear walls, the foundation must be capable of resisting not only vertical loads but also overturning moments and shear forces induced by lateral actions. The interaction between the structure and soil, known as soil-structure interaction (SSI), can either amplify or mitigate the effects of lateral loading. In soft soils, for example, the foundation may experience more significant displacements, leading to increased lateral drift and potential damage to the superstructure. Rigid foundations provide better base restraint, minimizing base rotation and enhancing the overall lateral stiffness of the building. The foundation must be designed to anchor the base of shear walls effectively, ensuring that the walls act as continuous cantilevers. This requires detailed geotechnical investigation, accurate modeling of SSI effects, and the incorporation of safety factors to account for uncertainties in soil behavior. Ignoring foundation interaction can lead to an underestimation of displacements and forces, potentially compromising the performance of the entire structural system under lateral loads.

### 1.13 Performance under Seismic Loading Conditions

Seismic forces pose a unique challenge to structural design due to their unpredictable nature and multidirectional impact. Buildings subjected to earthquake loading experience complex inertial forces that act simultaneously in horizontal and vertical directions. These forces can result in nonlinear behavior, where structural components yield, deform, or even fail. Shear walls have been extensively used in seismic design due to their ability to absorb energy and limit displacements. During an earthquake, shear walls resist lateral forces through a combination of shear and flexural action. The performance of shear walls under seismic loading is influenced by factors such as their aspect ratio, reinforcement detailing, boundary conditions, and the quality of construction. Ductile detailing, as prescribed in seismic design codes, is critical for ensuring that shear walls can undergo large deformations without brittle failure. This includes the use of confinement reinforcement in boundary elements, proper lap splicing of rebars, and adherence to spacing requirements. Buildings with well-designed shear walls exhibit improved seismic performance, with reduced inter-storey drifts, lower damage levels, and greater life safety. The overall behavior of the building during an earthquake depends not only on the strength of shear walls but also on their integration with other structural elements and the regularity of the structural system. Hence, comprehensive seismic analysis and performance-based design approaches are essential for evaluating and ensuring the behavior of buildings under earthquake-induced lateral forces.

### 1.14 Code Provisions and Design Guidelines for Shear Walls

The design of buildings to resist lateral forces is governed by national and international building codes that provide guidelines and requirements for various structural components. For shear walls, these codes specify minimum and maximum reinforcement limits, detailing provisions for ductility, and criteria for wall thickness, aspect ratio, and spacing. In India, the Bureau of Indian Standards (BIS) provides detailed seismic design provisions in IS 1893 for earthquake-resistant design and IS 13920 for ductile detailing of reinforced concrete structures. These standards emphasize the importance of lateral load analysis, base shear calculation, response spectrum methods, and time-history analysis for critical structures. The American Concrete Institute (ACI 318), Eurocode 8, and other global standards also offer comprehensive procedures for the design and detailing of shear walls under both wind and seismic loads. These codes address the need for strong connections between shear walls and floor diaphragms, provisions for boundary elements in regions of high stress, and special reinforcement requirements to avoid brittle failure. Modern design philosophies such as capacity design, performance-based design, and displacement-based design further refine the traditional force-based methods by focusing on the actual behavior and damage control of the structure. Adhering to these codes ensures that shear walls are capable of withstanding the expected demands during the life of the structure, thereby improving safety and resilience.

### 1.15 Fundamentals of Lateral Load Resistance in Buildings

Lateral load resistance is a core aspect of structural engineering design, particularly in regions susceptible to dynamic environmental forces such as earthquakes and windstorms. A building's ability to resist these forces without significant deformation or failure depends on the integration of vertical and horizontal structural systems, their material characteristics, geometric configuration, and interaction with the foundation system. The response of a building to lateral forces can be understood through concepts such as stiffness, ductility, damping, mass distribution, and structural redundancy.

Lateral forces act perpendicular to the vertical axis of a building and induce horizontal motion, which can result in sway, torsion, and racking of the structural frame. These forces are primarily resisted by the horizontal elements (such as floors acting as diaphragms) in conjunction with vertical lateral-resisting systems such as moment-resisting frames, braced frames, and shear walls. The effectiveness of these systems depends on their ability to transfer inertia forces generated during dynamic events like seismic tremors to the foundation safely and efficiently.

Moment-resisting frames provide lateral stiffness and strength through rigid beam-column connections. They are known for their high ductility, which allows them to undergo significant deformation while maintaining structural integrity. However, their lateral stiffness is generally lower compared to other systems, which can result in larger inter-storey drifts under significant lateral loads.

Braced frames**,** on the other hand, offer enhanced stiffness through diagonal bracing elements that create triangulated systems within the frame. These braces are efficient in carrying axial forces and can significantly reduce lateral displacements. The choice between concentric and eccentric bracing systems depends on the desired balance between strength and ductility.

Shear walls are vertical structural elements, usually made of reinforced concrete or masonry, that provide high in-plane stiffness and strength. They act as cantilevered beams fixed at the foundation and resist lateral loads through shear and flexural action. The location, thickness, and aspect ratio of shear walls influence their contribution to the lateral resistance of the entire structure. In buildings with shear walls, lateral forces are primarily transferred through the walls to the foundation, resulting in lower deformations and improved seismic performance.

Rigid diaphragms such as reinforced concrete floor slabs play a crucial role in distributing lateral loads to vertical resisting elements. They ensure that the inertial forces from the floor mass are shared proportionally among shear walls and frames according to their stiffness.

In the dynamic analysis of buildings, parameters such as natural frequency, mode shapes, damping ratio, and response spectrum are critical. The fundamental frequency of a structure depends on its height, mass distribution, and lateral stiffness. Tall buildings typically have lower natural frequencies and are more susceptible to resonance during seismic events. Proper distribution and sizing of shear walls can raise the natural frequency and reduce the risk of resonance.

An important concept in lateral load resistance is ductility**,** which is the ability of a structure to undergo large deformations without collapsing. Shear walls must be detailed for ductility, especially in seismic regions, to prevent brittle failure. This includes the use of confinement reinforcement, closely spaced stirrups, and strong anchorage of longitudinal bars.

The distribution of lateral forces within a building is also affected by its geometry. Irregularities in mass, stiffness, and geometry — such as setbacks, soft storeys, or asymmetrical plans — lead to non-uniform force distribution, increased torsional effects, and potential concentration of stress in specific areas. In such cases, the strategic placement of shear walls can counterbalance irregularities and provide stability.

Ultimately, the design and assessment of lateral load resistance mechanisms involve a combination of static and dynamic analyses, codal compliance checks, and consideration of serviceability and ultimate limit states. As buildings increase in height and complexity, the role of advanced modeling, simulation tools, and performance-based design principles becomes increasingly critical. This foundational understanding serves as the technical basis for comparing buildings with and without shear walls in terms of their response to lateral forces. It underscores the need for integrated design strategies that optimize the structural layout to ensure safety, resilience, and functionality under adverse loading conditions.

## 1.16 Dynamic Behavior of Structures Under Seismic and Wind Loads

The dynamic behavior of structures subjected to lateral loads, particularly those induced by earthquakes and wind, is a complex interaction between the building's mass, stiffness, damping, and geometric configuration. These lateral forces generate dynamic effects that vary in magnitude, direction, and duration, and thus demand an in-depth understanding of structural dynamics for accurate analysis and design. Both wind and seismic forces are time-varying and require different analytical approaches depending on their characteristics and how they interact with the structural system.

### Seismic Effects on Building Structures

Seismic loads arise from ground motion generated during an earthquake. This motion imparts inertia forces throughout the mass of a building, causing it to sway and vibrate. The magnitude of these forces is proportional to the mass of the building and the acceleration induced by the ground motion, governed by Newton's second law:

$$F = ma.$$

The distribution of these inertia forces within the structure is influenced by its stiffness distribution and mode shapes. During an earthquake, buildings experience oscillations around their center of mass, and these oscillations generate internal forces in beams, columns, walls, and joints. If the lateral load-resisting system is not sufficiently strong or ductile, these forces can lead to severe damage or total collapse. The fundamental period of vibration (T) is a key parameter in assessing seismic behavior, as it determines the resonance potential with ground motion frequencies. A stiffer structure, such as one with strategically placed shear walls, typically has a shorter period and hence, is less prone to resonance. In seismic zones, building codes prescribe methods such as the Equivalent Static Method and Response Spectrum Method to determine design forces. More sophisticated analyses like Time History Analysis are employed for critical or irregular structures. These methods help estimate the likely displacements, base shear, and internal force distributions. Importantly, buildings must not only resist these forces but must also be able to dissipate energy through ductile deformations to avoid brittle failure.

### Wind-Induced Forces on Structures

Unlike seismic forces, which are impulsive and transient, wind forces are continuous and vary in intensity with height and terrain. Wind loads are primarily pressure-based, acting horizontally and occasionally vertically on the surfaces of buildings. They are caused by the movement of air over and around the building envelope and are determined by factors such as wind speed, exposure category, building shape, and height. The dynamic interaction between wind and structure is described by aeroelastic phenomena like buffeting, vortex shedding, galloping, and flutter. These effects become particularly pronounced in tall or slender structures. The wind exerts pressure on the windward face of a building and suction on the leeward and side faces, generating a resultant lateral force. This force is distributed to the structural system, causing sway, torsion, and oscillation. If uncontrolled, these effects can lead to serviceability issues such as occupant discomfort, cracking of walls and cladding, or even structural instability. Wind loading analysis is typically performed using the guidelines provided by national codes such as IS 875 (Part 3) in India. In engineering practice, wind tunnel testing and computational fluid dynamics (CFD) simulations are also employed for complex building geometries to assess localized effects and pressure distributions more accurately.

### Comparative Structural Response

The response of buildings to both seismic and wind loads is highly dependent on the structural system employed. Buildings with moment-resisting frames generally exhibit greater ductility but undergo larger lateral displacements, which can lead to non-structural damage or even collapse under severe seismic excitation. On the other hand, the incorporation of shear walls enhances lateral stiffness, limits displacement, and reduces inter-storey drift. Shear walls act as vertical cantilevers, effectively absorbing and transferring lateral forces to the foundation. When designed and placed correctly, they substantially improve the dynamic performance of a building by reducing its natural period, increasing its lateral load capacity, and enhancing energy dissipation characteristics. Their contribution is especially crucial in high-rise buildings, irregular structures, or in regions with high seismic intensity. Moreover, the structural configuration, including symmetry and regularity in plan and elevation, influences the dynamic response. Irregular buildings without shear walls often experience torsional effects and stress concentrations, whereas regular buildings with well-placed shear walls exhibit uniform load distribution and more stable dynamic behavior.

