iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL
FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** III **Month of publication:** March 2025

DOI: https://doi.org/10.22214/ijraset.2025.67972

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue III Mar 2025- Available at www.ijraset.com

Seismic Behavior Analysis of RC Structures with Variable Shear Wall Orientations and Filler Slabs: A Comparative Study of Structural Classes

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Abstract: Reinforced concrete (RC) structures, popular designs in construction, boast strength and durability. Consideration of their seismic performance becomes critical in earthquake-prone regions. This article discusses the seismic behavior of these structures, with a focus on shear wall configurations and filler slabs. The intention is to deeply understand their roles, benefits, and possible improvements that enhance seismic resilience. Shear walls provide significant increases in stiffness through lifter strength and produce lower levels of lateral displacements. In this regard, they dissipate the seismic energy through inelastic deformations. Filler slabs reduce the weight of the overall structures, thus less seismic forces acting on them, and induce an improved energy dissipation. Several advances have occurred in relating advanced materials like ultra-high-performance concrete (UHPC) and fiber-reinforced polymers (FRPs) in increasing performance through improvements in the design of these elements. Some of these improved quality controls and reduction of several construction cycles are prefabricated modular construction. The most important aspects of evidence are that the two factors, shear walls, and filler slabs, work best for optimum performance against earthquakes. Research findings provide further direction into newer avenues for research, including smart materials and sensor technologies; performance-based design adoption; and sustainability in seismic design. These improvements are paramount in creating safe and resilient RC structures against damage due to seismic events.

Keywords: Earthquake resilience, filler slabs, prefabrication, reinforced concrete, seismic performance, shear walls etc.

I. INTRODUCTION

The use of reinforced concrete (RC) structures and applications were so much in demand in construction owing to their strength, versatility, and affordability. Components of such structures consist of concrete reinforced with steel bars or meshes, thus providing excellent compressive strength and enhancing tensile strength. However, their performance during seismic loads causes critical concern for most structures located in an earthquake-prone region. Another critical issue concerning most researchers on the seismic performance of RC structures is the energy absorption and dissipation by the structures caused by seismic waves and, subsequently, the avoidance of catastrophic failure and the occupancy protection.

Dynamically induced loads by earthquakes produce shaking, with large amounts of horizontal and vertical forces acting on buildings. Ground shaking should be considered for the structural design of RC structures, depending on appropriate detailing, material selection, and structural configuration. Important parameters affecting the seismic performance of RC structures are stiffness, ductility, and energy dissipation capacity of the building. Combinations of the fundamental principles that govern a seismic design- including appropriate reinforcement detailing, concrete confinement, and structural elements, such as shear walls and filler slabs-would improve such structures' ability to resist seismic loads.

A. *Importance of Shear Walls and Filler Slabs inEnhancing Seismic Resistance*

The effects of shear walls and filler slabs are inevitable in the seismic design of any RC structure. Definitely, a shear wall is a vertical structural element that gives lateral stiffness and enhances strength, thus improving the capacity of a building to resist the action of horizontal seismic forces. Shear walls behave like vertical cantilevers, connecting the superstructure and foundation by transferring seismic input forces downwards, minimizing overall lateral displacements and increasing stability.

Shear walls can be classified into coupled, cantilever, and core walls, each of which suits a specific advantage depending on design and seismic requirement for the building. Coupled shear walls consist of two or more walls connected together by coupling beams or slabs to enhance ductility and energy dissipation.

Cantilever walls are simply continuous extending from the foundation to the top of the building, having considerable lateral stiffness and strength. Core walls constitute parts of most buildings, situated generally against elevators or stairwells, which serve as the structural core for increasing torsional resistance.

Filler slabs are horizontal structural elements forming floor and roof systems for RC buildings. These slabs comprise concrete plus lightweight filler material such as hollow blocks, polystyrene, or cellular concrete. This clearly reduces the total weight of the building and therefore seismic forces acting upon it. Furthermore, this improves thermal insulation and acoustic insulation in the building, making it energy efficientand occupant friendly.

In seismic design, the filler slabs distribute the seismic forces through the building system, further constraining the probabilities of occurrence of partial failure. With this additional reduced weight, it makes the demands on the structural elements, such as beams and columns, very much less in volume, which in turn makes them perform better during a seismic event. Thus, with strategic placement of shear walls in associations with filler slabs in RC structures, it is possible to achieve balanced and effective seismic design overall.

II. SEISMIC RESPONSE OF RC STRUCTURES

A. *Overview of Seismic Forces and Their Impact on RCStructures*

This energy release gives rise to seismic waves causes ground shaking. The following dynamic loads are characterized as being rapid oscillation and reversals of direction for the structures. Reinforced Concrete (RC) type of structures, induce severe seismic forces requiring proper design of the structures as they can lead to structural damage or collapse upon application of large forces. This comes mainly from the horizontal forces inducing lateral displacement, requiring RC structures to provide an adequate lateral stiffness and strength against such movement. This also refers to vertical seismic forces that multiply already existing loads in some structural components, necessitating a thoroughseismic design.

B. *Key Parameters Influencing Seismic Response*

The seismic response of RC structures is the outcome of several critical parameters:

Concrete property, Steel, their strength, ductility, and durability rule a parameter which governs its seismic performance. Enhanced resistance can be gained through high strength materials, while ductile materials dissipate the energy.

1) The structural layout and geometry concerning beams, columns, shear walls, and slabs will determine its behavior. A symmetrical, regular configuration significantly performs better under seismic activities, as in this case, the stresses are uniform within the member.
2) The mass inside the structure is responsible for affecting the dynamic behavior of the structure. In this sense, uneven mass distribution will generate some degree of torsional activity and will raise those demands on some structural elements.
3) The transmission and dissipation processes of seismic forces by a structure depend, first of all, on how it is founded and secondly on the nature of the soil underneath. Poor soil conditions amplify seismic waves, leading to greater forces being transmitted ontothe structure.
4) The structure can absorb energy by inelastic behavior, such as yielding of steel or cracking of concrete, which reduces seismic demands. Notably, damping mechanisms either intrinsic or added will considerablyimprove the performance

C. *General Strategies for Improving Seismic Performance*

Several strategies can be pursued to enhance theperformance of RC structures during earthquakes:

1) Using high-performance materials that will have improved strength and ductility. Innovations like fiber- reinforced concrete can take these advantages further.
2) Designing regular and symmetric structural layouts that will fulfill uniform distribution of stresses. Introducing shear walls and bracing systems will improve considerably lateral stiffness and strength.
3) Detailing the reinforcement for seismic design by means of satisfactory anchorage, lap splices, and confinement. Careful consideration is given for critical zones like beam-column joints.
4) Design decoupling, which is expected to substantially consider bas isolating the components from ground shaking impacts to avoid the detrimental effects on seismic performance of the superstructure.
5) Providing supplementary damping devices connected to the structure, like viscous dampers or tuned mass dampers, to dissipate vibrations energy and reduce displacements.
6) It could be retrofitted with techniques, such as additional shear walls, steel braces, or post-tensioning from outside to make existing structures better seismicresistant.

