Seismic Performance of Reinforced Concrete Buildings: A Study on Shear Wall Configurations and Filler Slab System

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Abstract. Reinforced concrete (RC) structures stand as enduring architectural elements which showcase exceptional strength and construction durability in their widespread usage. Earthquake-prone areas require evaluation of their seismic performance because these regions experience frequent seismic activity. The article examines how these structures respond to seismic activity by testing different shear wall designs and filler slab arrangements. The study aims to investigate the complete understanding of their operational functions to their beneficial effects which seismic protection systems can strengthen through their enhancements. The use of shear walls enables buildings to achieve higher stiffness while preventing excessive lateral movement through their lifter strength capacity. The material operates as a seismic protection system because it absorbs seismic energy through its permanent deformation process. Filler slabs function because they decrease the total building weight which results in decreased seismic force impacts and better energy dissipation for the structure. By improving their design, innovative materials like fiber-reinforced polymers (FRPs) and ultra-high-performance concrete (UHPC) have improved performance. Prefabricated modular construction introduces advanced quality control systems which shorten operational time by decreasing multiple construction phases. Evidence shows that shear walls and filler slabs work together to achieve maximum performance when facing earthquake threats. The study's findings indicate new directions for research, such as the use of performance-based design, smart materials and sensing technologies, and sustainable practices in seismic design. The improvements establish essential resources which develop safe RC structures that withstand seismic events without sustaining damage.

Keywords— Shear walls, reinforced concrete, infill slabs, prefabrication, seismic performance, and earthquake resistance etc.

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1 Introduction

Construction projects used reinforced concrete (RC) structures because they provided high strength with multiple application options and their construction expenses remained low. The building structural components use concrete which workers strengthen with steel bars or steel meshes to produce materials that have high compressive strength and enhanced tensile strength. Buildings situated in earthquake-prone areas encounter major challenges because their seismic load performance becomes their primary assessment factor. The seismic behavior of RC structures presents a significant challenge for researchers who need to study both the effects of seismic waves on building energy performance and the methods to prevent dangerous failures while protecting occupant safety.

Earthquakes create dynamic loads which result in ground shaking that produces strong horizontal and vertical forces which impact building structures. The structural design of RC structures must include ground shaking effects because the selection of materials and building details and architectural design will determine their ability to withstand earthquakes. The seismic performance of RC systems depends on three essential factors which include the building's stiffness and ductility and its capability to dissipate energy. The application of basic seismic design principles which establish proper reinforcement detailing and concrete confinement requirements as well as design specifications for structural elements like shear walls and filler slabs will enhance building capacity to withstand seismic forces.

1.1 The Shear walls with filler slabs' function in enhancing seismic resistance

The designers need to understand the fundamental impacts which shear walls and filler slabs provide, when they construct their seismic systems for all RC structures. A shear wall functions as a vertical building component which provides both lateral structural support and additional building strength, thereby increasing a building's ability to withstand horizontal seismic forces. Shear walls function as vertical cantilever structures which extend seismic input forces from a building's superstructure to its foundation, resulting in decreased lateral movements while improving overall structural integrity.

The three types of shear walls include coupled walls, cantilever walls, and core walls which provide unique benefits that designers can use to fulfill specific building design needs and earthquake protection standards. To improve ductility and energy dissipation, coupled shear walls are made up of two or more walls joined by coupling beams or slabs. Because the walls that reach from the foundation to the highest point of the structure are supported by the foundation base, cantilever walls provide buildings with significant lateral stability. Most buildings use core walls as structural elements which extend through their elevator and stairwell systems to provide primary structural support that helps the building resist twisting forces.

Filler slabs function as horizontal structural components which create floor and roof systems for reinforced concrete structures. The slabs consist of concrete together with lightweight filler materials which include hollow blocks and polystyrene and cellular concrete. The construction method eliminates building materials which results in lower overall building weight and therefore decreases seismic forces which act on the structure. The building achieves energy efficiency through its thermal and acoustic insulation improvements which create a comfortable environment for people who occupy the space.

The building system uses filler slabs to distribute seismic forces which results in decreased chances of partial structural failure. The additional weight reduction creates lower volume requirements for structural components like beams and columns. The structural components show improved performance during earthquakes. The combination of shear wall placement and filler slab usage in reinforced concrete structures provides an effective method for achieving balanced seismic design.

2 RC Structures' Seismic Reaction

2.1 Overview of Earthquake Forces and How They Affect RC Structures

Seismic waves develop from this energy release which leads to ground shaking. The following dynamic loads produce rapid oscillation and direction reversals which generate oscillations through the structures. The RC type of structures creates strong seismic forces which engineers need to design because these forces can cause their structures to break apart when hit by powerful forces. RC structures need to deliver sufficient lateral stiffness and strength because horizontal forces create lateral movement which must be controlled. The system requires thorough seismic design because vertical seismic forces multiply existing structural loads at certain components of the build.

2.2 Important Factors Affecting Seismic Reaction

RC constructions' seismic reaction is determined by a number of crucial factors. Steel's strength, ductility, combined durability determine a characteristic that controls its seismic performance. High strength materials provide enhanced resistance because ductile materials function as energy dissipators. The building system will operate according to its architectural design which includes dimensions and positions of beams and columns and shear walls and slabs. Seismic activities produce better structural performance for symmetrical regular configurations because these structures experience uniform stress distribution throughout their members. The structure's dynamic behavior depends on the mass distribution present within the building envelope. The uneven mass distribution will create torsional activity which will increase demands on specific structural components. The foundation system and soil characteristics determine how a structure transmits and dissipates seismic forces. Poor soil conditions cause seismic waves to intensify, increasing the forces that affect the structure. Lower seismic demands can be achieved by the structure absorbing energy through inelastic behavior, such as steel yielding with concrete cracking. The performance of systems will experience major improvements through both intrinsic and added damping mechanisms.