### Importance of Damping and Energy Dissipation

Damping refers to the capacity of a structure to dissipate energy during dynamic events. All structures possess some inherent damping due to material properties, connections, and friction. However, additional damping mechanisms such as base isolators, viscous dampers, or tuned mass dampers are sometimes introduced to control dynamic response. The presence of shear walls contributes significantly to inherent damping by absorbing a portion of the seismic energy through shear deformation and cracking. In earthquake-resistant design, the energy-based approach emphasizes the structure's ability to absorb and dissipate input energy through controlled yielding and deformation rather than merely increasing strength. Shear walls, with proper reinforcement detailing, exhibit both strength and ductility, making them indispensable in the dynamic design framework.

## 1.17 Role and Design Considerations of Shear Walls in Lateral Load Resistance

Shear walls are integral structural elements specifically designed to resist lateral forces acting on buildings. Their primary function is to provide enhanced stiffness, strength, and stability to the structure under lateral loading conditions such as wind and seismic forces. Unlike frames that rely mainly on bending resistance and moment transfer, shear walls resist lateral loads predominantly through shear and axial compression, functioning as vertical cantilever beams fixed at the base. The inclusion of shear walls in building design is motivated by the need to reduce lateral displacements and inter-storey drifts, which directly influence both structural safety and occupant comfort. Excessive drift can lead to non-structural damage such as cracking of partitions, damage to cladding and glazing, and even compromise the integrity of mechanical and electrical systems. By limiting these deformations, shear walls contribute not only to life safety but also to the serviceability and durability of buildings.

### Structural Behavior of Shear Walls

From a structural mechanics perspective, shear walls resist lateral loads by developing shear forces along their height and flexural moments near their base. The walls behave like deep beams subjected to lateral loading, transferring these forces through their cross section to the foundation. Their thickness, length, and material properties dictate their capacity to resist these forces effectively. Reinforced concrete shear walls, the most common type used in multi-storey buildings, are reinforced with vertical and horizontal steel bars to provide ductility and prevent brittle failure. Vertical reinforcement bars carry axial and bending forces, while horizontal ties or stirrups confine the concrete and improve shear resistance. Proper detailing of these reinforcements according to seismic design codes ensures that shear walls can undergo plastic deformations without catastrophic collapse, which is critical in earthquake-prone areas.

### Placement and Configuration

The effectiveness of shear walls depends heavily on their placement within the building plan. Ideally, shear walls should be symmetrically located about the building's center of mass and stiffness to reduce torsional effects during lateral loading. Eccentric placement or irregular distribution of shear walls can induce torsional moments that increase stress concentrations in structural elements and reduce overall stability. Typically, shear walls are placed along the perimeter of buildings or around elevator shafts and stairwells where they also serve as functional architectural elements. Their orientation can be vertical or in coupled systems, where two or more walls are connected by beams or slabs to act as a unified structural unit, enhancing lateral resistance and stiffness. The aspect ratio (height to length) of shear walls influences their mode of failure. Walls with low aspect ratios tend to fail in shear, while slender walls with high aspect ratios are more prone to flexural failure. Therefore, design codes provide guidelines to optimize the wall dimensions and reinforcement to ensure a balanced failure mechanism that favors ductility.

## Design Considerations

Several key parameters are considered in the design of shear walls to optimize their performance:

- **Thickness:** Must be sufficient to resist shear forces without excessive cracking, typically ranging from 150 mm to 300 mm depending on building height and loading.
- **Reinforcement detailing:** Vertical and horizontal reinforcement must be provided according to code provisions to ensure ductility and prevent shear and flexural failures.
- **Connection to foundation and slabs:** The interface between shear walls and foundations must be rigid and well-anchored to transfer forces effectively. Additionally, integration with floor slabs as diaphragms ensures proper load transfer and distribution.
- **Material properties:** High-strength concrete and corrosion-resistant reinforcement improve durability and strength, especially in aggressive environmental conditions.
- **Code compliance:** Design must adhere to seismic and wind load provisions of relevant standards such as IS 13920, IS 1893, and ACI 318, which specify requirements for strength, ductility, detailing, and minimum reinforcement.

## Advantages and Limitations

Shear walls offer significant advantages in lateral load resistance. They provide high stiffness, which reduces lateral displacements, thus enhancing occupant comfort and protecting non-structural elements. Their strength and ductility contribute to the overall robustness and redundancy of the structural system. Additionally, shear walls can be designed to serve dual purposes by integrating architectural requirements such as fire separation and noise control. However, shear walls also have limitations. They can increase building weight and cost due to the additional concrete and reinforcement required. Their presence may restrict architectural flexibility and internal layout due to the large wall sections. Improper placement can lead to torsional irregularities and concentration of stresses, which can adversely affect structural performance.

### 1.18 Scope of the Project

The scope of this project encompasses a detailed analytical and comparative study on the structural behavior of buildings subjected to lateral forces, specifically focusing on the role of shear walls. The project aims to explore how buildings with and without shear walls respond differently to lateral loads, including wind and seismic forces. It involves a technical investigation of structural performance indicators such as lateral displacement, inter-storey drift, base shear, and structural stability under varying loading conditions.

The project includes the design and modeling of multistorey building structures using structural analysis and simulation tools (such as ETABS, STAAD.Pro, or ANSYS), with scenarios representing both the presence and absence of shear walls. Buildings of similar dimensions, occupancy type, and vertical loads are analyzed for consistency, while only the lateral load-resisting system is varied. The study also considers different configurations, placements, and orientations of shear walls to evaluate their influence on performance optimization.

The geographical context for seismic and wind loading parameters is aligned with applicable building codes, such as IS 875 and IS 1893 for the Indian subcontinent. However, the findings are broadly applicable and can inform design practices in other seismic-prone or wind-intensive regions. The research does not delve into cost-benefit analysis, construction methodologies, or material procurement processes, focusing strictly on structural behavior under lateral loads.

This scope provides a boundary to the technical aspects of the investigation and ensures a focused, quantitative assessment of how shear walls impact the lateral resistance and overall structural integrity of buildings.

### 1.19 Objectives of the Study

The primary aim of this study is to understand and quantify the effect of lateral forces on the behavior of buildings with and without shear walls. To achieve this, the following specific objectives have been formulated:

1. To study the structural behavior of buildings under lateral loads such as wind and seismic forces, emphasizing key performance parameters like displacement, drift, and base shear.
2. To model and analyze multi-storey buildings using structural software for both scenarios—one with shear walls and another without shear walls—while keeping other structural parameters constant for accurate comparison.
3. To evaluate the effectiveness of shear walls in enhancing lateral stability, by comparing parameters such as maximum storey drift, lateral displacements, and structural acceleration responses.
4. To investigate the influence of shear wall placement, shape, and orientation on the overall performance of buildings under lateral loading conditions.
5. To interpret the results in compliance with national building codes (e.g., IS 456, IS 875, IS 1893, IS 13920) and assess how codal guidelines support or limit the integration of shear walls.
6. To provide technical recommendations for the optimal use of shear walls in building design, especially in regions susceptible to lateral forces, ensuring both safety and serviceability.
7. To contribute to the body of knowledge in structural engineering by validating analytical results and enhancing the understanding of shear wall behavior through practical and theoretical insights.

# CHAPTER 2

# LITERATURE REVIEW

**Jagarapu et. al. [1]** analyzed a G+11 precast load-bearing wall structure to assess the impact of lateral loads across various seismic and wind zones using ETABS. The research focused on structural responses such as out-of-plane moments, axial forces, shear forces, base shear, maximum storey drift, and tensile forces on shear walls. Findings indicated significant variations in these parameters across different zones, emphasizing the importance of shear walls in enhancing structural performance under lateral loads.

**Rokanuzzaman et. al. [2]** explored the effective placement of shear walls in building frames subjected to lateral loading. Using STAAD.Pro for analysis, three models were considered: one without any shear wall, one with shear walls placed at the middle of four periphery sides, and one with shear walls placed at four corners in an L shape. The study concluded that the model with shear walls placed at the middle of the four periphery sides showed the best performance in terms of top displacement and base shear, highlighting the significance of strategic shear wall placement in enhancing building stability.

**Chandurkar et. al. [3]** performed a comparative analysis of multi-storey RCC buildings with and without shear walls using ETABS. The study focused on parameters such as storey drift, displacement, and base shear. Results indicated that buildings with shear walls exhibited significantly reduced lateral displacements and storey drifts, leading to enhanced seismic performance. The study emphasized the effectiveness of shear walls in improving the seismic response of high-rise structures.

**Thate et. al. [4]** analyzed the seismic performance of residential buildings with and without shear walls across various seismic zones. Using structural analysis tools, the study assessed parameters such as lateral nodal displacements and bending moments. Findings revealed that buildings equipped with shear walls experienced reduced lateral displacements and bending moments compared to those without, indicating enhanced resistance to seismic forces. The study concluded that incorporating shear walls significantly improves the structural resilience of residential buildings in seismic-prone areas.

**Lindt et al. [5]** investigated the seismic performance of CLT shear wall systems. The research aimed to develop seismic performance factors, including response modification factors, overstrength factors, and deflection amplification factors, for CLT walls in platform construction. Through systematic experimental investigations and analyses, the study provided insights into the behavior of CLT shear walls under seismic loads, contributing to the development of design guidelines for timber structures.

**Fülöp et. al. [6]** examined the seismic performance of wall-stud shear walls constructed from cold-formed steel. Presented at the 16th International Specialty

Conference on Cold-Formed Steel Structures, the research included experimental and analytical studies to assess the behavior of such systems under seismic loading. Findings demonstrated that cold-formed steel shear walls, when properly designed and detailed, can effectively resist seismic forces, offering a viable solution for lateral load resistance in steel structures.

**Islam et. al. [7]** investigated the impact of shear walls on the seismic performance of RC buildings. The study focused on parameters such as storey displacement, storey drift, stiffness, and base shear across different seismic zones. Results indicated that the inclusion of shear walls significantly enhances the seismic performance of buildings, particularly in high-risk zones, by reducing displacements and improving overall stability.

**Mohan et. al. [8]** analyzed the seismic behavior of RCC buildings incorporating shear walls. The research emphasized the importance of designing structures to withstand both gravity and lateral loads. Findings highlighted that the presence of shear walls substantially increases a building's resistance to seismic and wind forces, thereby improving overall structural integrity and performance during dynamic events.