Table I. Key Parameters Influencing Seismic Response Of Rc Structures

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.

III. SHEAR WALLS IN RC STRUCTURES

A. Role and Function of Shear Walls

Shear walls are vertical structural components within the reinforced concrete (RC) structure primarily meant to resist lateral force action like forces exerted by wind or earthquakes. They provide sufficient lateral strength and stiffness and act as a primary lateral force-resisting system in many reinforced concrete structures. They are expected to transfer lateral loads from floor and roof systems to the foundation to provide stability and maintain the integrity of buildings during the event of an earthquake. Some advantages offered by shear walls include:

First, they greatly increase the lateral stiffness of buildings, thereby reducing lateral displacements during earthquakes. Second, they provide great strength to resist lateral loads, preventing structural failure. Furthermore, shear walls can dissipate seismic energy through inelastic deformations, thus not transmitting forces to other structural elements as high. Finally, limiting lateral movements, shear walls contribute to the general stability of the structure, and soprevent drift and predilection for collapse.

B. Types of Shear Wall Configurations

To meet the functional requirements and design constraints, there are various configurations of shear walls. Coupled shear walls comprise two or more shear walls connected by means of beams or slabs (coupling beams). The shear walls become more stiff and ductile through coupling action with this type of connection. A cantilever shear wall extends vertically from the foundation to the roof without any intermediate supports. It functions as a vertical cantilever, providing great lateral stiffness and strength. Core walls, which are usually located around elevator shafts or stairwells, make up a structural core that provides both torsional and lateral resistance. These walls run continuously from thefoundation to the roof.

The comparative analysis of these configurations, on one hand, highlights distinct advantages and disadvantages. Coupled shear walls provide greater ductility and energy dissipation during earthquakes because the coupling beams undergo significant inelastic deformations during seismic events. In this case, the design and detailing of coupling beams becomes a very critical aspect for effective performance. Indeed, the criterion offers maximum lateral stiffness and strength while it suits very tall buildings. A cantilever shear wall has the simplest design and construction advantage, though it may not have the ductility presented by coupled systems.

Finally, the real core wall combines the best qualities of a cantilever and coupled wall as it can provide very good lateral and torsional resistance. Of course, core walls manage very tall buildings, but their design is difficult and complex with respect to the interaction between the core and other structural members.

Table III. Comparative Analysis Of Shear Wall Configurations

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

C. Design Considerations

Shear wall design conforms to certain theories and specifications to render them effective against seismic. High- strength concrete and sufficient reinforcement, concrete compressive strength (f_c^')} and yield strength of reinforcement (f_y), aspect ratio known as height-to-width ratio, are among the principles of design. Lower aspect ratios (short and wide) contribute to increased lateral stiffness, whilehigher aspect ratios (tall and narrow) provide flexibility,however, stiffness is less.

Adequate detailing of longitudinal and transverse reinforcement promote ductility, resisting brittle failure.These include boundary elements, confinement reinforcement, and proper anchorage. To transfer forces directly into the foundation and roof, there must be a continuous load path.

Several variables define shear wall performance against seismic forces. An axial load-to-cross-sectional wall area relationship, particularly axial load ratio, directly induces changes in stiffness and strength. Greater axials increase capacity and reduce ductility. Thickness is important because, as thickness increases, so do stiffness and strength; however, so do weight and cost. Door and window openings, which weaken shear walls, must have proper reinforcement to provide strength and stiffness. Interaction with the foundation is essential. A poor foundation design could lead to differential settlements, and thus reduce shear wall performance.

The shear capacity of a shear wall can be calculated usingthe equation:

Meghdadian and Ghalehnovi (2022) focused on studying retrofitting core RC shear wall systems with openings using steel plates and FRP sheets. They found that the systems wereable to perform better during seismic activities and were cost-effective.

Data from the performance of different earthquakes bring home the point of utilizing shear walls for good performance. Shear walls that were well designed significantly reduced damage and rates of collapse endured.

$$V_n = 0.17 f'_c b_w d + \rho_v f_y A_v \qquad (1)$$

where Vn is the nominal shear strength, f' is the concrete compressive strength, bw is the width of the wall, d is the depth of the wall, ρv is the reinforcement ratio, and Av is the area of shear reinforcement.

The moment capacity is given by:

$$M_n = A_s f_y (d - a/2) \qquad (2)$$

where Mn is the nominal moment capacity, As is the area of tensile reinforcement, fy is the yield strength of reinforcement, d is the effective depth, and a is the depth of the equivalent stress block.

The wall's lateral stiffness can be approximated by:

$$K = \frac{12EI}{h^3} \qquad (3)$$

where K is the lateral stiffness, E is the modulus of elasticity of concrete, I is the moment of inertia of the wall section, and h is the height of the wall.

For coupled shear walls, the coupling beam stiffness andstrength significantly affect the overall performance.

D. Case Studies and Empirical Data

He mentions that there is evidence from the literature review of experiments and case examples on how shear walls performed during seismic events. Huang et al. (2024) conducted a research on the seismic behavior of precast composite walls (PCWs) with varying forms of reinforced concrete brace by means of numerical simulation techniques. The findings of this research revealed that the bracing setups had substantial effects on mechanical properties of PCWs by buildings during the Mexico City Earthquake in 1985. The indication does not differ much during the Northridge Earthquake of 1994, where core wall systems can be attributed to the improved performance of buildings through increased resistance against lateral as well as torsional loads, indicating the importance of core walls in high-rise buildings.

Fig. 1 Represents different configurations for shear walls in multi-story buildings. The schematic representation elaborates on the structure and mutual reference of the walls compared with the whole building frame.

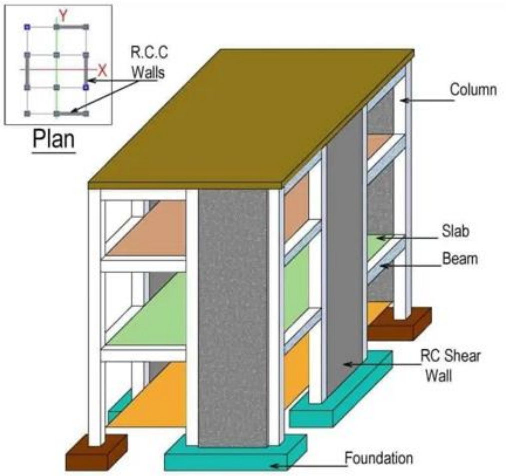


Fig. 1. Different configurations of shear walls in a multi-story building

Walls provide lateral stiffness, strength, and energy dissipation to an earthquake-resisting structure in order to keep it safe and secure during the seismic attack because incorporation of shear walls into RC structures is vital for ensuring the seismic performance of these structures Therefore, these walls need to be designed, detailed, and considered by various influencing factors so that their effectiveness can be maximized.

IV. FILLER SLABS IN RC STRUCTURES

A. Definition and Purpose of Filler Slabs

Filler slabs are such floor slabs constructed in RC structures. They are concrete slabs with the filling primarily consisting of hollow blocks, bricks, or light-weight concrete, replacing part of the concrete in tension zone with non- structural low-density filler materials. The aim is to provide reduced concrete and steel at construction without affecting structural integrity or load-bearing capacity.