2.3 General Strategies for Improving Seismic Performance

The earthquake performance of RC structures can be improved through multiple strategies which organizations can implement. The application of high-performance materials will result in better strength and ductility performance. The advantages of fiber-reinforced concrete exist because this technology creates new possibilities for stronger materials. Structural engineers must develop building designs which combine regular shapes with symmetric patterns since these designs will create consistent stress distribution. The building will achieve substantial improvements in its lateral strength and stiffness through the installation of shear walls and bracing systems. The seismic design process requires engineers to establish proper reinforcement details through lap splices and anchorage and confinement. The design team must investigate all critical areas especially beam-column joints because they represent essential building points. The design decoupling process will lead to substantial impact analysis which will include base isolation systems that protect building components from ground shaking effects. Engineers need to install additional damping systems which include viscous dampers and tuned mass dampers to the building structure for vibration energy dissipation and displacement reduction. Through retrofitting techniques like adding more shear walls, steel braces, and external post-tensioning, the current building structure can improve its seismic resilience.

Table 1. Important Factors Affecting RC Structures' Seismic Response

Parameter	**Description**
Material Properties	Strength, ductility, and durability of concrete and reinforcing steel.
Structural Configuration	Layout and geometry, including placement of beams, columns, and shear walls.
Mass Distribution	Distribution of mass within the structure, affecting dynamic characteristics.
Foundation and Soil Conditions	Interaction with the foundation and soil conditions, influencing force transmission.
Damping and Energy Dissipation	Ability to dissipate energy through inelastic behavior and damping mechanisms.

3 Shear Wall in RC Buildings

3.1 Shear Walls' Function and Role

Shear walls are vertical structural components used in reinforced concrete buildings that offer defense against lateral stresses like wind and seismic activity. Because they provide various reinforced concrete systems with adequate lateral strength and stiffness, the components serve as the primary system that resists lateral forces. In order to maintain building stability and safeguard the structure during seismic events, the elements must transfer lateral load from the structure's floor and roofs to the base. The advantages of shear walls include multiple benefits which start with their ability to improve building lateral stiffness which decreases earthquake-related building movements. The structures possess exceptional strength which enables them to withstand lateral loads while maintaining their structural integrity. Shear walls enable seismic energy dissipation through their inelastic deformations which lead to reduced force transmission to other structural components. The structural elements perform two functions which include restricting lateral movement and providing stability to the structure thus preventing both drift and potential collapse.

3.2 Shear Wall Configuration Types

Several shear wall layouts can satisfy the project's functional needs and design restrictions. Coupled shear walls are made up of several shear walls joined by slabs or beams (coupling beams). Through coupling action, the connection type increases the stiffness and ductility of the shear walls. Without any intermediary supports, a cantilever shear barrier stretches vertically from a foundation to the roof. The construction provides significant lateral toughness and rigidity by acting as a vertical cantilever. Core walls, which usually encircle elevator shafts as well as stairwells to offer both torsional along with lateral support, make up a building's structural core. From the cornerstone to the roof, these walls are continuous.

Through a comparative analysis, the two layouts demonstrate their unique advantages and disadvantages. Because their connection beams undergo significant inelastic deformations during earthquakes, the linked shear walls provide enhanced earthquake performance through increased ductility and dissipation of energy capabilities. Because coupling beams directly affect the system's operational success, they need special consideration during the design phase. Because it is applicable to very tall structures, the criterion gives buildings the most lateral stiffness and strength. Although the cantilever a shear wall structure is one of the most straightforward to design and build, it is not as ductile as coupled systems.

The real core wall achieves exceptional resistance against lateral loads and torsional loads by combining the best engineering elements from both cantilever and linked wall systems. For extremely tall buildings, the core wall is the primary structural component; nevertheless, the intricate interaction between the core with the other structural elements makes the design process difficult.

Table 2. Comparative Evaluation of Shear Wall Designs

Configuration	Advantages	Disadvantages
Coupled Shear Walls	High ductility, good energy dissipation	Complex design and detailing, potential damage in coupling beams
Cantilever Shear Walls	High stiffness and strength, simpler design	Lower ductility, may require more material
Core Walls	Excellent lateral and torsional resistance	Complex design, interaction with surrounding elements

3.3 Design Factors

The efficiency of shear wall design against seismic forces depends on certain assumptions and requirements. High strength concrete, sufficient reinforcement, concrete's compressive strength (fc'), the yield strength of the reinforcement (fy), and the width to height ratio (aspect ratio) are among the design elements. Higher proportion ratios (tall and narrow) offer flexibility but less stiffness, whereas lower aspect proportions (short and wide) contribute to enhanced lateral stiffness. Engineers use their design skills for effective ductility through longitudinal and transverse reinforcement which prevents brittle failure. The three elements of these systems include boundary elements and confinement reinforcement together with proper anchorage. A continuous load path exists when building elements connect to both foundation and roof systems for force transmission.

Shear wall performance during seismic events depends on multiple factors that determine its ability to withstand seismic forces. The axial load ratio, which defines the relationship between axial load and wall cross-sectional area, produces direct effects that change both stiffness and strength properties. Ductility reduction occurs when higher axial loads lead to increased capacity. Designers need to consider thickness because its increase results in greater stiffness and strength but also causes higher material weights and expenses. The door and window openings which reduce shear wall strength need to be reinforced properly to achieve necessary strength and stiffness requirements. The foundation needs to be understood because it creates a crucial connection to the building structure. A foundation design that lacks quality will create differential settlement problems which will decrease the effectiveness of shear walls.

The following formula can be used to determine a shear wall's shear capacity:

The importance of using shear walls for effective performance is highlighted by data from the efficiency of various earthquakes. The carefully planned shear walls reduced building damage while preventing structural collapse.

The equation defines nominal shear strength as Vn which depends on concrete compressive strength f' and wall width bw and wall depth d and reinforcement ratio ρv and shear reinforcement area Av.

The moment capacity can be found using:

The nominal moment capacity, denoted by Mn, is dependent upon As and fy as well as d and a.

One way to estimate the lateral stiffness of the wall is to:

The entire performance of a building is determined by the coupling beam rigidity and coupled shear wall strength.

3.4 Case Studies and Empirical Data

Huang et al. (2024) , claims that the literature evaluation uses real-world case studies and experimental research to demonstrate shear wall effectiveness during seismic testing. He examined the response to earthquakes of precast composite walls (PCWs) with various kinds of reinforced concrete bracing using numerical modeling techniques. The study's conclusions showed that various bracing arrangements significantly altered the mechanical properties of PCWs that were present in structures during the 1985 Mexico City Earthquake. Core walls are essential for high-rise construction, as evidenced by the similar performance of the buildings' core walls during the 1994 Northridge Earthquake, which increased the building's strength against both horizontal and torsional stresses. Various shear wall configurations that architects can employ in multi-story buildings are seen in Figure 1. The schematic illustration goes into detail about the walls' mutual reference and structure in relation to the entire building frame.