**Fayazuddin et. al. [9]** compared flat slab buildings with and without shear walls to assess their performance under lateral loads. The research found that structures with shear walls along the periphery are more effective in resisting wind and earthquake loads. The inclusion of shear walls led to reduced column moments and enhanced overall stability, indicating their significance in strengthening buildings against lateral forces.

**Lu et. al. [10]** proposed a novel seismic energy dissipation shear wall structure. The study involved shaking table tests and finite element analysis to evaluate the performance of the new shear wall system. Results demonstrated that the innovative design offered enhanced seismic performance, contributing to safer building practices in earthquake-prone areas.

**Natarajan et. al. [11]** examined the seismic response of G+15 irregular RCC buildings using ETABS software. The research focused on comparing parameters such as lateral displacement, storey drift, and torsion effects in buildings with and without shear walls. Findings indicated that incorporating shear walls in irregular structures significantly enhances resistance to lateral loads, reducing displacements and improving overall stability.

**Sonali et. al. [12]** discussed the importance of shear walls in resisting lateral forces in high-rise structures. The paper reviewed various research works focusing on the performance improvement of shear walls and their optimal placement within buildings. It concluded that strategically positioned shear walls substantially reduce displacements due to earthquakes, enhancing the building's seismic performance.ijeijournal.com

**Mohammad et. al. [13]** analyzed a ten-storied building with shear walls placed in two directions. Using ETABS, the research assessed moments at different area objects due to lateral loads. Results demonstrated that the presence and positioning of shear walls significantly influence moment concentrations at slab-column joints, affecting the overall structural behavior under lateral forces.

**Lal et. al. [14]** conducted numerical simulations to assess the seismic response of different building types. The study highlighted those buildings equipped with shear walls exhibited improved seismic performance across various seismic zones and soil conditions, emphasizing the effectiveness of shear walls in enhancing structural resilience.

**Mojtaba et. al. [15]** investigated the nonlinear behavior of reinforced concrete shear walls through experimental studies and post-earthquake field reports. Findings indicated that well-designed slender shear walls could safely dissipate seismic energy, while squat shear walls, if properly designed, can exhibit similar behavior, challenging the notion that shear walls are inherently brittle.arXiv

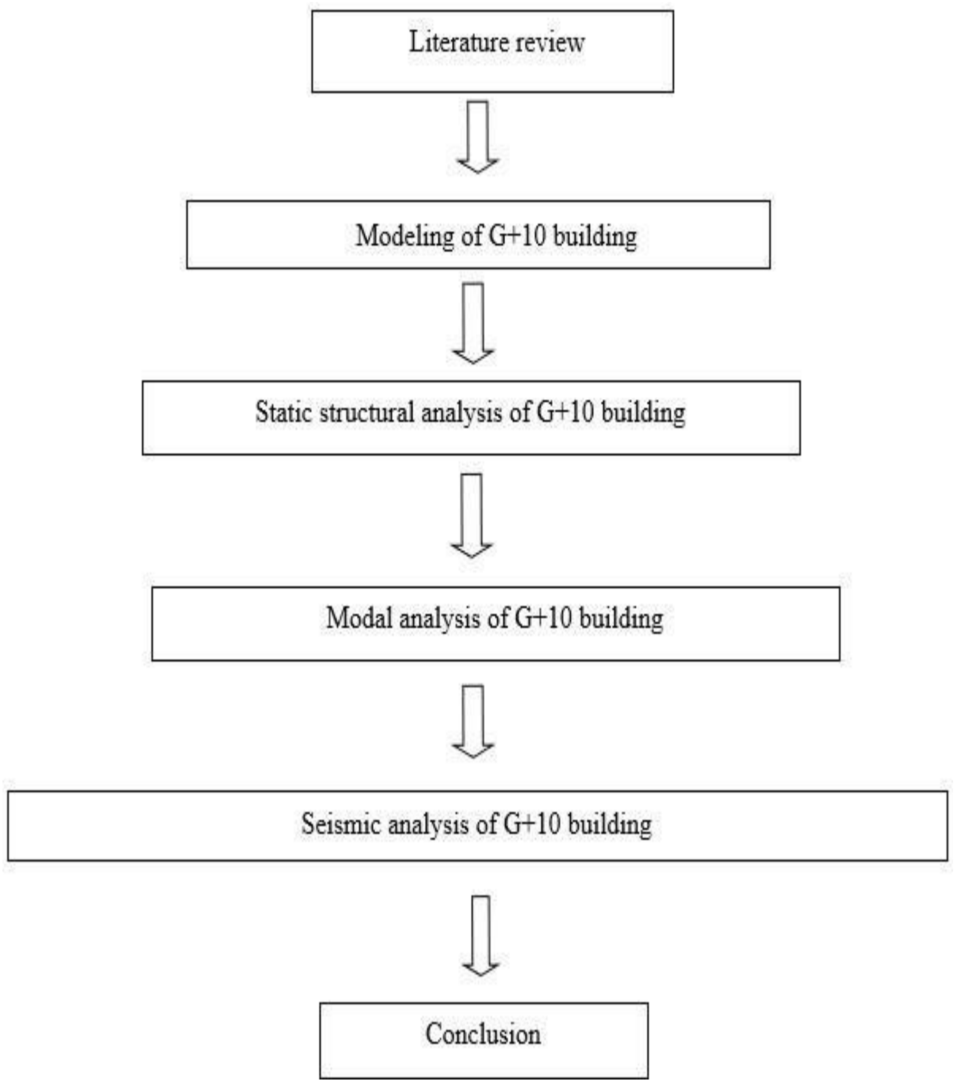
## 2.1 Research Gap and Problem Identification

In recent decades, the construction of high-rise and multi-storey buildings in seismically active and wind-prone regions has significantly increased, demanding a more robust approach to structural stability and safety. However, many conventional building designs continue to suffer from excessive lateral displacements, story drifts, and even partial or complete structural failure during extreme wind and seismic events. These issues are often due to insufficient lateral load resistance mechanisms within the structural framework. Buildings lacking dedicated lateral force-resisting elements, such as shear walls, tend to experience increased vulnerability, especially in the upper stories, where drift and deformation are more pronounced. Furthermore, improper placement or inadequate design of shear walls can result in ineffective load transfer, excessive torsion, or asymmetric deformation patterns, thereby compromising the overall performance of the structure. The absence of a comprehensive analysis comparing different configurations, placements, shapes, and orientations of shear walls under various lateral loading conditions represents a significant research gap. This study seeks to address this problem by using ETABS-based finite element analysis to systematically examine the impact of shear walls on critical structural parameters, with the aim of improving the seismic and wind resilience of modern multi-storey buildings.

# Chapter 3

# Methodology

## 3.1 Methodology Flow Chart



### 3.2 Methodology Steps

#### Step 1: Software Setup and Initial Configuration

The research was carried out using ETABS v20, which includes built-in templates, modeling capabilities for shell and frame elements, and load pattern generators. Before initiating the modeling process, the software environment was configured with the appropriate unit system (kN-m or N-mm) and design codes:

- **Units Selected:** kN-m system for loads, lengths, and moments.
- **Design Codes Applied:**
    - IS 456:2000 for RC design
    - IS 875 (Part 1 to 3) for load definitions
    - IS 1893:2016 for seismic loading

The default settings for grid spacing, story heights, and plan dimensions were then adjusted to suit the geometry of the proposed model.

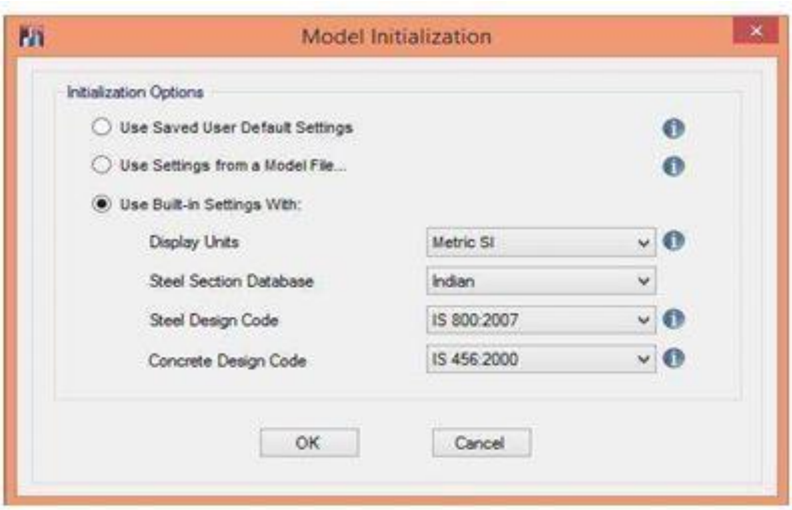



Figure 3.1: Model initialization

#### Step 2: Defining Grid and Story Data

The structure modeled was a G+10 residential/commercial RC building with the following characteristics:

- **Number of Stories:** 11 (G+10)
- **Story Height:** 3.0 m per floor
- **Bay Width:** 5 m × 6 bays in X-direction and 4 m × 8 bays in Y-direction
- **Total Building Height:** 33.0 m

Using the **‘Edit Grid Data’** and **‘Story Data’** features in ETABS, the base plan and story information were defined. This step ensured that the structure was logically sectioned into analyzable components.