The various benefits that these types of slabs bring to the whole system are, first, less expensive construction due to reduction in volume of concrete and steel, resulting to reduced material and transport costs. Second, using these light filler materials means a significant reduction in the weight of the overall structure. This further contributes to a reduction in the seismic forces under which the building shall be subjected to, thus improving the seismic performance of the structure. Furthermore, hence filler slabs result a short and better thermal and acoustically insulated than the conventional solidslabs. The users or occupants thus have more comfort.

B. Types and Materials

1) Different Types of Filler Slabs

Based on the filler material and construction type, filler slabs can be divided into types. Commonly, they are classifiedas:

- Hollow Block Slabs: These slabs use hollow blocks made of concrete, clay, or other lightweight materials as fillers. These blocks are placed between the reinforcements before pouring concrete.
- Ribbed Slabs: Has elongated ribs or beams in one or both directions and has lightweight materials such as hollow blocks or polystyrene as fillings between the ribs.
- Brick Filler Slabs: Fill bricks as lava filler between thereinforcements.

2) Common Materials Used and Their Properties

The above-mentioned materials used have points of similarity in as far as being lightweight, non-combustible, as well as good thermal and acoustic insulation-type fill slabs.

Some common materials include:

- Hollow Concrete Blocks: These blocks are precast ones having hollow cores, provide good thermal insulation plus reduced the weight of the slab.
- Clay Blocks: These blocks are very lightweight because they made from fired clay and give excellent thermal and acoustic insulation.
- Polystyrene Blocks: Polystyrene blocks have the advantage of being extremely lightweight and processing espacially superior thermal insulation, as a result mostly they are used in ribbed slab constructions.
- Lightweight Concrete: It is concrete made with lightweight aggregates and is used in filling the spaces between ribs in ribbed slabs, ensuring a balance between weight reduction and structural soundness

Table IV. Properties Of Common Filler Materials

Material	Density (kg/m³)	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

C. Design Considerations

1) Design Principles and Standards

The design of filler slabs involves a number of principles that must be maintained and for which standards must be satisfied in order to be safe and perform well. Key design considerations are the even distribution of loads over the slab and the location of filler material so that it fills the non- structural zones. Proper reinforcement placement is important in terms of strength for the tensile stresses caused and prevention of cracking. Optimizing span and depth is necessary to balance material with structural efficiency. Last but not least, design and construction should comply with standards such as those set by ACI codes, Eurocodes, or any country's specific national standards.

2) Structural and Seismic Performance Considerations

Filling Slab need to be designed and constructed to satisfy criteria of structural performance as well as those of seismic performance. The prime aspects are as below:

Flexural Strength. The slab should be able to provide that much flexural strength, which is again able to resist the live and dead loads. The moment of resistance can be calculated by Equ. (2).

Shear Strength: Ensuring the slab can resist shear forces iscritical. The shear capacity V_n is given by.

$$V_n = 0..17 f'_c bd + \rho_v f_y A_v \qquad (4)$$

where f'_c is the concrete compressive strength, b is the width, d is the depth, ρ_v is the reinforcement ratio, and A_v is the area of shear reinforcement.

Limiting deflections to prevent serviceability issues, calculated using:

$$\Delta = \frac{5wL^4}{384EI} \qquad (5)$$

where Δ is the deflection, www is the load per unit length, L is the span length, E is the modulus of elasticity of concrete, and I is the moment of inertia.

D. Case Studies and Empirical Data

1) Review of Experimental Studies and Real-World Examples

Filler slabs-if examples are any indication-have been validated through several experimental investigations and applications in real life. Mahrous et al. (2022) conducted a study on reinforced masonry core walls with boundary elements, in which it was found that the incorporation of fillerslabs could adequately reduce seismic demand. This hasvadeoverall performance.

Zhang et al. (2022) also conducted a case study involving an experiment on shaking tables of prefabricated concrete shear wall structures. It resulted in the finding that filler slabs reduced weight of structures, thus decreasing seismic forces and improving their seismic performance.

E. Analysis of Performance Data from Past Earthquakes

Performance records of earlier earthquakes are useful to find out the merit of using filler slabs. For instance, during the 2010 Chile Earthquake, the buildings with filler slab constructions were less damaged compared to buildings of solid slabs, mainly due to less seismic forces acting on the lighter structure.

Fig. 2 shows the making of a ribbed filler slab, depicting reinforcement, filling, and pouring of concrete. It should show both the dropped volume of concrete and the distribution of reinforcements.

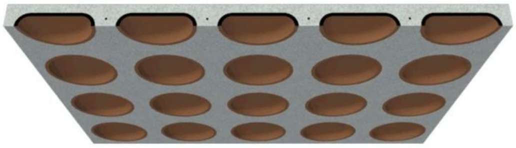


Fig. 2. Construction of a ribbed filler slab, showing the placement ofreinforcement, filler materials, and the pouring of concrete

Highly economical, light, and seismic-resistant buildings can be made with filler slabs within RC structures. These slabs save a considerable volume of concrete and steel, making them an excellent approach in modern construction, considering that they are also good in seismic performance

V. COMPARATIVE ANALYSIS

A. Comparative Assessment of Shear Walls and Filler Slabsin Terms of Seismic Performance

Shear walls and filler slabs are structural elements that are essentially required in the design of reinforced concrete (RC) structures, more so in regions with severe seismic activity. The structural seismic action is resisted by vertical few elements termed as shear walls, providing the large lateral stiffness and strength necessary for this purpose. The resultant effectiveness is to minimize lateral displacements and avoid structural failure. On the contrary, fillers are applicable as lighter filler material that occupies the tension zone of slabs to lessen the overall seismic forces acting on the structure because it brings down weight. The seismic performance of shear walls has proved to be one of the most effective ways of improving the lateral load-resisting design of RC structures. Their primary responsibility would be to act as vertical cantilevers resisting lateral forces through their stiffness and strength. The performance of shear walls in earthquake conditions is characterized by high stiffness reducing lateral displacement, and also the shear walls absorb and dissipate the seismic energy released during an earthquake by inelastic deformation that increases the ductile performance. Additionally, Shear walls are connected to the roof slab to resist horizontal forces caused by lateral seismic events with the foundation, thereby providing a continuous load path from roof to foundation in terms of overall structural stability. On their own, filler slabs, when incorporated into the design, would give added reduction to the structure weight, and so would result in a reduction in seismic forces as generated during an earthquake. The contribution of filler slabs towards performance during seismic activity relates to a reduction in the mass of the structure which would, in turn, translate to lower seismic forces induced during an earthquake. Advantages of these filler slabs towards seismic performance include lower seismic demands due to reduced mass, improved energy dissipation due to distributed cracking in the tension zone, and enhanced thermal and acoustic insulation, which all contribute to the performance of the overall building.