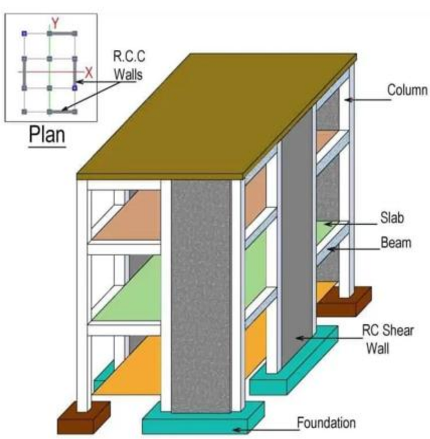

Fig. 1. Various shear wall layouts in a multi-story structure

Earthquake-resistant structures depend on walls to deliver lateral stiffness and strength and energy dissipation capabilities which enable the structure to maintain safety throughout seismic events The design of RC structures' shear walls determines their seismic performance, necessitating careful planning and examination of several variables that affect wall performance.

4 Filler Slabs for RC Buildings

4.1 Filler Slabs: Definition and Use

One type of floor slab used in RC buildings is called a filler slab. Hollow blocks, bricks, and lightweight concrete are used in the concrete slabs as filling materials. Non-structural a low-den filler materials are used to replace some of the cement in the tension zone. By requiring less concrete and steel, the initiative aims to lower construction costs without sacrificing structural integrity or load-bearing capacity.

These slabs provide a number of advantages for the system as a whole. Firstly, construction costs are lower since less concrete and steel are used, which lowers material and transportation expenses. By using these light filler substances during construction, the overall weight of the structure is reduced. The building's seismic performance improves as a result of decreased seismic forces. When compared to conventional solid slabs, the usage of filler slabs results in improved acoustic and thermal insulation performance that lasts for a shorter length of time. As a result, the occupants or users are more comfortable.

4.2 Materials and Types

Filler slabs are categorized according to their building techniques and choice of filler material. The most often used classification scheme separates them into:
• Hollow Block Slab: These slabs are filled with hollow blocks composed of clay, concrete, or other lightweight materials. Before the concrete is poured, the blocks are placed in between the reinforcement bars.
• Ribbed Slabs: Using lightweight components, the structure is made up of expanded ribs that run in a few different directions.The structure uses lightweight components and is made up of elongated ribs that run in a single direction or two.
• Brick Filler Slabs: Bricks are used as filler in these slabs, and they are placed in between the reinforcement bars.

Typical Materials and Their Characteristics:

Three features are shared by the above described materials. All of the materials that fit this criteria have three distinct qualities that define them:
• Hollow Concrete Block: These precast blocks with hollow cores offer superior thermal insulation and lower the slab's weight.
• Clay Blocks: Made of fired clay, these blocks provide superior acoustic and thermal insulation and are incredibly light.
• Polystyrene Blocks: Due to its exceptional lightweight and outstanding thermal insulation, polystyrene blocks are primarily utilized in ribbed slab constructions.
• Lightweight Concrete: The substance is made of concrete with ribbed slab gaps between the ribs created by light aggregates, which helps preserve structural integrity while lowering total weight.

Table 3. Characteristics of Typical Filler Materials

Material	**Density (kg/m^3)**	**Thermal Conductivity (W/m·K)**	**Acoustic Insulation (dB)**	**Cost (Relative)**
Hollow Concrete Blocks	1200 - 1500	0.72 - 1.0	45 - 50	Moderate
Clay Blocks	700 - 1000	0.25 - 0.35	50 - 55	High
Polystyrene Blocks	10 - 50	0.03 - 0.04	20 - 25	Low
Lightweight Concrete	1600 - 2000	0.3 - 0.4	40 - 45	Moderate

4.3 Design Factors

1) Design Standards and Principles

When designing filler slabs, engineers must adhere to a number of safety regulations while carrying out the necessary design concepts. Engineers need to design the slab system to distribute loads evenly across the entire slab area while they must position filler materials to occupy all nonstructural regions. Designers need to place reinforcement materials correctly because this method determines how well the design will withstand tensile forces and protect against cracking. Engineers need to find the optimal system for material use which will provide both structural effectiveness and material utilization. The design and construction process requires compliance with multiple standards which include ACI codes Eurocodes and national standards established by each specific country.

2) Considerations for Seismic and Structural Performance

The Filling Slab design and construction must meet requirements for both structural performance and seismic performance testing. The main requirements of the project include these two elements. For the slab to sustain both live and dead loads, it must exhibit the necessary flexural strength. Equation can be used to determine the moment of resistance. (2).

Shear Strength: It's crucial to make sure the slab can withstand shear stresses. The cutting capacity Vn is determined by.

$$V_n = 0..17 f'_c bd + \rho_v f_y A_v \tag{1}$$

Concrete compressive strength is defined by the conditions f' b d and ρv and Av.

The calculated deflections establish serviceability limits which need to be maintained through its calculation method:

$$\Delta = \frac{5wL^4}{384EI} \tag{2}$$

where Δ is the deviation, w is the load for each unit length, a L is the span's length, a E is the concrete's modulus of elasticity, and I is a moment of inertia.

4.4 Evaluation of Historical Earthquake Performance Information

To determine the benefits of employing filler slabs, performance records from previous earthquakes are helpful. For example, buildings using filler slab structures sustained less damage during the 2010 Chilean earthquake than buildings with solid slabs, mostly because the lighter structure was subject to less seismic power.

The construction of a rib filler slab, including concrete pouring, filling, and reinforcement, is shown in Fig. 2. It should display the placement of reinforcement as well as the volume of concrete that was dropped.