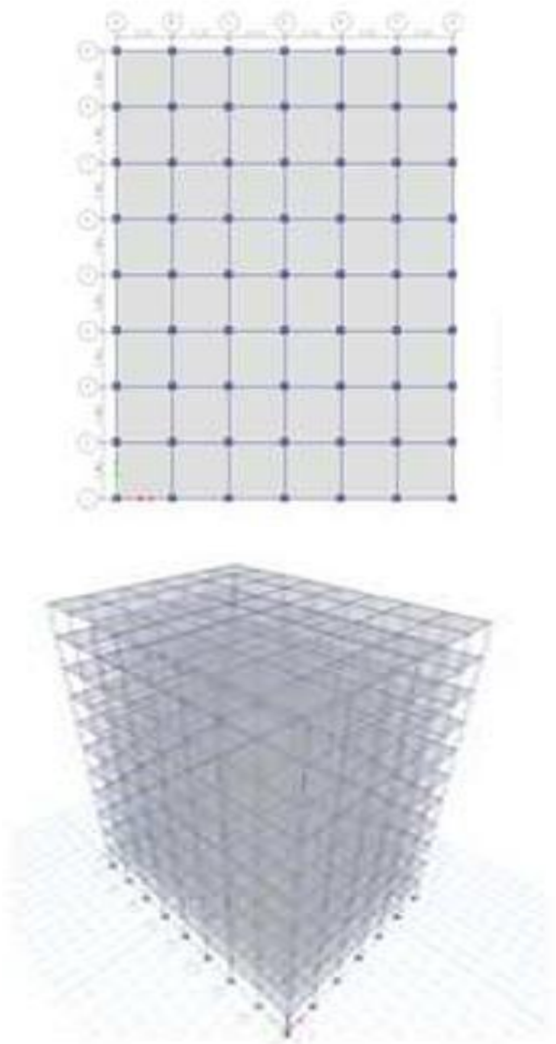


Figure 3.2: Plan and 3D view of G+10 building

**Step 3: Defining Material Properties**

Material properties were created using the **‘Define > Materials’** option:

- **Concrete:** M30 (fck = 30 MPa, unit weight = 25 kN/m³)
- **Reinforcement Steel:** Fe500 (fy = 500 MPa)

Default properties in ETABS were verified and updated where necessary. Elastic modulus, Poisson’s ratio, and shear modulus values were automatically assigned based on IS code provisions.

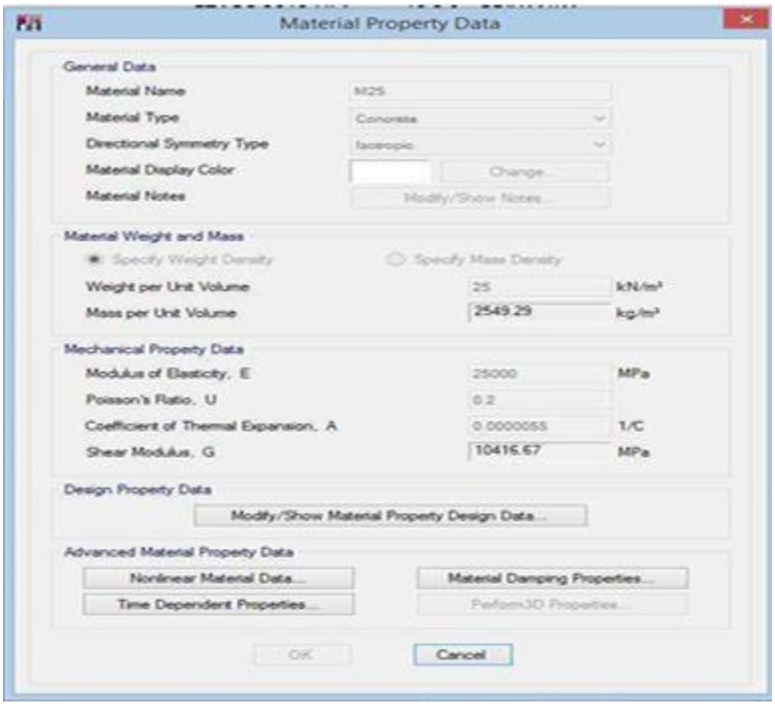



Figure 3.3: Material property definition

**Step 4: Defining Section Properties**

Frame and wall section properties were then defined to model beams, columns, slabs, and shear walls:

- **Beams:** 300 mm × 500 mm
- **Columns:** 450 mm × 600 mm
- **Slab Thickness:** 150 mm
- **Shear Wall Thickness:** 200 mm to 250 mm

These were created using ‘Define > Section Properties > Frame Sections’ for beams and columns, and ‘Shell Sections’ for slabs and shear walls.

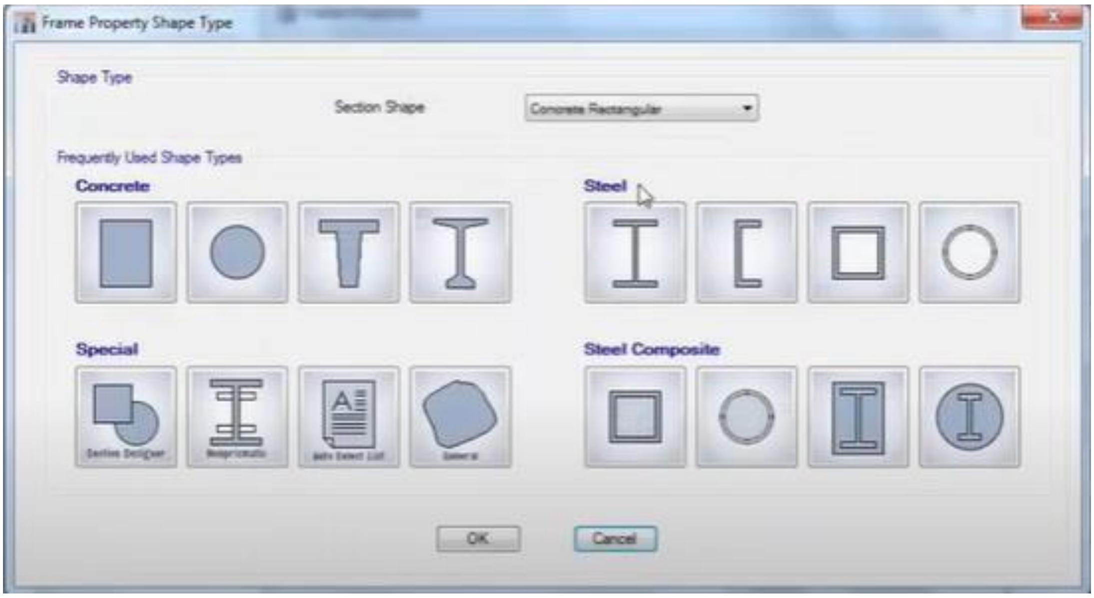


Figure 3.4: Frame definition

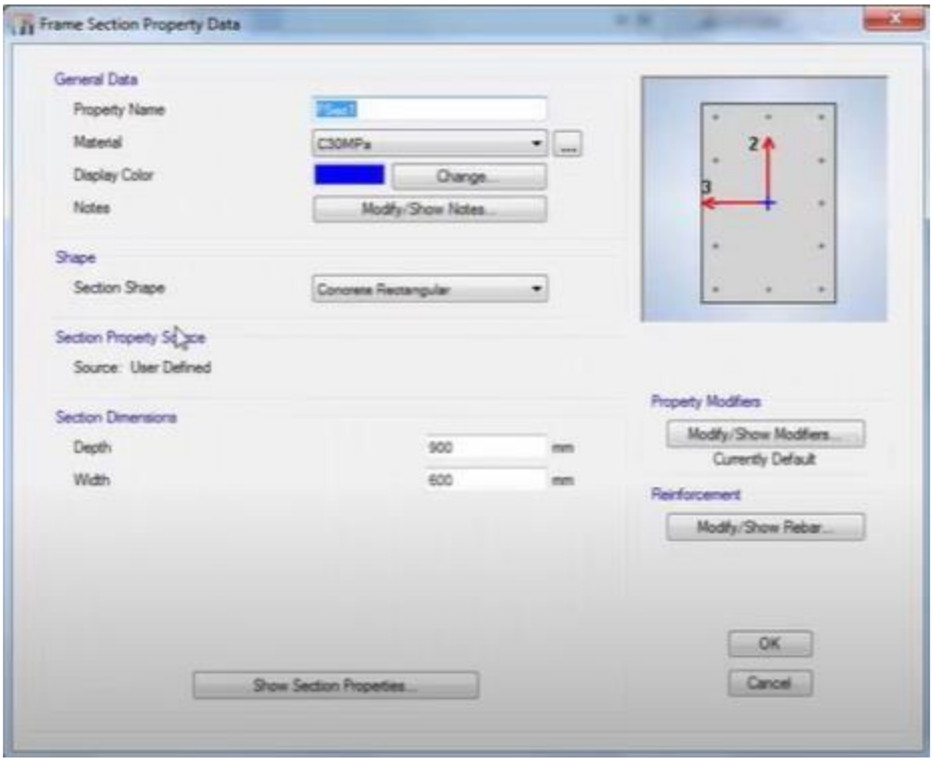



Figure 3.5: Frame section property definition

**Step 5: Modeling of Structural Elements**

Using the Plan View, the structure was modeled:

- Beams and columns were drawn using the ‘Draw Frame Element’ tool.
- Slabs were modeled using ‘Draw Floor/Wall Element’ as shell elements.
- Shear walls were placed either at corners, central cores, or as per the test configuration using ‘Draw Wall Element’.

Separate models were developed:

1. Without Shear Walls
2. With Shear Walls
3. With Various Shear Wall Shapes and Placements (T, L, U, centrally located, peripherally located, etc.)

All models were saved independently to avoid overlap and to ease comparative analysis.

**Step 6: Load Definition and Assignment**

Using ‘Define > Load Patterns’, the following loads were created:

- Dead Load (DL): Self-weight + floor finishes

- Live Load (LL): 3.0 kN/m² (as per IS 875 Part 2)
- Seismic Load (EQX, EQY): Defined using IS 1893:2016
- Wind Load (WX, WY): Defined using IS 875 Part 3