B. Advantages and Limitations of Each Approach

These walls could deliver certain benefits: their high lateral strength and stiffness significantly improve resistance to lateral load of a building. As they undergo severe inelastic deflections, high ductility and energy dissipation features come along with this. Direct tensions and transmissions offer great energy dissipation and absorption through them in case of an earthquake. Thus, shear walls ensure structural stability by providing continuous load paths to the foundations, often ensuring that seismic forces are transferred efficiently onto the base.

However, shear walls also have some drawbacks. They may raise construction costs, due to the procurement of additional materials and labor, and they might impose certain constraints on architecture as well: One cannot use this solution very freely in the flexibility of design for placement of the openings.

Now from the same, filler slabs provide base advantages: First, they cause a reduction in a weight of a structure as a whole. Of course, this lessens the forces by earthquake, affecting the building. Less concrete and steel are used in filler slabs, which makes the construction's total material costs lower. Occupants will find an increase in thermal and acoustic insulation standards over solid slabs due to the employment of a hollow structural system.

Filler slabs also possess some shortcomings. It causes a significant loss of stiffness since it does not contribute to the lateral stiffness of the structure. The incorporation of filler materials also complicates the construction process, which generally requires specific placement to achieve optimum performance.

TABLE V. COMPARATIVE ASSESSMENT OF SHEAR WALLS AND FILLER SLABS

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

VI. MODELLING AND ANALYSIS

This project focuses on optimizing the seismic performance of reinforced concrete (RC) structures by analyzing the role of shear walls and filler slabs. The work begins with a literature review of seismic resilience in RC structures, followed by designing structural models with varying orientations and positions of shear walls and filler slabs.

Using ETABS software, these models undergo Response Spectrum analysis to simulate seismic effects. Key parameters such as base shear, lateral displacement, and inter-storey drift are compared across models. Finally, recommendations are developed for effective shear wall placement and filler slab use, aiming to improve stability, safety, and cost-efficiency in seismic design.

The analysis of G+10 storey building was carried out by using the ETABS software for buildings provided with moment resisting structural system situated in seismic zone V.

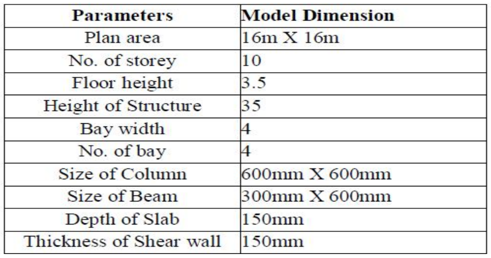
Various seismic parameters such as base shear, top storey displacement, storey drift and time period were obtained.

Building has lower stiffness and strength along Y direction due to less number of columns in its grids so the analysis of the building is carried out along y axis only. Below mentioned table 1 shows the various details of the building models.

A. Structural Data

The different structural models of a 10 storey height are prepared for the comparative study based on various parameters for this study. In all of the models under consideration, the storey height is maintained at 3.5m. The bay width is maintained in both directions, resulting in a symmetrical structural configuration in both directions.

Table VI: Dimensions of structure models



Parameters	Model Dimension
Plan area	16m X 16m
No. of storey	10
Floor height	3.5
Height of Structure	35
Bay width	4
No. of bay	4
Size of Column	600mm X 600mm
Size of Beam	300mm X 600mm
Depth of Slab	150mm
Thickness of Shear wall	150mm

For the purposes of analysis, different types of structural configurations are modelled for each case and analysed using ETABS software.

For each case, a conventional structure with the shear wall at the plan's outer periphery is modelled and compared to a shear wall structure with different opening configuration models.

Make a model with a vertical opening and staggered opening in a shear wall structure system of size (2m X 1.75m). The following are the different types of models that were used in this study:

Model I: Shear wall structure without opening.

Model II: Shear wall structure with vertical opening of size (2m X 1.75m).

Model III: Shear wall structure with staggered opening of size (2m X 1.75m).

B. *Loading Details*

- Live load and Floor finish load is taken as 3kN/m2 and1kN/m2 respectively for all models and models are also subjected to seismic loadings.
- The seismic loading is taken for all the building as perIS1893:2016 (part:I) Various parameters selected for the seismic loading are,
- Seismic Zone = Zone-V
- Seismic zone factor = 0.36
- Type of structure = Shear wall structure
- Storey Height = 35m for 10Storey
- Importance factor = 1
- Response reduction = 5 Factor
- Soil type =Type II (Medium Stiff Soil).

C. *Load Combinations*

The strength criteria for forces and moments load combinations are based on IS 456: 2000. For static and seismic loading, load combinations are based on IS 875 and IS 1893.

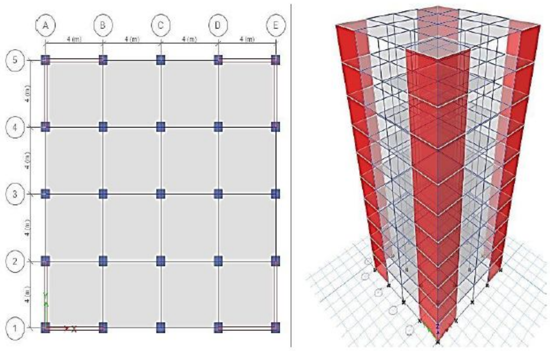


Fig.3.Plan and 3D model of shear wall structure without opening

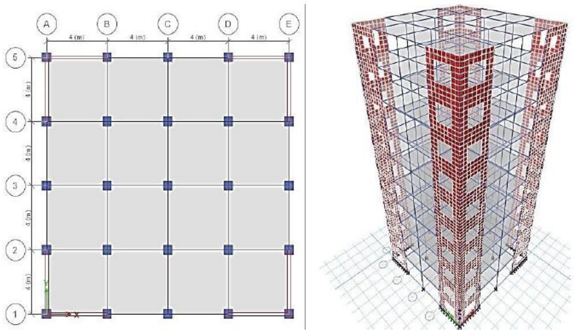


Fig. 4: Plan and 3D model of shear wall structure with vertical opening of size (2mX 1.75m).

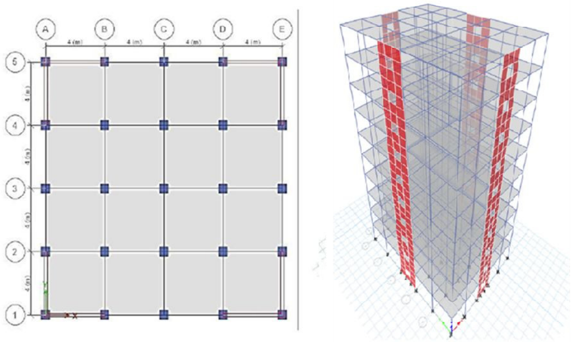


Fig. 5: Plan and 3D model of shear wall structure with staggered opening of size (2mX 1.75m).

Structural models with various opening configurations are analyzed using both linear static (Equivalent Static Method) and dynamic methods (Response Spectrum Method).
According to IS 1893 (Part 1) – 2016, a 5 percent damping factor is used to define the response spectrum function.
All of the models created in ETABS 2017 are analyzed by these methods and a comparative study will be based on the results obtained in order to find the optimum result of the shear wall structure system with different opening in the structure.