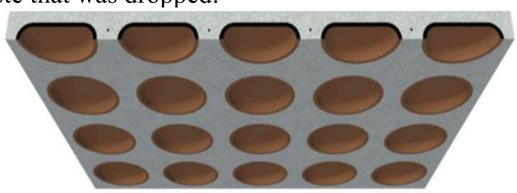

Fig. 2. Building a rib filler slab, demonstrating the concrete pouring, filler material placement, and reinforcement

Filler slab within RC constructions can be used to create extremely affordable, lightweight, and seismically resistant buildings. Given that these slabs have good seismic performance and save a significant amount of steel and concrete, they are a great option for contemporary construction.

5 Comparative Analysis

5.1 Seismic Performance Comparison of Shear Walls with Filler Slabs

When designing reinforced concrete (RC) buildings, shear walls and infill slabs are structural components that are practically necessary, especially in areas with high seismic activity. A small number of vertical components known as shear walls provide the significant lateral strength as well as stiffness required for this purpose by resisting the structural seismic activity. As a result, lateral displacements are reduced and structural collapse is prevented. Conversely, because fillers reduce weight, they can be used as lighter filler substance that fills the tense zone of slabs to reduce the overall forces of earthquakes acting on the structure.

One of the best methods for enhancing the lateral load-resisting design of RC buildings has been shown to be the seismic effectiveness of shear walls. Their main duty would be to function as vertical cantilevers, using their strength and rigidity to withstand lateral stresses. In addition to absorbing and dispersing the seismic energy produced during an earthquake through inelastic deformation that improves ductile performance, shear walls' high stiffness reduces lateral displacement.

In order to provide a continuous path of load between roof to base in terms of total structural integrity, shear walls are also attached to the roofing slab to withstand horizontal stresses brought on by lateral earthquakes with the base. Filler slabs alone would reduce the weight of the structure when added to the design, which would lower the seismic forces produced during an earthquake.

Filler slabs' contribution to performance following seismic activity is related to the structure's decreased mass, which would result in less seismic force generated during an earthquake. These filler slabs provide several benefits for seismic performance, including lower seismic demands because of their reduced bulk, better energy dissipation because of the tension zone's distributed cracking, and increased thermal and acoustical insulation, all of which improve the building's overall performance.

5.2 Benefits and Drawbacks of Every Method

The strong lateral rigidity and strength of these walls greatly increase a building's resistance to lateral loads. High ductility as well as energy dissipation characteristics accompany severe inelastic deflections. In the event of an earthquake, direct tensions along with transmissions provide excellent energy absorption and dissipation. Therefore, by offering constant load routes to the foundations, shear walls guarantee structural stability and frequently guarantee that earthquakes are effectively passed onto the base.

Shear barriers do, however, have certain disadvantages. Due to the need to purchase more personnel and materials, they may increase building costs. They may also place restrictions on architecture: This technique is not very flexible in terms of where the openings can be placed in the design.

Filler slabs now offer the following fundamental benefits: Initially, they result in a decrease in the overall weight of a structure. Naturally, this reduces the building's exposure to seismic pressures. Filler slabs use less steel and concrete, which lowers the overall cost of building materials. The use of a hollow core structure will result in higher both acoustic and thermal criteria for occupants compared to solid slabs.

Additionally, filler slabs have certain drawbacks. Since it doesn't add to the structure's lateral stiffness, it results in a considerable loss of stiffness. The construction process is made more difficult by the addition of filler materials, which typically need to be positioned precisely for best results.

Table 4. Comparative Evaluation of Shear Walls with Filler

Aspect	Shear Walls	Filler Slabs
Seismic Resistance	High lateral stiffness and strength	Reduces seismic forces through weight reduction
Energy Dissipation	High due to inelastic deformations	Moderate, distributed cracking
Structural Stability	Provides continuous load path	Limited contribution to lateral stiffness
Cost	Higher due to additional materials	Lower due to reduced concrete and steel
Architectural Flexibility	Limited due to placement constraints	Higher flexibility in design

6 Analysis and Modelling

The goal of this study is to maximize the seismic effectiveness of RC (standard reinforced concrete) buildings by examining the function of filler slabs and shear walls. After reviewing the literature on seismic resilience in reinforced concrete structures, structural models with different shear wall and filler slab orientations and locations are designed.

To mimic seismic effects, these models are subjected to Response Spectrum analysis using ETABS software. Important metrics are compared between models, including base shear, lateral shifting, and inter-story drift. In order to increase stability, safety, and cost-effectiveness in seismic design, suggestions are finally made for the location of shear walls and the usage of filler slabs.

The the ETABS program for buildings with moment-resistant structural systems located in earthquake zone V was used to analyze the G+10-story skyscraper.

Numerous earthquake metrics were acquired, including base shear, a top storey relocation, storey drift, and time period.

Because there are fewer columns in the building's grids, the building's stiffness and strength are lower along the Y direction, hence the building's study is limited to the Y axis. Table 1 below displays the different building model details.

6.1 Structural Data

Based on different parameters for this study, the numerous structural models of a ten-story height are built for the comparison analysis. The height of the storey is kept at 3.5 meters in all of models that are being examined. Because the bay width is preserved in both directions, the structural design is symmetrical in both directions.

ETABS software is used to model and analyze various structural configurations for each scenario.

For every scenario, a shear wall layout with various opening configuration models is compared to a traditional construction with the shear wall at the outer edge of the plan.

Create a model of a two-by-one-and-a-half-meter shear wall construction system with vertical and staggered openings. The various model types that were employed in this investigation are as follows:

Model I: Unopened shear wall construction.

Model II: The shear wall construction with a 2 m x 1.75 m vertical aperture.

Model III: The shear wall construction with a 2 m x 1.75 m staggered aperture

6.2 Loading Details

• All models are subjected to seismic loadings, and the actual load and floor finish load are calculated as 3kN/m2 and 1kN/m2, respectively.

• According to IS1893:2016 (part I), seismic loading is measured for every building. The parameters chosen for the earthquake load are,

Zone-V is the seismic zone.

• The seismic zone factor is 0.36.
• Shear wall structure is the type of structure.
• For ten stories, the storey height is 35 meters.
• The importance factor is 1.
• Response decrease is equal to five factors.

Description Type II (Medium - Stiff Soil) is the type of soil.

6.3 Load Combinations

IS 456: 2000 serves as the foundation for the strength requirements for force and moment load combinations. Load combinations for seismic and static loads are based upon IS 875 along with IS 1893.