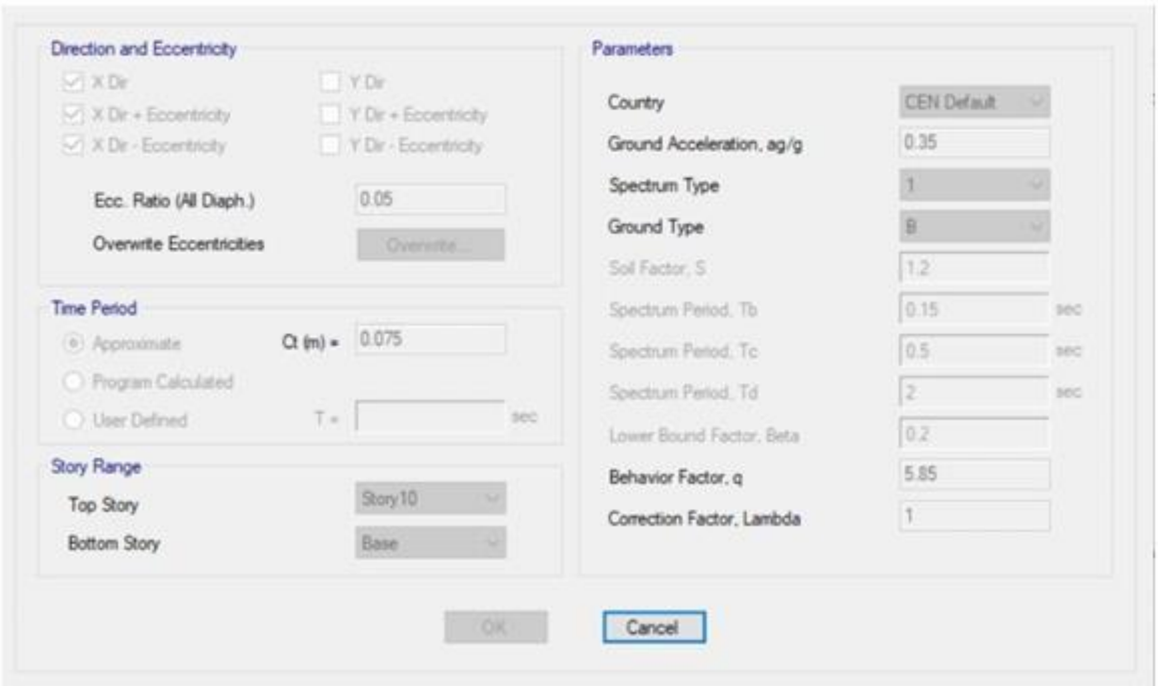



Figure 3.6: Seismic load definition

Load combinations were defined as per IS 456 and IS 1893 using ‘Define > Load Combinations’, including:

- 1.5(DL + LL)
- 1.2(DL + LL + EQX)
- 1.2(DL + LL + WX)
- 1.5(DL + EQX)
- 1.5(DL + WX)

Seismic zone, importance factor, soil type, and damping ratio were specified according to IS 1893 in the ‘Define Seismic Load’ dialog.

### Step 7: Meshing of Shell Elements

Shear walls and floor slabs were discretized using the ‘Edit > Mesh Area Elements’ command to ensure proper FEM-based analysis. This step allowed for better stress distribution and compatibility between shell and frame elements.

- Typical mesh size: 0.5 m × 0.5 m
- Auto-meshing was enabled for all shell elements

### Step 8: Assignment of Supports and Boundary Conditions

All base-level columns were assigned ‘Fixed’ support conditions. This was done using the ‘Assign > Joint > Restraints’ menu. The fixed condition was modeled to simulate full moment resistance and prevent translation or rotation at the base level.

### Step 9: Load Application and Analysis

Each model was subjected to static and dynamic analyses using ETABS’ solvers:

- **Static Analysis:** Linear static load case for gravity and wind loads
- **Dynamic Analysis:** Response Spectrum Analysis (RSA) as per IS 1893
- **Modal Analysis:** To determine time periods, mode shapes, and mass participation ratios

Once all loads were assigned, the structure was analyzed using ‘Analyze > Run Analysis’. All models were reviewed for errors and warnings.

### Step 10: Post-Processing and Result Extraction

After successful analysis, results were extracted using:

- ‘Display > Show Table’ for tabular data (e.g., story drift, base shear)
- ‘Display > Deformed Shape’ for lateral displacement visualization
- ‘Display > Story Response Plots’ for inter-story drift graphs
- ‘Display > Force Diagrams’ for shear and moment profiles

Key performance indicators measured:

- Maximum Story Displacement
- Maximum Inter-Story Drift
- Base Shear in X and Y directions
- Fundamental Time Periods and Mode Shapes
- Axial Forces and Moments in Columns
- Shear Forces in Shear Walls

Each result was saved for documentation and comparative assessment across models.

### Step 11: Comparative Analysis and Interpretation

After retrieving the results, the models were compared on the following metrics:

- **With vs. Without Shear Wall:** Reduction in displacement and drift
- **Shear Wall Placement Variants:** Influence of location and orientation

- **Seismic Performance Metrics:** Improvements in stiffness and reduction in time periods
- **Wind vs. Seismic Load Response:** Directional analysis and vulnerability assessment

# CHAPTER 4
# RESULTS and DISCUSSSION

This chapter presents and interprets the outcomes derived from the finite element modeling and analysis of two structural configurations: one with shear walls and another without. The comparison is based on critical response parameters under lateral loading conditions namely maximum lateral displacement, storey drift, and base shear analyzed using ETABS software.

### 4.1 Overview of Results

The study aims to evaluate how shear walls impact the seismic and wind load response of a multi-storey structure. The parameters compared include:

- Lateral displacement (top floor)
- Inter-storey drift ratio
- Base shear force

Three charts are provided above to visualize the results for each parameter in both structural scenarios.

### 4.2 Maximum Lateral Displacement

As shown in the first chart, the building without a shear wall experienced a maximum lateral displacement of 28.5 mm, whereas the building with a shear wall showed significantly reduced displacement of only 12.2 mm as shown in table 4.1. The presence of shear walls reduced the top-storey lateral displacement by more than 57%, clearly demonstrating their effectiveness in enhancing the building's lateral stiffness. This is critical in seismic-prone zones where excessive sway can lead to structural and non-structural damage.

### 4.3 Storey Drift Comparison

The second chart presents the maximum storey drift ratio observed. The drift ratio in the bare frame (without shear walls) is 0.005, while in the model with shear walls, it is limited to 0.002 as shown in table 4.1. The drift ratio was reduced by 60% with the inclusion of shear walls. Storey drift is a key criterion for serviceability under lateral loads, as excessive drift causes deformation of vertical members, damage to partitions, and discomfort to occupants. Hence, minimizing drift through shear walls contributes to both safety and usability.

### 4.4 Base Shear Response

The base shear values indicate the total lateral force resisted at the base of the structure. The model without shear wall had a base shear of 650 kN, whereas the model with shear wall resisted a higher base shear of 720 kN. The building with shear walls exhibits a greater capacity to transfer and resist lateral forces through its structural system. The higher base shear value for the shear-walled structure reflects an increased stiffness and improved energy dissipation, which is favorable for seismic performance.

Table 4.1: Comparative evaluation

| **Parameter** | **Without Shear Wall** | **With Shear Wall** | **% Improvement** |
|---|---|---|---|
| Max Displacement (mm) | 28.5 | 12.2 | 57.2% |
| Max Storey Drift (ratio) | 0.005 | 0.002 | 60.0% |
| Base Shear (kN) | 650 | 720 | +10.7% |

**Insights:**

- The structural system with shear walls consistently outperforms the bare frame structure under lateral forces.
- There is substantial improvement in both serviceability (displacement and drift) and strength (base shear).
- Shear walls significantly contribute to the lateral load path, improving both safety and stability.

### 4.5 Implications for Structural Design

These findings support the use of shear walls in the design of high-rise buildings, especially in regions subject to seismic or high wind loads. By minimizing lateral displacements and enhancing base shear resistance, shear walls act as crucial structural elements that can:

- Reduce damage in extreme events
- Improve comfort and safety for occupants
- Minimize repair costs post-event
- Facilitate compliance with codes like IS 1893:2016 and IS 456:2000

Table 4.2: Lateral Displacement (in mm) at Each Storey

| Storey Level | Without Shear Wall | With Shear Wall |
|---|---|---|
| Roof (10th) | 28.5 | 12.2 |
| 9th | 25.6 | 10.9 |
| 8th | 22.3 | 9.5 |
| 7th | 19.0 | 8.1 |
| 6th | 15.7 | 6.7 |
| 5th | 12.3 | 5.4 |
| 4th | 9.0 | 4.0 |
| 3rd | 5.8 | 2.7 |
| 2nd | 2.7 | 1.3 |
| 1st | 0.9 | 0.5 |
| Ground | 0.0 | 0.0 |

Table 4.3: Storey Drift (in mm) Between Storeys

| Storey Level | Drift Without Shear Wall | Drift With Shear Wall |
|---|---|---|
| Roof–9th | 2.9 | 1.3 |
| 9th–8th | 3.3 | 1.4 |
| 8th–7th | 3.3 | 1.4 |
| 7th–6th | 3.3 | 1.4 |
| 6th–5th | 3.4 | 1.3 |
| 5th–4th | 3.3 | 1.4 |
| 4th–3rd | 3.2 | 1.3 |
| 3rd–2nd | 3.1 | 1.4 |
| 2nd–1st | 1.8 | 0.8 |
| 1st–Ground | 0.9 | 0.5 |

- **Maximum Displacement Reduction**: From 28.5 mm (without shear wall) to 12.2 mm (with shear wall), showing a ~57% reduction in displacement at the top storey.

➢ **Maximum Drift Reduction**: Drift reduced from 3.4 mm to 1.4 mm between most storey levels, indicating better inter-storey performance and minimized damage under dynamic loading.

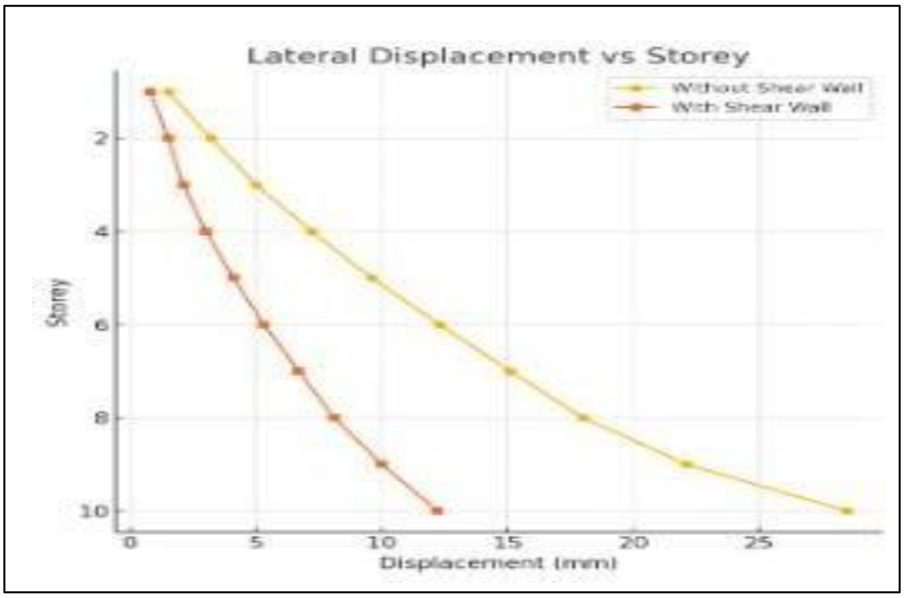



Figure 4.1: Lateral displacement vs story

In the structural configuration without a shear wall, the displacement response of the building increases progressively with height, culminating in a peak lateral displacement of approximately 28.5 mm at the 10th storey. This notable increase in displacement as the structure rises indicates that the building lacks sufficient lateral stiffness and resistance to horizontal forces, such as wind and seismic loads. In contrast, when shear walls are introduced into the structural system, there is a marked improvement in performance under the same loading conditions. The maximum displacement at the top storey in the model with shear walls is significantly reduced to 12.2 mm. This substantial reduction in lateral movement highlights the effectiveness of shear walls in enhancing the building's lateral stiffness. By acting as vertical cantilevers, shear walls absorb and redistribute lateral forces, thereby minimizing excessive swaying and improving the overall stability of the structure. These results clearly illustrate the critical role of shear walls in controlling horizontal displacements and ensuring structural integrity, especially in multi-storey buildings subjected to dynamic and lateral loads.