D. Construction of Filler slab

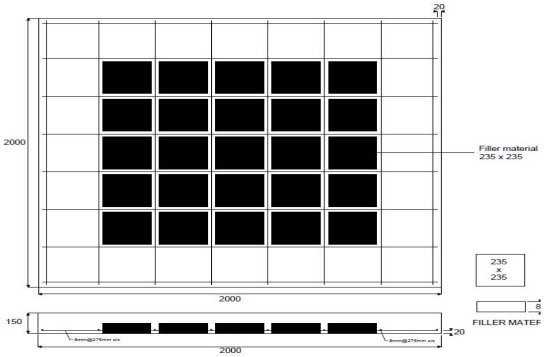


Fig. 6. Typical Filler slab design

The shuttering of the slab is placed and fixed firmly. Reinforcing bars are placed over the shuttering as per the slab design. These bars are tied at every cross-section using binding wire. Cover blocks are used to maintain a gap at the bottom of the bars. Filler blocks are placed over the shuttering, leaving a 20mm gap between the reinforcement. M20 grade concrete is prepared and poured over the reinforcement.
A needle vibrator is used to remove air voids and compact the concrete. Deshuttering should be done after 7 days. Curing must be done for 28 days to achieve full strength.

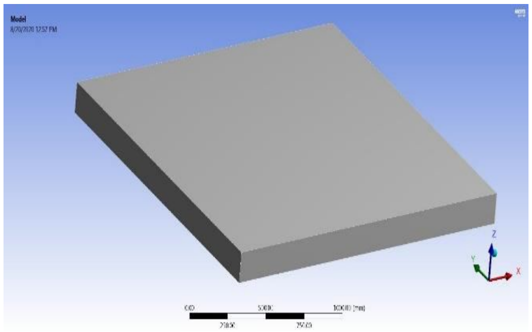


Fig. 7(a) Geometry conditions of conventional slab

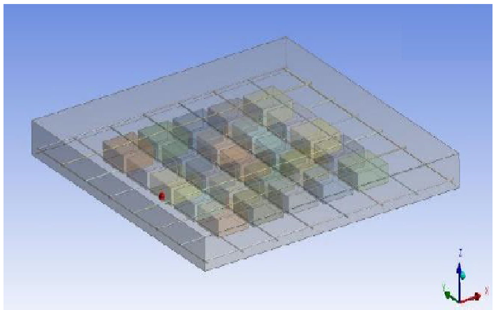


Fig. 7(b) Geometry conditions of the filler slab

The basic properties of the filler material were found experimentally, and the results are shown in Table 2. [14]

Table VII: Filler material properties

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 Methods of test for aggregates for concrete.
2. IS 2386-1 1963 Methods of test for aggregates for concrete.
3. IS 2720-5 1985 Methods of test for soils.

The implementation of shear walls with filler slabs would be synergistic and combine the unique advantages of both systems to maximize the performance of the overall RC structure during an earthquake event. The integration allows shear walls to offset the stiffness loss associated with the use of filler slabs while at the same time allowing these filler slabs to reduce the seismic weight imposed on shear walls. Such an arrangement will usually result in better seismic performance because the high stiffness, as well as the strength of the shear walls, could be correctly set off with associated weight reduction through the filler slabs to obtain a structure that is efficient and resilient. Of course, such filler slabs reduce the quantity of concrete and steel used, which makes it easier on the budget for construction without compromising the integrity of the structure. Filler slabs with shear walls will provide the flexibility demanded in dimensional architectural design while offering lateral resistance needed.

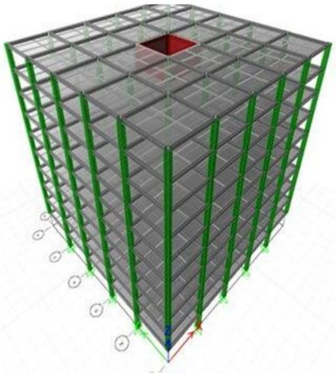


Fig. 8. Effects of combining shear walls with filler slabs in a multi- story RC building

The synergism that arises from combining shear walls with filler slabs in a multi-storey RC building is presented in the Fig.8. This should demonstrate the interaction between shear walls and filler slabs along with the benefits of their combined structural load transfer and weight reduction.

In this sense, shear walls and filler slabs improve seismic performance in RC constructions. In their independence, they have benefits and disadvantages, but joined they can lead to the development of a very optimized, resilient, and cost- efficient design making features of each element. This helps promote better seismic resistance, structural stability, and the overall performance of the building.

VII. RESULTS AND DISCUSSION

The results of a shear wall structural system with various opening configuration models are compared in terms of storey displacement, storey drift, storey shear, and time period using various methods, such as the Equivalent Static Method (ESM), Response Spectrum Method (RSM), and others (RSM). Because of the similar results obtained due to symmetry in plan of the various models under consideration, the results have only been shown in the longitudinal direction.

This section contains tables and graphs for model-1, model-2, and model-3 results in terms of time period, storey displacement, storey drift, and storey shear.

A. Time Period

The equivalent static method is used to plot the time period vs. mode number graphs for model-1, model-2, and model-3. Table 8 shows the time period vs. mode number results for models, and Fig. 9 depicts the variation of time period vs. mode number.

Table 8: Time period (sec) for different 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

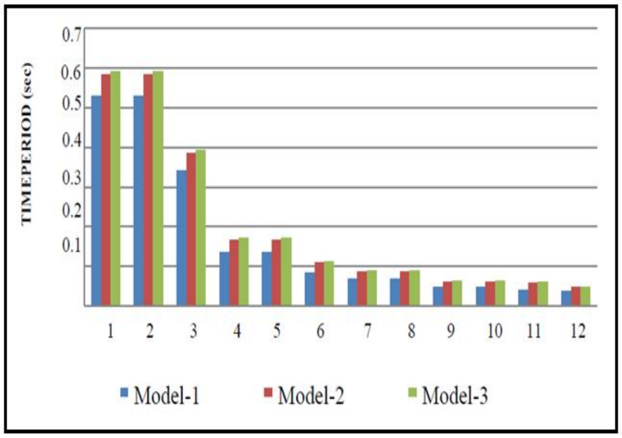


Fig. 9. Time period vs. mode number for different models

From the Equivalent Static Method, Table 8 shows the time period for different modes for model-1, model-2, and model-3. The results show that for all of the models, the time period is greatest for mode-1. The time period for a shear wall structure without an opening is 0.531 seconds, 0.585 seconds for a vertical opening, and 0.591 seconds for a staggered opening, indicating that the time period increases when a shear wall is provided with an opening. When compared to shear wall structures with staggered opening, the time period for shear wall structures with staggered opening is longer with vertical opening and also a without opening.

A. *Storey Displacement*

The ESM and RSM plot the storey displacements for different storey graphs for model-1, model-2, and model-3. Table 9 shows the maximum storey displacement for each model at the top storey, and Figs. 10 and 11 show the variation of storey displacement vs. storey level for ESM and RSM, respectively.