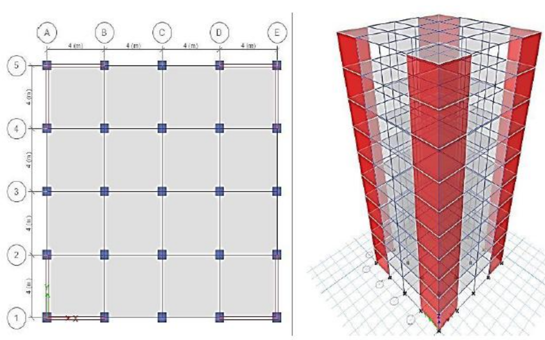

Fig.3. Shear wall structural plan and three-dimensional model without opening

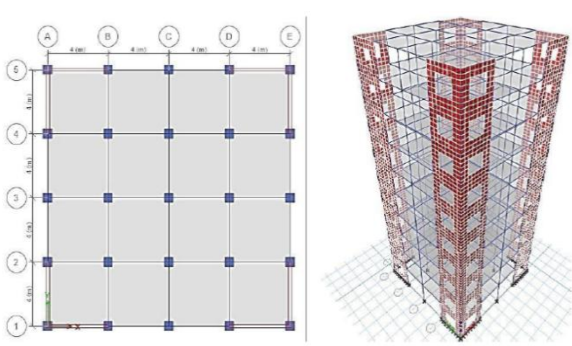

Fig. 4: Shear wall structure plan and 3D model with a vertical aperture of 2 m by 1.75 m.

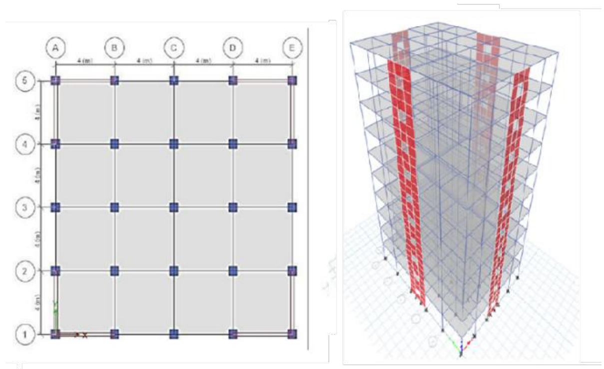

Fig. 5: Plan with 3D model of a shear wall construction with a 2 m x 1.75 m staggered aperture

Both linear static methods (Equivalent Static Technique) and dynamic methods (the Response Spectral Method) are used to examine structural models with different opening configurations.

The response spectral function is defined using a 5% damping factor, following IS 1893 (Part 1) – 2016.

These techniques are used to examine all of the models produced in ETABS 2017. Based on the findings, a comparative analysis will be conducted to determine the best outcome for the walls of shear structure system with various structural openings.

6.4 Filler Slab Construction

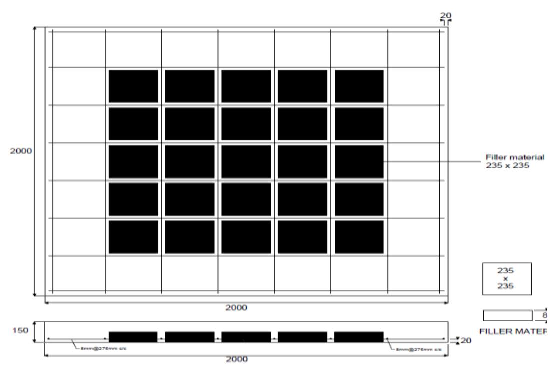

Fig. 6. Standard Filler Slab Design

The slab's shuttering is positioned and securely fastened. According to the slab design, reinforcing bars are positioned over the shuttering. Binding wire is used to secure these bars at each cross-section. To keep a space at the bottom between the bars, cover blocks are utilized. The shuttering is covered with filler blocks, leaving a 20 mm space between the reinforcement. The reinforcement is covered with prepared M20 grade concrete.

The concrete is compacted and air gaps are eliminated with a needle vibrator. After seven days, deshuttering should be completed. To reach maximum strength, curing are required to be conducted for 28 days.

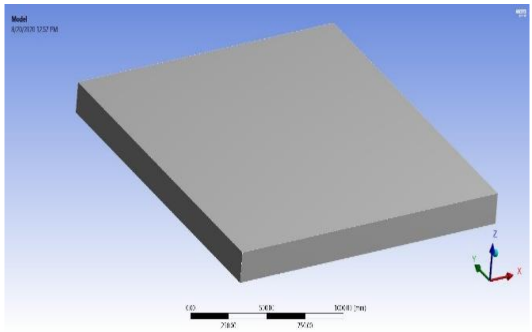

Fig. 7(a) Conventional slab geometry conditions

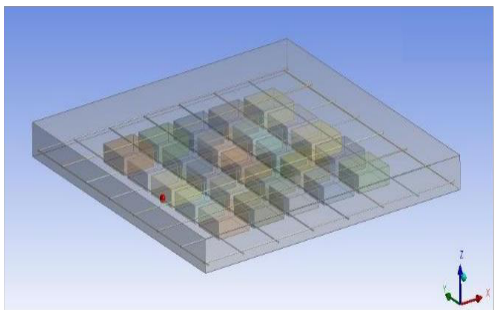

Fig. 7(b) The filler slab's geometry conditions

Table 5 displays the basic features of the a filler substance that were discovered through experimentation. [14]

Table 5. Properties of filler materials

Property	Granite dust	Foundry sand	Range as per Code	Acceptable or Not acceptable
Specific Gravity [1]	2.32	2.05	2 – 2.5	Acceptable
Moisture content [1]	1.45%	Nil	-	-
Cone penetration test (liquid limit) [2]	16%	5.04%	-	-
Bulking [1]	66.67%	18.75%	30 - 40	Not acceptable
Fineness modulus (Sieve analysis) [2]	1.62 (very fine sand)	2.3 (Medium sand)	2 – 3.5	Acceptable
Maximum Dry density (Proctor test) [3]	1.19 g/cc	1.75 g/cc	Around 1.182	Acceptable

1. IS 2386-3 1963 Concrete aggregate test methods.
2. IS 2386-1 1963 Concrete aggregate test methods.
3. IS 2720-5 1985 Soil Testing Procedures.