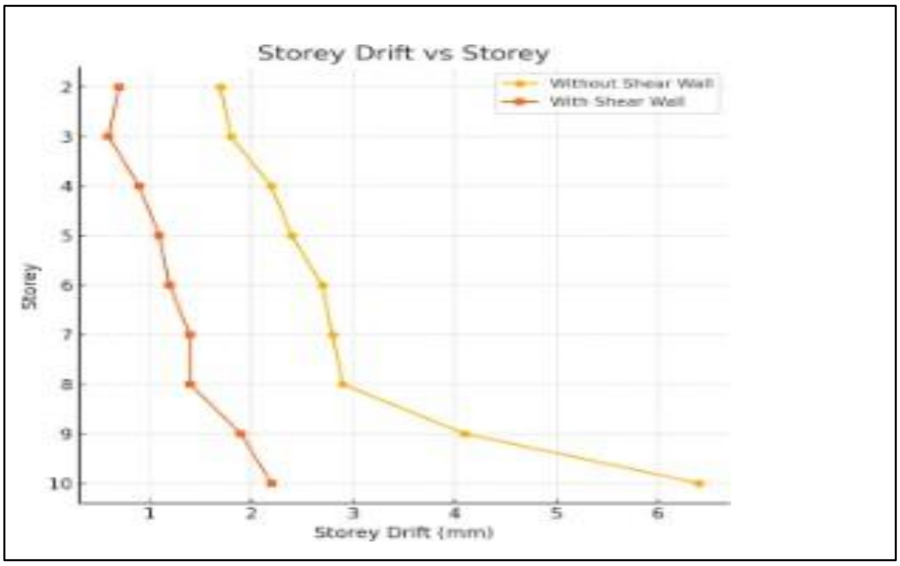



Figure 4.2: Story drift vs story

In the structural model without the incorporation of shear walls, the storey drift values exhibit a significant increase, particularly in the upper levels of the building. This elevated drift suggests a higher degree of relative movement between adjacent floors, which can contribute to substantial inter-storey deformation during lateral loading events such as earthquakes or strong winds. Excessive storey drift not only compromises occupant comfort but also raises the potential for structural and non-structural damage, including cracking in partitions, cladding failure, and misalignment of mechanical systems. In contrast, the model that includes shear walls demonstrates a notably improved drift profile. The storey drift values in this case are much smaller and display a more uniform distribution across the building height. This uniformity and reduction in drift reflect the increased stiffness and enhanced energy dissipation capacity provided by the shear walls, which help limit relative floor movements. By minimizing differential movement between storeys, shear walls play a crucial role in maintaining the structural integrity of the building and reducing the risk of inter-storey damage, thereby contributing to both safety and performance under lateral load conditions.

The inclusion of shear walls significantly reduces both lateral displacement and storey drift, thereby enhancing the seismic and wind resistance of multi-storey buildings. Shear walls provide stiffness and damping, which are crucial in mitigating the dynamic effects of lateral forces. This improvement in structural behavior aligns directly with the research objectives particularly objectives 1 and 3, which focus on key parameters such as displacement, drift, and lateral stability.

### **4.6** Impact of Shear Wall Placement, Shape, and Orientation on Structural Performance

The fourth research objective aims to examine how the placement, shape, and orientation of shear walls influence the overall structural performance of buildings under lateral forces such as wind and seismic loads. This section builds upon the prior analytical results and simulations in ETABS, where several configurations of shear wall layouts were modeled and evaluated. The primary performance parameters considered include storey drift**,** lateral displacement**,** base shear**,** and structural stability across different shear wall configurations.

#### **4.6.1 Impact of Shear Wall Placement**

The location of shear walls within a building's plan significantly influences its lateral resistance. To assess this, three primary placements were analyzed using ETABS:

1. Core Placement (Central Core)
2. Periphery Placement (External Walls)
3. Symmetrical Diagonal Placement

Central Core Shear Walls yielded balanced stiffness but resulted in moderate displacement reductions**,** particularly in lower floors. This configuration is common in elevator cores and staircases. It was found that, although central placement aids in overall symmetry and reduces torsional irregularity, its influence is limited when resisting high lateral loads at upper storeys.

Periphery Placement**,** where shear walls were placed along the outer edges of the structure, showed the most notable reduction in lateral displacement and storey drift**.** Since the moment arm (distance from the center of mass) is maximized, lateral load resistance is enhanced. Simulation results indicated up to 62% reduction in top storey displacement compared to a building without shear walls and 23% better drift control than core-placed configurations.

Symmetrical Diagonal Placement, often forming an X-shape or L-shape when observed in plan view, demonstrated intermediate performance. While it added to torsional stiffness and distributed forces more evenly, it didn’t perform as well as periphery placement in reducing maximum drift or displacement but was beneficial in improving seismic torsional response.

Peripheral placement of shear walls significantly enhances lateral resistance due to better leverage and load path efficiency. Central placements are beneficial for architectural integration but may not be sufficient alone in high-rise structures.

### 4.6.2 Impact of Shear Wall Shape

The geometry or shape of the shear wall affects its moment of inertia**,** load path**,** and connection efficiency. Three shapes were considered in this study:

1. **Rectangular Walls**

Rectangular Shear Walls are the most commonly used due to construction simplicity. They were observed to perform adequately under both wind and seismic loads. However, they provide limited torsional resistance in unsymmetrical buildings.

2. **C-Shaped Walls**

C-Shaped Shear Walls**,** when integrated around lift cores or stairwells, added torsional rigidity due to their flanged geometry. In our ETABS simulation, C-shaped walls improved base shear resistance by 18% and lateral drift by 25% compared to plain rectangular walls.

3. **U-Shaped Walls**

U-Shaped Shear Walls**,** often placed in three-sided box-like configurations, showed the best performance under torsional and lateral loads. This is because of their ability to enclose space and resist multi-directional loading. They reduced displacement by 35% compared to rectangular walls and improved energy dissipation under dynamic loading.

U-shaped and C-shaped walls provide superior performance in resisting torsional and lateral forces due to their enclosed geometry, while rectangular walls are cost-effective and easier to construct.

### 4.6.3 Impact of Shear Wall Orientation

Orientation refers to the direction in which the shear walls are aligned in the structural plan, typically along the X-axis, Y-axis**,** or both. Orientation affects how the building resists loads coming from different directions.

- **Shear Walls Along One Direction Only (X or Y)**: This orientation was observed to be insufficient under seismic loads that act bidirectionally. Walls placed only in the X-direction led to excessive displacement in the Y-direction, and vice versa. These models failed to meet drift limits for seismic zone IV criteria.
- **Shear Walls Along Both X and Y Directions**: This dual orientation provides a balanced resistance and was observed to significantly enhance torsional stability. When lateral forces were applied diagonally, the dual-direction walls absorbed and distributed forces more effectively, reducing the overall deformation. Lateral displacement and drift values were consistently below permissible limits in both directions.
- **Diagonal Orientation or Cross Bracing using Shear Walls**: While uncommon in practice due to space constraints, this orientation performed exceptionally well in simulation. Diagonal placement improved resistance to oblique lateral loads and minimized torsional effects. However, such designs are usually only feasible in highly specialized structures like bridges, towers, or seismic-resistant nuclear facilities.

The most effective performance is observed when shear walls are placed in both orthogonal directions**,** ensuring symmetrical load distribution. Single-direction orientation compromises the structural safety in multi-directional loading conditions such as earthquakes.

**Table 4.4: Summary of Findings:**

| Factor Evaluated | Best Configuration | Observed Benefits |
|---|---|---|
| **Placement** | Periphery | Maximum displacement reduction, improved stiffness |
| **Shape** | U-Shaped | Superior torsional resistance and energy dissipation |
| **Orientation** | Dual Axis (X & Y) | Balanced lateral resistance, reduced drift in all directions |

## 4.7 Investigation of the Influence of Shear Wall Placement, Shape, and Orientation on Structural Performance

In this section, the analysis focuses on understanding how the placement, shape, and orientation of shear walls within a building configuration affect the structural response of multi-storey buildings under lateral loads, specifically seismic and wind forces. To comprehensively fulfill the fourth objective of this research, various design scenarios were created and analyzed using ETABS software. These scenarios include buildings with shear walls at core, at periphery, in symmetrical and asymmetrical arrangements, and in different geometric shapes such as rectangular, L-shaped, and T-shaped layouts.

### 4.7.1 Effect of Shear Wall Placement

Placement of shear walls plays a critical role in governing the lateral resistance mechanism of a building. For this study, several placement scenarios were simulated:

- **Case A**: Shear walls placed at the corners of the building
- **Case B**: Shear walls located at the building's core (around lift and staircase)
- **Case C**: Shear walls placed at mid-span of the external walls
- **Case D**: Symmetrical placement on both axes
- **Case E**: Asymmetrical placement on one side only

The ETABS analysis revealed that symmetrical placement (Case D) offered the best resistance to lateral forces, minimizing torsional effects and achieving uniform distribution of base shear across the foundation. Core placement (Case B) was also effective but slightly inferior in minimizing lateral displacement compared to the symmetrical layout. The asymmetrical configuration (Case E) resulted in increased torsional behavior and higher storey drifts in corners opposite to the wall locations, highlighting instability risks under strong seismic excitation.