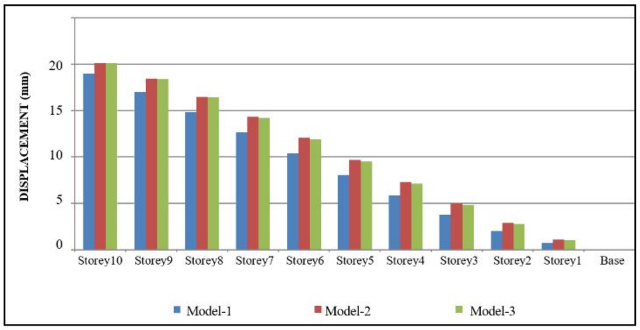


Fig. 10. Storey Displacement vs. storey level for different models by ESM

Figure 10 depicts the ESM's result. Shear wall structure without opening has a maximum displacement of 21.443 mm, shear wall structure with vertical opening has a maximum displacement of 23.19 mm, and shear wall structure with staggered is 23.17 mm which represent that displacement is increases when opening is provide in shear wall but storey displacement for staggered opening is slightly less compare to vertical opening.

Table 9 Maximum Storey Displacement (mm) at the top storey

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

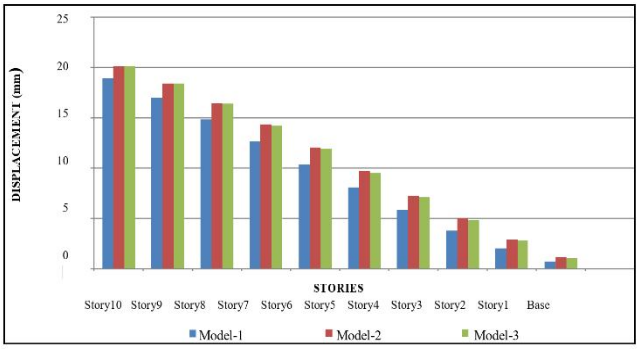


Fig. 11. Storey Displacement vs. storey level for different models by RSM

The maximum displacement for a shear wall structure without opening is 18.946 mm, for a shear wall structure with vertical opening is 20.161 mm, and for a shear wall structure with staggered opening is 20.123 mm, as shown in Fig. 11, indicating that displacement increases when a shear wall is provided with an opening. However, when compared to shear wall structures with vertical openings, storey displacement is slightly lower for shear wall structures with staggered openings. RSM produces results that are similar to those obtained by ESM.

B. *Storey Drift*

The Equivalent Static method and the Response Spectrum method are used to plot the storey drift vs. storey level graph for model 1, model 2, and model 3. Table 10 shows the variation of storey drift with storey level for different models by ESM and RSM, respectively. Fig. 12 and Fig. 13 show the variation of storey drift with storey level for different models by ESM and RSM.

Table 10. Maximum Storey Drift vs. Storey level.

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)

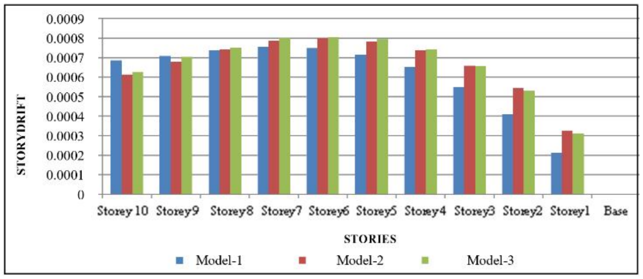


Fig. 12. Storey drifts vs. storey level for different models by ESM.

Table 10 shows that the maximum storey drift for various models occurs at various storey levels. We can deduce from this that when a shear wall opening is provided, the maximum storey drift is shifted toward the base in both ESM and RSM cases. The maximum drift for a shear wall structure without opening is 0.000755, for a shear wall structure with vertical opening is 0.000798 and for a shear wall structure with staggered opening is 0.000806, as shown in Fig. 12, indicating that storey drift increases when a shear wall has an opening. In the entire model under consideration, storey drift is at its maximum for staggered opening.

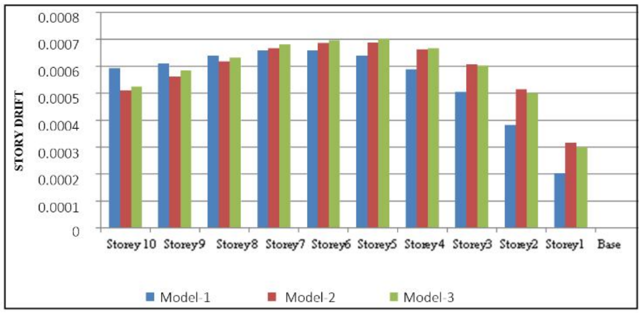


Fig. 13 Storey drift vs storey level for different models by RSM.

The maximum drift for a shear wall structure without opening is 0.00066, for a shear wall structure with vertical opening is 0.000688, and for a shear wall structure with staggered opening is 0.0007, as shown in Fig. 13. This indicates that storey drift increases when a shear wall has an opening. In the entire model under consideration, storey drift is greatest for staggered opening. Both methods produce similar results.

C. Storey Shear

Storey shear vs. storey level curves are plotted by Equivalent Static Method and Response Spectrum method for model, model2 and model 3. Table 11 represent the maximum value of Base shear for models and Fig.14 and Fig.15 shows the variation of storey drift with the storey level for different models by ESM and RSM respectively.

Table 11: Base Shear for different Model.

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

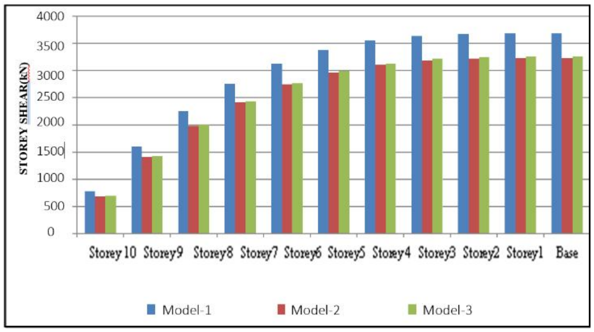


Fig. 14. Storey shear vs. storey level for different models by ESM.

The maximum storey shear for a shear wall structure without opening is 3684.0406 kN, for a shear wall structure with vertical opening is 3227.3181 kN, and for a shear wall structure with staggered opening is 3256.4847 kN, indicating that storey shear decreases when a shear wall has an opening, but storey shear is greater for staggered opening than for vertical opening.

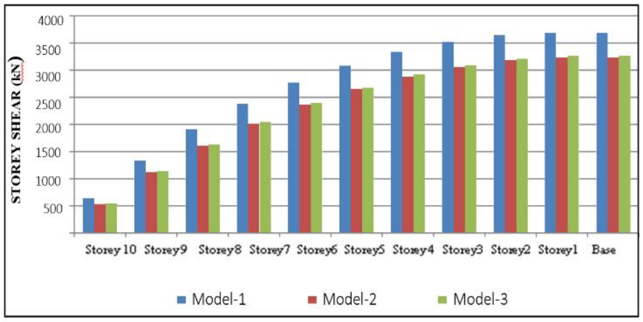


Fig. 15. Storey shear vs. storey level for different models by RSM.