In order to optimize the overall performance of the RC structure during a seismic event, shear walls and filler slabs would be implemented in a synergistic manner, using the special advantages of both systems. Through integration, filler slabs can lessen the seismic weight placed on shear walls while also compensating for the stiffness loss caused by their utilization. Because the high strength and stiffness from the shear walls can be appropriately set off with corresponding weight reduction using the filler slabs to create an efficient and robust structure, this configuration will typically result in greater seismic performance. Naturally, these filler slabs utilize less steel and concrete, which lowers building costs without sacrificing structural integrity. Filler slabs with shear barriers will provide the necessary lateral resistance and flexibility for dimensional architectural design.

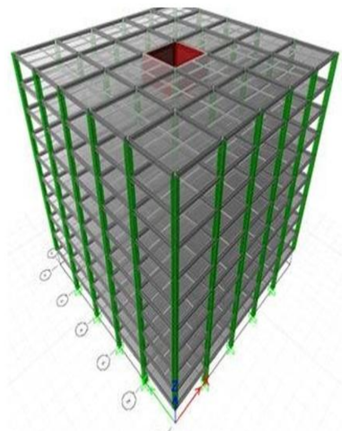

Fig. 8. Impact of mixing filler slabs and shear walls in a multi-story reinforced concrete structure

Figure 8 illustrates the synergy that results from integrating shear walls with fillers slabs in a multi-story reinforced concrete building. This should illustrate how shear walls as well as filler slabs interact, as well as the advantages of their combined mechanical transfer of load and weight reduction.

In this way, infill slabs and shear walls enhance the seismic performance of RC buildings. They both have advantages and limitations when used separately, but when combined, they can result in a design that is highly robust, cost-effective, and optimal. This enhances the building's overall performance, structural stability, and seismic resistance.

7 Results Analysis

Using a variety of techniques, including the Equivalent Stability Method (ESM), Reaction Spectral Method (RSM), and others, the outcomes of a shear wall building system with different opening configurations models are compared in regard to storey displacement, a storey drift, storey shear,, and time period. The results were only displayed in the straight line because of the identical outcomes attained as a result of the symmetry in the plans of the different models under examination.

Graphs and charts for model-1, model-2, as well as model-3 results in the context regarding time period, storey displaced, storey drift, as well as storey shear are included in this section.

7.1 Time Period

The time period vs. modal number graphs for models 1, 2, and 3 are plotted using the analogous static method. The models' period of time vs. mode number findings are displayed in Table 6, and time period vs. modal number variation is shown in Fig. 9.

Table 6. The models' period of time vs. mode number

Mode	Model-1	Model-2	Model-3
1	0.531	0.585	0.591
2	0.531	0.585	0.591
3	0.341	0.385	0.391
4	0.135	0.166	0.17
5	0.135	0.166	0.17
6	0.083	0.108	0.112
7	0.067	0.086	0.089
8	0.067	0.086	0.089
9	0.046	0.06	0.062
10	0.046	0.06	0.062
11	0.04	0.056	0.059
12	0.037	0.048	0.048

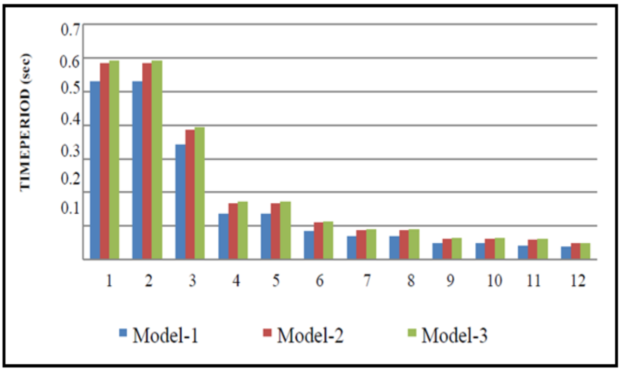

Fig. 9. Time interval versus mode number for various models

Table 8 displays the time duration for various modes for models 1, 2, and 3 based on the Equivalent Static Method. The findings indicate that mode-1 has the longest time period across all models. The time period rises when shear wall is given an opening; it is 0.531 seconds for a shear wall construction without an opening, 0.585 seconds for an upward opening, then 0.591 seconds for an staggered opening. Shear wall constructions with staggered openings have a longer time period with vertical openings and without openings than shear wall constructions with staggered openings.

7.2 Storey Displacement

The storey shifts for various storey graphs for models 1, 2, and 3 are plotted using the ESM and RSM. The maximum storeys displacement with each model at the highest point storey is displayed in Table 9, and Figs. 10 and 11 illustrate how storey displacement varies with storey level with ESM and RSM, respectively.

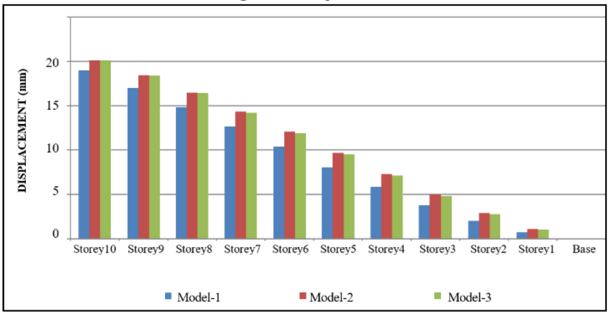

Fig. 10. Storey level versus storey displacement for various models by ESM

Figure 10 displays the results of the ESM study. The greatest displacement of a shear wall structure with a vertical entrance is 23.19 millimeters, that of a normal shear wall frame with no apertures is 21.443 millimeters, whereas and that of a shear wall structure with staggered apertures is 23.17 millimeters. Although the stagger open condition results in a less storey movement than a vertical opening condition, the results demonstrate that shear wall motion increases when apertures are present.