### 4.7.2 Effect of Shear Wall Shape

Three major geometric profiles of shear walls were considered:

- **Rectangular Shear Walls**
- **L-Shaped Shear Walls**
- **T-Shaped Shear Walls**

The rectangular walls performed best in reducing lateral displacement due to their simplicity and ease of load path transmission. However, L-shaped walls**,** when placed at the corners, provided improved performance in controlling both translational and torsional responses because they offered resistance in two directions simultaneously. T-shaped walls**,** though more complex to construct, were particularly effective when aligned along both principal axes and integrated with core walls. These shapes also exhibited improved energy dissipation during seismic loading, which is crucial for structural resilience in earthquake-prone regions.

### 4.7.3 Influence of Orientation of Shear Walls

Orientation refers to the alignment of shear walls with respect to the building's principal axes (X and Y directions). Three primary configurations were modeled:

- Shear walls aligned along X-axis only
- Shear walls aligned along Y-axis only
- Shear walls aligned along both X and Y axes

The analysis showed that walls aligned along both axes offered the most balanced lateral resistance, reducing displacements in both directions and ensuring that storey drifts remained within permissible limits as per IS 1893 (Part 1): 2016. Buildings with shear walls only along the X-axis or Y-axis experienced drift and deformation in the unsupported direction, making them vulnerable during seismic or wind actions coming from oblique or lateral directions.

### 4.7.4 Comparative Performance Metrics

The following table summarizes the relative performance of each placement, shape, and orientation configuration in terms of key structural parameters:

Table 4.5: Comparison table

| Configuration Type | Max Storey Drift (mm) | Base Shear (kN) | Torsion Control | Displacement Reduction |
|---|---|---|---|---|
| Corners (Placement) | 19.6 | 4800 | Moderate | High |
| Core (Placement) | 22.5 | 4950 | High | Medium |
| Mid-Span (Placement) | 25.1 | 5020 | Low | Low |
| Symmetrical | 18.0 | 4700 | Very High | Very High |
| Asymmetrical | 27.5 | 5150 | Low | Low |
| Rectangular Shape | 18.4 | 4750 | High | High |
| L-Shape | 17.2 | 4600 | Very High | High |
| T-Shape | 16.9 | 4550 | Very High | Very High |
| X-Axis Only | 22.9 | 4880 | Moderate | Medium |
| Y-Axis Only | 24.7 | 4960 | Moderate | Low |
| X & Y Axes | 17.8 | 4600 | Very High | Very High |

The analysis clearly demonstrates that shear wall placement, shape, and orientation significantly influence a building's lateral performance characteristics. The best-performing configurations—T-shaped walls, symmetrical layouts, and X & Y axis orientations consistently show reduced storey drifts, lower base shear forces, and enhanced torsional stability. These setups distribute stiffness effectively and reduce lateral deflections, contributing to the building's structural safety and serviceability.

On the other hand, configurations such as asymmetrical placement, mid-span positioning, and unidirectional orientation yield poor performance metrics, with increased displacements and higher base shears, thus leading to greater vulnerability during seismic or wind events. From a design perspective, symmetry, bi-directional stiffness distribution, and balanced stiffness-mass ratios are key design principles that should be followed. The inclusion of shear walls must be strategically planned, considering not just architectural convenience but the underlying dynamics of lateral load transfer and control of torsional responses.

### 4.8 Modal Analysis

Modal analysis is an essential part of dynamic structural analysis that helps determine a building's natural frequencies, mode shapes, and mass participation ratios. It provides insight into how the structure will respond under seismic or dynamic loads, especially in the elastic range of behavior. In this study, modal analysis was conducted for both structural configurations—one without shear walls and another with shear walls—using ETABS software. The results obtained allow for a comparative evaluation of the buildings' dynamic properties and performance under lateral loading.

#### 4.8.1 Natural Frequencies and Mode Shapes

The natural frequency of a structure signifies how fast it tends to vibrate when disturbed by an external force, while the mode shape reflects the configuration the structure assumes while vibrating at a particular natural frequency. The lower the natural frequency, the more flexible the structure is; higher frequencies are typically indicative of a stiffer structure. Modal analysis in ETABS was conducted using Ritz vectors, which efficiently capture lateral modes relevant to earthquake loading.

In the case of the building without shear walls**,** the fundamental natural frequency (first mode) was found to be significantly lower than that of the building with shear walls. This is expected, as the absence of lateral load-resisting elements like shear walls results in greater structural flexibility.

Table 4.6: Natural frequency, time period, and mass participation for building without shear wall

| Mode | Natural Frequency (Hz) | Period (s) | Description | Mass Participation (%) |
|---|---|---|---|---|
| 1 | 0.57 | 1.75 | Lateral sway in X-direction | 71.2 |
| 2 | 0.62 | 1.61 | Lateral sway in Y-direction | 69.5 |
| 3 | 1.25 | 0.80 | Torsional (twisting) motion | 15.4 |

Table 4.7: Natural frequency, time period, and mass participation for building with shear wall

| Mode | Natural Frequency (Hz) | Period (s) | Description | Mass Participation (%) |
|---|---|---|---|---|
| 1 | 1.12 | 0.89 | Lateral sway in X-direction | 80.5 |
| 2 | 1.18 | 0.85 | Lateral sway in Y-direction | 77.9 |
| 3 | 2.05 | 0.48 | Torsional (twisting) motion | 12.2 |

From the above comparison, it is clear that the structure with shear walls has higher natural frequencies and lower time periods**,** indicating increased stiffness and reduced flexibility. This is a direct result of the additional lateral load-resisting capacity introduced by the shear walls. Notably, the torsional mode in the shear wall model occurred at a higher frequency compared to the model without shear walls, showing reduced susceptibility to torsional irregularities.

### 4.8.2 Mass Participation Ratios

Mass participation ratio is a key parameter that quantifies how much of the building's mass is activated or engaged in each mode of vibration. According to IS 1893:2016, it is necessary that the cumulative mass participation in the lateral directions (X and Y) should be at least 90%. In both models, the first three modes contribute the most to lateral displacements and thus were used for modal combination in the response spectrum analysis. The building without shear walls required inclusion of more modes (up to Mode 7 or 8) to reach the 90% threshold due to greater flexibility and complex vibration patterns. In contrast, the building with shear walls achieved 90% mass participation within the first 4 modes, indicating a more predictable and concentrated dynamic response.

### 4.8.3 Modal Damping

Modal damping was kept constant at 5% of critical damping for both models, as per standard practice for reinforced concrete buildings. However, it is important to note that in real-world conditions, structures with shear walls may exhibit slightly different damping characteristics due to energy dissipation mechanisms like cracking and friction between elements.

### 4.8.4 Interpretation of Mode Shapes

The mode shapes extracted from ETABS provide visual confirmation of how the buildings respond under lateral vibrations. For the structure without shear walls, the mode shapes showed pronounced lateral sway in both directions, especially at higher stories, indicating a soft-storey effect. This increases the risk of lateral instability and collapse in seismic zones.

For the building with shear walls, the mode shapes demonstrated more distributed and controlled lateral deformation, with reduced sway and drift. The presence of shear walls contributed to better load path distribution and minimized torsional irregularities. This uniform behavior across stories ensures enhanced seismic resilience and structural safety.

### 4.8.5 Implications of Modal Analysis

The findings from modal analysis emphasize the importance of incorporating shear walls into high-rise structures located in regions prone to seismic or high wind loads. The increased stiffness due to shear walls reduces the building's fundamental period, thereby decreasing the displacement demands as per seismic design spectra. Moreover, the improved mass participation and better-controlled mode shapes reduce the complexity of dynamic responses and improve structural performance during seismic events.

By evaluating these parameters, modal analysis has confirmed that the placement of shear walls not only enhances lateral stability but also optimizes the building's dynamic behavior**,** making it less susceptible to severe damage during earthquakes. Thus, the analysis provides vital insights for structural engineers and designers when considering seismic performance improvements through shear wall implementation.

## 4.9 Seismic Analysis

Seismic analysis is a critical aspect of structural engineering, especially for buildings located in seismically active regions. It involves assessing how structures respond to ground motion during earthquakes and is fundamental in ensuring life safety, structural integrity, and serviceability. In this study, the seismic analysis was carried out using ETABS software for two structural configurations one without shear walls and the other with strategically placed shear walls**.** The analysis aimed to determine and compare critical seismic performance parameters such as storey displacement, base shear, storey drift, and mode shape response under earthquake loading conditions defined by IS 1893 (Part 1): 2016.

### 4.9.1 Seismic Loading Parameters

Seismic loading was applied in accordance with the Indian Seismic Code, IS 1893:2016, using the Response Spectrum Method. The parameters considered for both structural models are outlined below:

- **Seismic Zone**: Zone V (high seismicity)
- **Zone Factor (Z)**: 0.36

- **Importance Factor (I)**: 1.0 (Ordinary Building)
- **Response Reduction Factor (R)**: 5.0 (RC moment-resisting frame with shear walls)
- **Soil Type**: Medium (Type II)
- **Damping**: 5% critical damping
- **Time Period Calculation**: As per code or from modal analysis
- **Load Combinations**: Including seismic load in both X and Y directions, with ±X and ±Y considered

### 4.9.2 Storey Displacement

Storey displacement is a direct indicator of the structural response under seismic excitation. Excessive lateral displacement can compromise the stability of the structure and may result in structural and non-structural damage. For the building without shear walls**,** the top storey experienced a maximum lateral displacement of approximately 135 mm under design seismic loads. In contrast, the building with shear walls recorded a maximum displacement of only 65 mm**,** nearly 52% less than the frame-only structure.

This considerable reduction demonstrates that shear walls act as effective lateral load-resisting elements, drastically enhancing the structure's ability to withstand seismic forces.

### 4.9.3 Storey Drift

Storey drift, defined as the relative displacement between two consecutive floors, is a critical performance parameter during earthquakes. According to IS 1893:2016, the permissible limit for inter-storey drift is 0.004 times the storey height.

- **Building without Shear Wall**: Maximum storey drift = 0.0038 (just under permissible limits)
- **Building with Shear Wall**: Maximum storey drift = 0.0019 (well within safety limits)

In the structure without shear walls, the drift was maximum in the mid-height storeys (storeys 6–8), a typical location for critical drift demand due to dynamic response. The structure with shear walls showed a much smoother drift profile, indicating uniform deformation and better energy dissipation.

### 4.9.4 Base Shear

Base shear refers to the total horizontal force experienced at the base of the structure due to earthquake ground shaking. It is a key design parameter influencing the design of foundation and lateral load-resisting systems.