Result obtain by RS Mis shown in Fig.13 maximum storey shear for the shear wall structure without opening is 3683.4432kN, for shear wall structure with vertical opening is3227.8819 kN and The storey shear for a shear wall structure with staggered opening is 3257.4202 kN, indicating that while storey shear decreases as openings are added to the shear wall, storey shear is greater for staggered openings than for vertical openings. The results obtained using both methods are identical.

D. *Stress Distribution in Shear Wall*

Model-1, model-2, and model-3 stress distribution in the shear wall using the equivalent static method. Table 12. shows the maximum value of shell stress for various models, while Figs. 16, 17, and 18 show the ESM shell stress distribution for various models.

Table 12 Maximum value of stress in shear wall for different Model.

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

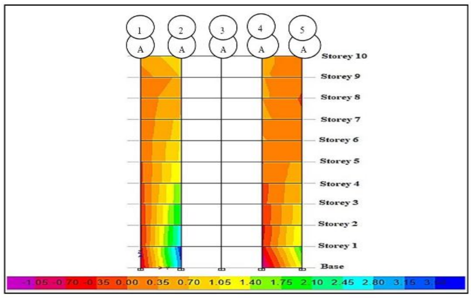


Fig. 16 Shell stress distribution in shear wall without opening

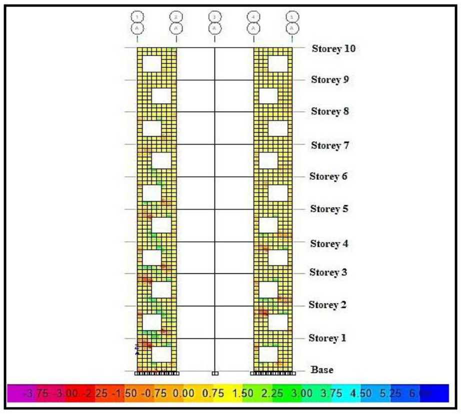


Fig. 17. Shell stress distribution in shear wall without opening

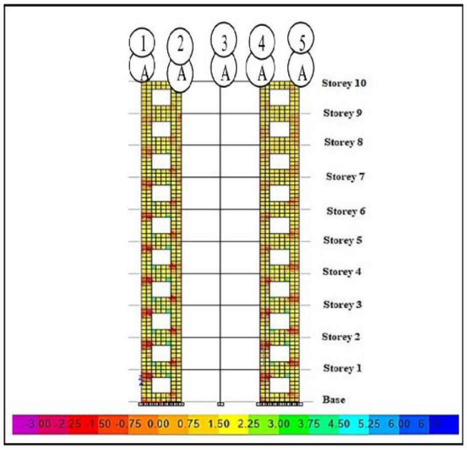


Fig.18. Shell stress distribution in shear wall with staggered opening.

The maximum value of shell stress for a shear wall structure without opening is 3.45 MPa, 6.91 MPa for a shear wall structure with vertical opening, and 6.35 MPa for a shear wall structure with staggered opening, indicating that shell stress increases when a shear wall has an opening, but it is less for staggered opening than for vertical opening. When compared to vertical openings, stress concentration around the opening is lower for staggered openings in shear walls.

VIII. RECENT ADVANCES AND INNOVATIONS

A. Overview of Recent Research and TechnologicalAdvancements

In the past few years, there's been much activity in seismic engineering, but certainly upcoming within the spectrum of RC structures design and construction. The field has seen much research on ways to improve the lateral performance of RC structures using innovative materials and cutting-edge techniques that involve both. Much progress has been made in understanding the behavior of shear walls and filler slabs, which has brought many designs toward being more efficientand resilient under seismic events.

Numerous investigations have been done into different aspects concerning shear walls, such as high-performance materials, improved modeling techniques, and better construction methods. For instance, researchers examined the hybrid shear wall seismically behaved, which differs in its materials, such as concrete and steel, in relation to the strength and ductility principles to optimize them. Advancements in numerical modeling have also allowed increasingly accurate simulations of seismic responses for the designs of buildingsbetter equipped to resist earthquake forces.

B. Innovative Materials and Construction Techniques

High-performance materials use in construction work of RC structures is indeed a remarkable step from conventional construction practice. UHPC and fiber-reinforced polymers (FRPs) are two such materials which promise additional enhancement in seismic performance for shear walls and filler slabs.

Ultra-high performance concrete (UHPC): it typically has superior strength, durability, and ductility compared to standard concrete. The use of UHPC in shear walls can greatly enhance their bearing capacity and abilities to dissipate energy. This material could allow thinner and lighter walls, which is, however, not less strong, that contributes to reducing seismic forces.

Fiber-reinforced polymers: composites formed from a polymer matrix reinforced with glass, carbon, and aramid fibers. FRPs have been predominantly adapted to retrofit and strengthen existing RC structures to make them seismically performance efficient. Their critical application has been because of their high strength-weight ratio and their suitability in instances where the dead weight is important, such as withfiller slabs.

Numerous innovative construction techniques have developed to improve the seismic performance of an RC building. Prefabrication and modular constructions have become increasingly preferred for their efficiency and quality control advantages. As an example, prefabricated components such as shear wall panels and filler slabs could be manufactured off-site under controlled conditions to ensure high quality and precision. Once manufactured, these components are transported to the construction site and, hence, assembled faster with less labor cost.

C. Future Trends in the Design and Implementation ofShear Walls and Filler Slabs

As for what lies ahead in shear wall and filler slab design and implementation, many trends are bound to emerge. One of the more specific trends, among many others, is likely to be the integration of smart materials and sensors with RC structures. Smart materials, in particular, shape memory alloys (SMAs), will automatically change properties with respect to some external stimuli. This would ensure far more control of the structure during seismic events. In addition, embedding sensors within shear walls and filler slabs would provide real-time monitoring of the health of the structure and allow for the early assessment of deficiencies or damage as well as for preventive maintenance.

Another trend that will introduce the design of shear walls and filler slabs into the future is the use of sophisticated computation tools and artificial intelligence in structural design. Using AI algorithms, a vast amount of data collected from previously occurred seismic events to those simulated would help optimize shear walls and filler slabs according to individual conditions of the seismic event under which they will be used. This includes formulating performance-based design that will help structures be designed to meet specific performance objectives under various levels of seismic intensity.

It is also an important aspect in the coming time with the construction sector, future construction to have green materials and green practice in construction to mitigate the environmental effect on RC structures. Other areas defining the future include employing recycled materials, such as recycled aggregates in concrete, in energy-efficient construction practices. Fig. 4 captures all innovative materialsand construction techniques in the design of shear walls and filler slabs.