Table 7. Maximum Storey Movement (mm) at the highest floor

MODEL	Equivalent Static Method (ESM)	Response Spectrum Method (RSM)
Model-1	21.443	18.946
Model-2	23.19	20.161
Model-3	23.17	20.123

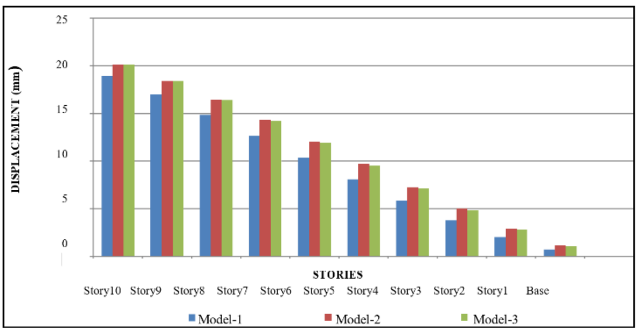

Fig. 11. Storey level versus storey displacement for various models by RSM

The largest displacement over a wall of shear frame without a standard opening is 18.946 mm, across a shear wall structure with a vertical aperture it is 20.161 mm, and over a fracture wall frame having a stagger opening it is 20.123 mm, as shown in Fig. 11. This implies that when a wall of shear is provided an opening, displacement increases. However, compared to shear wall structures with vertical openings, the storey displacement of shear wall structures with staggered openings is slightly smaller. The outcomes of RSM and ESM are similar.

7.3 Storey Drift

The Equivalent Static methodology and the reply Spectral method are used to plot storey drift vs. storey degree graph for models 1, 2, and 3. Table 8 shows how storey drift changes as storey level increases for various kinds by ESM or RSM. Storey drift increases with story degree for different models utilizing ESM and RSM, as shown in Figures 12 and 13.

Table 8. Storey level versus maximum storey drift.

MODEL	Equivalent Static Method (ESM)	Response Spectrum Method (RSM)
Model-1	0.000755(Storey-7)	0.00066 (Storey-6)
Model-2	0.000798(Storey-6)	0.000688(Storey-5)
Model-3	0.000806(Storey-6)	0.0007 (Storey-5)

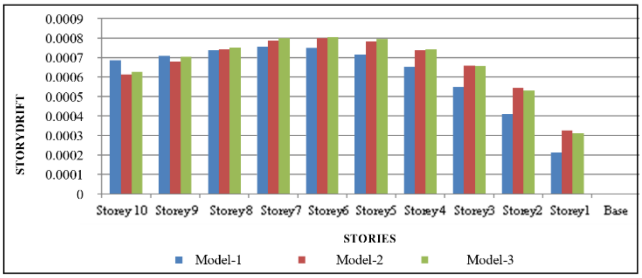

Fig. 12. Storey level versus storey drifts for several models by ESM.

Table 8 shows that the maximum amount of storey drift for various models occurs at different storey levels. This shows that whenever a shear wall with an aperture is provided, the largest storey drift moves towards the base in the two ESM or RSM situations. The greatest drift is 0.000755 for a shear wall building without an opening, 0.000798 for a shear wall design with a vertical opening, and 0.000806 for a shear wall design with a staggered opening, as shown in Fig. 12. This implies that when a wall of shear has an aperture, story drift increases. For staggered opening, storey drift is the highest for the entire model being evaluated.

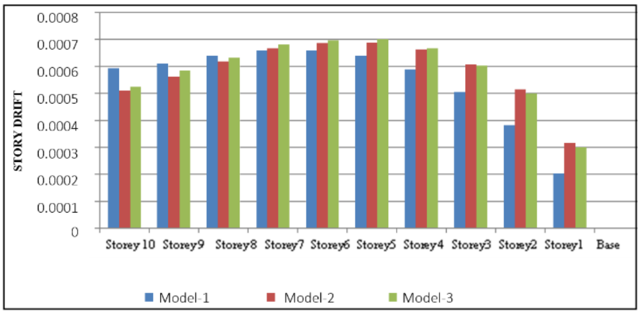

Fig. 13 Storey drift vs storey level for different models by RSM.

According to Fig. 13, the maximum drifting for a shear wall construction without an opening is 0.00066, with a shear wall design with a vertical opening it is 0.000688, whereas for a shear wall design with a staggered opening it is 0.0007. This suggests that when a wall of shear has an aperture, story drift rises. Storey drift is highest with staggered opening in the full model under evaluation. Both approaches yield comparable outcomes.

7.4 Storey Shear

Storey stress vs. storey altitude curves are plotted for models 1, 2, and 3 using the Equivalent Static approach and Response Spectrum technique. The models' maximum baseline shear values are shown in Table 9, and Figs. 14 and 15 show how storey drift changes with storey degree for a number of models using ESM or RSM, respectively.

Table 9: Base Shear for many models.

MODEL	Equivalent Static Method (ESM)	Response Spectrum Method (RSM)
Model-1	3684.0406	3683.4432
Model-2	3227.3181	3227.8819
Model-3	3256.4847	3257.4202

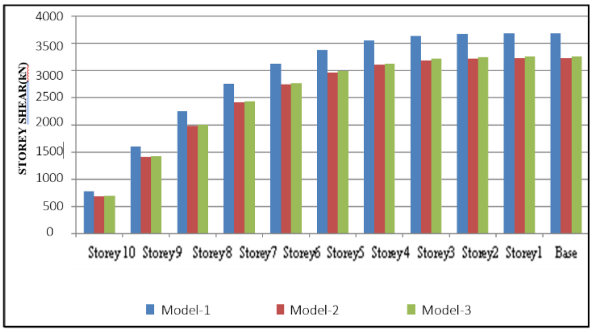

Fig. 14. Storey level versus storey shear for several models by ESM.

For shear walls without a standard opening, the maximum storey fracture is 3684.0406 kN; for shear walls with a horizontal opening, it is 3227.3181 kN; and for shear walls with a staggered opening, it is 3256.4847 kN. These numbers demonstrate that storey shear decreases when a shear wall has a regular opening, although it is more for staggered greenery than for vertical opening.

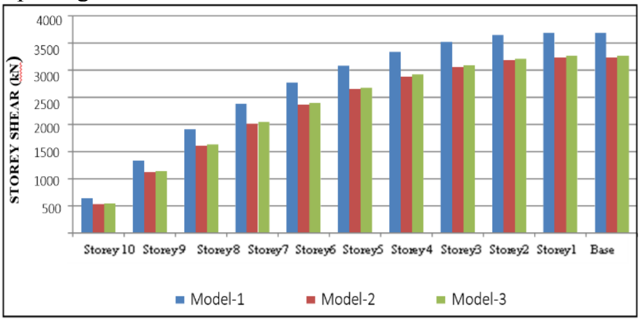

Fig. 15. Storey level versus storey shear for various models using RSM.