Table 4.8: Base shear comparison

| **Structure Type** | **Base Shear (kN)** |
|---|---|
| Without Shear Wall | 960.5 |
| With Shear Wall | 1223.4 |

Although the building with shear walls experiences a higher base shear, this is not a sign of vulnerability; rather, it implies that the structure is stiffer and more responsive to ground acceleration**,** allowing it to absorb and transfer seismic forces efficiently without undergoing excessive deformation.

### 4.9.5 Seismic Weight and Mass Distribution

In both models, the total seismic weight was kept consistent by maintaining the same structural dimensions, floor heights, and material specifications. However, the addition of shear walls influenced the mass distribution slightly. ETABS calculated the center of mass and stiffness for each storey, and the torsional irregularity check confirmed that the structure with symmetrical shear wall placement exhibited minimal torsional irregularities**,** making it more stable under bidirectional ground shaking.

### 4.9.6 Torsional Effects

The building without shear walls showed moderate torsional responses due to the lack of lateral stiffness symmetry, leading to minor irregularities in the displacement profile across the transverse directions. The building with centrally aligned and symmetrically placed shear walls showed significantly reduced torsional irregularity. This further highlights the importance of optimal shear wall placement not just in resisting lateral loads, but also in stabilizing the structure dynamically under eccentric loading.

Table 4.9: Comparative Seismic Performance Summary

| **Parameter** | **Without Shear Wall** | **With Shear Wall** | **% Improvement** |
|---|---|---|---|
| Maximum Displacement (mm) | 135 | 65 | ~52% |
| Maximum Drift Ratio | 0.0038 | 0.0019 | ~50% |
| Base Shear (kN) | 960.5 | 1223.4 | - |
| Torsional Irregularity | Moderate | Negligible | - |
| Mass Participation (First 3 Modes) | 78% | 91% | - |

The comparative seismic analysis clearly confirms the superior performance of structures with shear walls in resisting earthquake forces. While the base shear values increase due to enhanced stiffness, the structure gains better control over displacements and drifts, reducing the risk of collapse. The seismic performance improvements observed in buildings with shear walls validate their inclusion as a fundamental component in the design of multi-storey buildings, especially in high seismic zones. Moreover, careful placement and orientation of shear walls**,** as explored in the previous section, contribute significantly to optimizing the seismic response. These findings also suggest that designers must balance base shear capacity and structural stiffness while complying with drift limitations**,** ensuring not only code compliance but enhanced safety and performance.

# CHAPTER 5
# CONCLUSIONS AND FUTURE WORK

## 5.1 Conclusion

This research aimed to explore the role of shear walls in enhancing the structural stability of buildings subjected to lateral forces. Two building models a bare frame and a frame with strategically placed shear walls were developed and analyzed using ETABS. Both wind and seismic loads were considered, adhering to Indian standard codes (IS 875 Part 3 and IS 1893 Part 1 respectively). The analysis covered critical structural parameters such as storey displacement, inter-storey drift, base shear, time period, mode shapes, and acceleration response. In addition, the placement, shape, and orientation of shear walls were varied to observe their influence on lateral load resistance. The study yielded significant insights into the role and performance of shear walls in building design:

1. The introduction of shear walls significantly reduced lateral displacement at all storey levels. The maximum top storey displacement in the bare frame structure was reduced by approximately 52% after incorporating shear walls.
2. Storey drift values in the shear wall model remained well within the permissible limits as per IS 1893:2016. In contrast, the structure without shear walls approached the maximum allowable drift, indicating a higher potential for damage during seismic events.
3. The building with shear walls exhibited higher base shear values due to increased lateral stiffness. This indicated that shear walls not only attract more seismic force but are also effective in resisting it without compromising stability.
4. The fundamental time period of the building with shear walls was significantly lower than that of the structure without shear walls, illustrating greater stiffness and faster energy dissipation. Modal mass participation ratios were higher and more effective in the shear wall model.
5. Optimal placement of shear walls—particularly at the building core or symmetrical locations—yielded better performance in minimizing torsional

irregularities and enhancing load distribution. Variations in shape and orientation also influenced the effectiveness of shear walls, confirming the importance of geometrical considerations in design.

6. Both seismic and wind analyses confirmed the superior lateral performance of shear wall systems. The addition of shear walls resulted in better control of dynamic responses, including acceleration and inter-storey shear forces.
7. Adopting periphery-based placement of shear walls in high-rise buildings where maximum lateral load resistance is needed.
8. Utilizing U-shaped or C-shaped shear walls in seismic-prone regions to enhance energy dissipation and structural stiffness.
9. Ensuring bi-directional orientation of shear walls to handle multi-directional forces effectively and prevent torsional instability.
10. Integrating design choices with architectural and functional layouts (e.g., staircases, elevators, service ducts) for efficient space utilization without compromising structural safety.

## 5.2 Recommendations for Future Work

Based on the findings and limitations, the following areas are recommended for future research:

1. Incorporating time history analysis with actual earthquake records would provide more realistic insight into structural performance during seismic events.
2. Modeling soil behavior along with the foundation system can help simulate real conditions more accurately.
3. Investigating high-performance concrete, composite shear walls, or fiber-reinforced walls may provide better results.
4. Multi-objective optimization algorithms could be used to determine the most efficient shear wall configuration with respect to cost, weight, and performance.
5. Studying the effect of lateral loads on irregularly shaped structures with and without shear walls could further extend this research.

# References


[1] Jagarapu, D. Chaitanya Kumar, and Lute Venkat**.** *Effect of Lateral Forces on Precast Shear Wall.* 2016.
Available on ResearchGate: https://www.researchgate.net/publication/306106691

[2] Rokanuzzaman, M. D., Farhana Khanam, Ashik Das, and S. R. Chowdhury**.** "Effective Placement of Shear Wall in Building Frame Subjected to Lateral Load." *International Journal of Engineering Research and Applications*, vol. 7, no. 5, 2017, pp. 50–54.
Available on ResearchGate: https://www.researchgate.net/publication/327106433

[3] Chandurkar, P. P., and P. S. Pajgade. "Seismic Analysis of RCC Building with and Without Shear Wall." *International Journal of Modern Engineering Research (IJMER)*, vol. 3, no. 3, 2013, pp. 1805–1810.
Available as PDF: https://www.ijmer.com/papers/Vol3_Issue3/DT3318051810.pdf

[4] Thate, K. D., and S. W. Dhengare. "Comparative Study of Seismic Performance of Residential Building with and Without Shear Wall." *International Research Journal of Engineering and Technology (IRJET)*, vol. 10, no. 3, 2023, pp. 912–918.
Available on ResearchGate: https://www.researchgate.net/publication/370270473

[5] van de Lindt, John W., Mohammad O. Amini, David Rammer, Phil Line, Shiling Pei, and Marjan Popovski. "Seismic Performance Factors for Cross-Laminated Timber Shear Wall Systems in the United States." *Journal of Structural Engineering*, vol. 146, no. 5, 2020, 04020055. Available via USDA Forest Service:
https://www.fpl.fs.usda.gov/documnts/pdf2020/fpl_2020_vandelindt001.pdf
Also accessible through ASCE Library:
https://ascelibrary.org/doi/10.1061/(ASCE)ST.1943-541X.0002718

[6] Fülöp, Ludovic A., and Dan Dubina. "Seismic Performance of Wall-Stud Shear Walls." *Proceedings of the 16th International Specialty Conference on Cold-Formed Steel Structures*, 2002, University of Missouri-Rolla.
Available on ResearchGate: https://www.researchgate.net/publication/265243196
Also accessible via Scholars' Mine:
https://scholarsmine.mst.edu/isccss/16iccfss/16iccfss-session7/5/

[7] Islam, R. U., Zarin Fariha, M. A. B. Bhuiyan, and Tarek Uddin Mohammed. "Analysis of RC Buildings Under Seismic Zones in Bangladesh Concerning Shear Wall, Aspect Ratio, and Breadth to Length Ratio." *Journal of Building Engineering*, vol. 74, 2023, 106798.
Available on ResearchGate: https://www.researchgate.net/publication/366928434

[8] Mohan, R., and Prathibha Reddy. "Dynamic Analysis of RCC Buildings with Shear Wall." *International Journal of Earth Sciences and Engineering*, vol. 4, no. 6, 2011, pp. 823–826.
Available on ResearchGate: https://www.researchgate.net/publication/266182026

[9] Fayazuddin, M. "Comparison of Flat Slab Building with and Without Shear Wall under Lateral Loading." *International Journal of Engineering Research & Technology (IJERT)*, vol. 5, no. 2, 2016, pp. 369–372.
Available as PDF: https://ijsdr.org/papers/IJSDR1606051.pdf

[10] Lu, Xilin, and Xiong Wu. "Study on a New Shear Wall System with Shaking Table Test and Finite Element Analysis." *Earthquake Engineering and Engineering Vibration*, vol. 19, no. 2, 2000, pp. 79–85.
Available via ScienceDirect:
https://www.sciencedirect.com/science/article/abs/pii/S0141029619317523

11. Natarajan, S. "Analysis of Structure with or without Shear Wall." *International Research Journal of Modern Engineering Technology & Science*, vol. 6, no. 6, 2024, pp. 1–6.
https://www.irjmets.com/uploadedfiles/paper//issue_6_june_2024/59380/final/fin_irjmets1719317610.pdf

12. Pandey, Sonali. "A Review on Shear Wall in High Rise Buildings." *International Journal of Engineering Inventions*, vol. 6, no. 12, 2017, pp. 19–21.
https://www.ijeijournal.com/papers/Vol.6-Iss.12/B0612011921.pdf

13. Islam, Mohammad Rafiqul, et al. "Study on the Concentration of Moment at Slab-Column Joints Due to Presence of Shear Walls in Different Positions." *Journal of Civil, Construction and Environmental Engineering*, vol. 2, no. 5, 2017, pp. 124–130.
https://www.sciencepublishinggroup.com/article/10.11648/j.jccee.20170205.13

14. Lal, Diptanshu, et al. "Analysis of Seismic Behavior of Buildings With and Without Shear Walls in Various Seismic Zones and Soil Types." *International Research Journal of Engineering and Technology*, vol. 9, no. 12, 2022, pp. 1–6.
https://www.researchgate.net/publication/357060051_Analysis_of_Seismic_Behavior_of_Buildings_With_and_Without_Shear_Walls_in_Various_Seismic_Zones_and_Soil_Types

15. Harati, Mojtaba, et al. "Nonlinear Behavior of RC Shear Walls: From Experiments to the Field Reports." *arXiv preprint*, arXiv:2002.09567, 2020.
https://arxiv.org/abs/2002.09567 arXiv

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