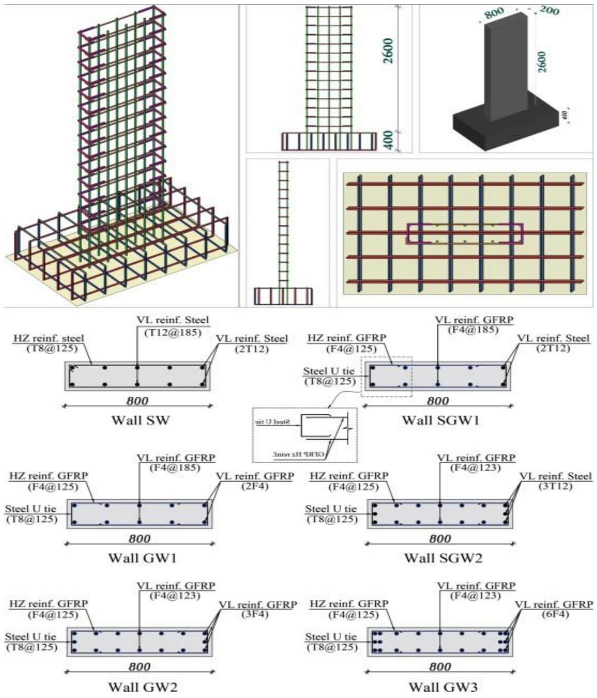


Fig. 19. The integration of innovative materials and construction techniques in the design of shear walls and filler slab

In general, advances in materials and construction techniques, along with computational tools, have propelled innovation in shear walls and filler slab design. These developments promise better seismic performance, efficiency, and sustainability in RC structures, thus developing a future well for safer, more resilient buildings to be built in seismic regions.

IX. CHALLENGES AND OPPORTUNITIES

A. Key Challenges in the Current Research and Practice

Even though reinforced concrete (RC) structures have now achieved remarkable advancements in their design and construction, various still seize the interest of seismic engineering. Among the interesting challenges confronting this field is prediction of the extremely complex behavior of RC structures subjected to seismic loads. Under the intrinsic variability of material properties, modes of construction, and inputs pertaining to earth quakes, accurately modeling and predicting structural responses pose significant challenges. Furthermore, the introduction of novel materials, or innovatively utilized construction techniques will warrant extensive evaluation and validation procedures which are usually time consuming and expensive.

It is also difficult to retrofit already constructed buildings. Most of those built before today's seismic codes have quite weak reinforcement and detailing; thus, they are not safe enough to sustain seismic events. Retrofitting such buildings to current standards poses not only technical but also logistical and financial problems, especially in very densely populated cities.

B. Potential Areas for Future Research

Future research in seismic engineering should focus on a wide variety of areas to overcome the challenges of an improved design. One sure area is the development of advanced materials with increased strength, ductility, and energy dissipation. Research into ultra-high performance concrete (UHPC) and fiber reinforced polymers (FRPs) should continue above all concerning their use in shear walls and filler slabs. In particular, there is sensitivity at those scales to enable better integration between research on smart materials and sensor technologies into RC. The adaptive behavior under seismic forces will be offered by the smart material of shape memory alloys (SMAs); embedded sensors will achieve real-time monitoring and damage detection of structures, which in turn will allow the development of self- healing and self-monitoring structures in the future. Thus, resilience and lifespan will be enhanced tremendously.

Future research is in computational tools advancements and artificial intelligence, which will also be very promising. AI and machine learning algorithms can analyze large data sets from past earthquakes and simulations, further improving predictive models and optimizing designs of structures to specific seismic conditions.

C. Opportunities for Improving the Seismic Performance ofRC Structures

There exist many possibilities for improving the seismic performance of RC structures. The most important one is performance-based design, where a structure is built for certain performance objectives corresponding to the different levels of seismic intensity. Performance-based design is, thus, an effective way of ensuring optimal efficiency and effectiveness in the use of materials and construction techniques while enhancing security and cost-effectiveness, rather than overdesigning the structure for all possible scenarios.

Another possibility is prefabrication and modular construction methods. These should set new standards for the reduced costs associated with improved quality and precision, shorter building time, less labor expended, and the final, overall seismic performance of the RC structures. Prefabricated shear walls and filler slab elements can be manufactured under controlled conditions to ensure reproducible quality and better performance under the earthquake scenario.

Finally, incorporating and promoting sustainability in seismic design would matter a lot. Use of recycled materials, energy-efficient construction techniques, and innovative design strategies reduces environmental impact while maintaining or improving seismic performance on RC structures. All of this will bring that future to make seismic engineering advance in creating safer, more resilient, and sustainable RC structures.

X. CONCLUSION

The performance of a shear wall structure with various opening configurations was investigated in this study, and various building parameters such as time period, storey displacement, storey drift, storey shear, and stress distribution were compared, and the following conclusions were reached:

1) Shear wall structures with no opening, vertical opening, and staggered opening have time periods of 0.531, 0.585, and 0.591 seconds, respectively.
2) In comparison to vertical opening and no opening in shear wall, staggered opening in shear wall takes more time.

3) By using the Equivalent Static Method, the storey displacement for a shear wall structure without opening, with vertical opening, and with staggered opening is 21.443 mm, 23.171 mm, and 23.169 mm, respectively.
4) According to the Response Spectrum Method, the storey displacement for a shear wall structure without opening, with vertical opening, and with staggered opening is 18.196 mm, 20.161 mm, and 20.123 mm, respectively.
5) The presence of an opening increases storey displacement in both methods, but storey displacement in a staggered opening in a shear wall is slightly less than in a vertical opening in a shear wall.
6) By using the Equivalent Static Method, the Storey drift for a shear wall structure without opening, with vertical opening, and with staggered opening is 0.000755, 0.000798 and 0.000806, respectively.
7) Storey drift for shear wall structure without opening, with vertical opening and with staggered opening are 0.00066, 0.000688 and 0.0007 respectively by Response Spectrum method.
8) Storey drift is higher for staggered openings than for vertical openings, but storey drift decreases toward the base for staggered openings than for vertical openings, according to both methods.

By using the Equivalent Static Method, the Storey shear for a shear wall structure without opening, with vertical opening, and with staggered opening is 3684.0406 kN, 3227.3181 kN, and 3256.484 kN, respectively.

The effects of shear walls and filler slabs on seismic performance have been appreciated in this review as critical components of the RC structures. Therefore, shear walls are available with great stiffness and lateral resistance to red outcome lateral displacement and absorb seismic energy in inelastic deformation. The filler slab lessens the total weight of the structural system, thus reducing the seismic forces acting on buildings and promoting better energy dissipation Most importantly, it shows that shear walls made of these advanced materials such as ultra-high-performance concrete (UHPC) and fiber-reinforced polymers (FRPs) can even further improve the performance of the filler slabs. Modular construction and prefabrication methods have also been linked with better quality control and shorter time of construction coupled with superior seismic performance.

Future Development and Practice will recommend research on the use of smart materials and sensor technologies towards the realization of adaptive and self-monitoring RC structures. The incorporation of performance-based design principles in advancing green seismic design would, moreover, foster more secure and resilient structures. It will also embrace their wider acceptance to ensure the future survivability of RC structures in seismic events. This would result in better safety, efficiency and sustainability for such infrastructures.

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