According to Fig. 13, the maximum storey fracture for a shear wall in a building with a standard opening was 3683.4432 kN, the highest storey shear with a shear wall structures with a vertical aperture is 3227.8819 kN, while the maximum story shear with a shear wall structure with an staggered aperture is 3257.4202 kN. This suggests that even when the shear wall has more voids, storey shear diminishes. Both strategies get the same results.

7.5 Shear Wall Stress Distribution

For models 1, 2, and 3, the corresponding static technique is used to distribute stress within the shear wall. While Figs. 16, 17, and 18 show the ESM shell allocation of stress for various models, Table 10 shows the highest shell stress level for various models..

Table 10. Maximum shear wall stress value for various models.

MODELS	SHELL STRESS (MPa)
Model-1	3.45
Model-2	6.91
Model-3	6.35

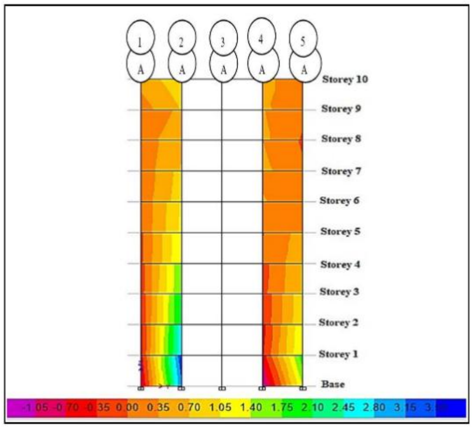

Fig. 16. Distribution of shell stress in a shear wall without an aperture

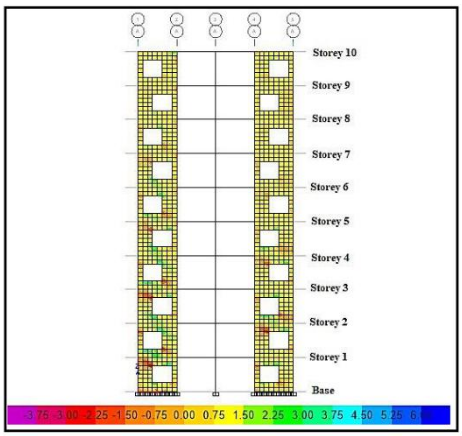

Fig. 17. Distribution of shell stress in a shear wall without an opening

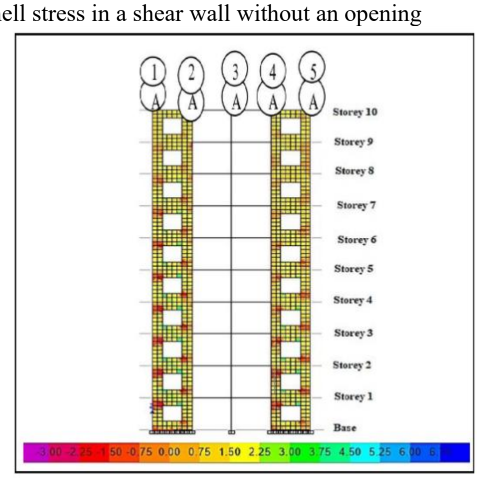

Fig.18. Distribution of shell stress in a shear wall with a staggered opening.

When a wall of shear has a standard aperture, shell stress increases, but it is not as much as it would be for a vertical opening. The maximum shell stress that may be achieved for a shear wall structure without producing is 3.45 MPa; for a shearing barrier structure with vertical opening, it is 6.91 MPa; and for a shear wall structure having staggered opening, it is 6.35

MPa. Compared to vertical apertures, staggered holes on shear walls offer less stress concentration around them.

Conclusion

The study measured time period, storey displacement, storey drift, storey shear, and stress distribution across several building specifications to investigate how alternative opening designs impact shear wall structural performance. • The time durations for shear wall constructions with no opening their doors, vertical normal opening, and stagger opening are 0.531, 0.585, & 0.591 seconds, respectively.

• Compared to horizontal openings and closed situations, staggered openings in walls of shear take longer to finish their responsibilities.
• The Comparable Static Algorithm determines the storey displacement with a shear wall construction with no opening at 21.443 mm, an open vertical entrance at 23.171 mm, and a staggered open at 23.169 mm.

• The Response Spectral Method determines the storey movement for shear wall construction with no opening at 18.196 mm, a vertical aperture at 20.161 mm, and a staggered aperture at 20.123 mm.

• Both approaches demonstrate that an openness results in a greater displacement of stories. In contrast to a vertical opening, a stagger opening in a wall of shear results in a somewhat smaller storey displacement. • Storey drift for a wall of shear construction without opening is calculated using the Comparable Static Method at 0.000755, with a vertical opening at 0.000798, and with a staggered opening at 0.000806.

• Storey drift of shear wall structures without openings is calculated using the Response Spectral method at 0.00066, with vertical openings at 0.000688, and with staggered openings at 0.0007.
• Compared to vertical apertures, staggered openings result in more storey drift. Nonetheless, both approaches demonstrate that, in contrast to vertical openings, storey drift diminishes toward the base with staggered openings.

Shear walls with filler slabs are identified in the study as critical components that impact the seismic resilience of reinforced concrete structures. Shear walls can regulate lateral movement along with transfer seismic energy amid inelastic material transformations because of their high stiffness and lateral strength. By using filler slabs, the overall weight of the structure is reduced, reducing the seismic pressures that affect buildings and improving their capacity to dissipate energy. The study shows that shear walls made of cutting-edge materials, such as fiber-reinforced polymers (FRPs) and ultra-high-performance concrete (UHPC), improve filler slab performance more. Prefabrication methods combined with modular construction lead to increased seismic defense capabilities, faster construction schedules, and better quality control.

In order to realize adaptable and self-monitoring RC structures, Future Growth and Practice will advise research on the application of intelligent substances and sensor technologies. Furthermore, incorporating performance-based design ideas into the advancement of green seismic engineering would promote more robust and safe structures. The study will offer proof of how reinforced concrete structures will withstand seismic activity in the future. Along with increased operational effectiveness and sustainable practices, the infrastructure will boost safety.

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