IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

"Inter-Relationship Of Various Types Of Infill Walls And Geometrical Parameters Of Rc Frame Building''

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Abstract*:* Lateral load effects on high rise buildings are quite significant and increase rapidly with increase in height. In high rise structures, the behavior of the structure is greatly influenced by the type of lateral system provided and the selection of appropriate. The selection is dependent on many aspects such as structural behavior of the system economic feasibility and availability of materials. The structural performance of high-rise buildings is critically influenced by lateral load-resisting systems, especially under seismic loading conditions. This study investigates the dynamic behavior of a high-rise building equipped with bracings and shear walls when subjected to response spectrum analysis. The primary objective is to evaluate the efficiency of combined structural systems in enhancing the seismic resistance and overall stability of tall structures. A comparative analysis is conducted using structural modeling software to assess parameters such as lateral displacement, inter-storey drift, base shear, and modal behavior. The incorporation of bracings and shear walls is found to significantly reduce seismic response, demonstrating improved stiffness and energy dissipation capacity. The results underscore the importance of integrated lateral load-resisting systems in modern high-rise design, ensuring safety, serviceability, and code compliance under dynamic earthquake loading.

In the design of high-rise buildings, ensuring structural stability and safety under seismic loads is a critical concern. This thesis presents a detailed analytical study on the seismic performance of a high-rise building incorporating both bracings and shear walls as lateral load-resisting systems. The building is analyzed using the Response Spectrum Method as per relevant seismic codes to assess its behavior under dynamic earthquake loading.

The objective of this study is to evaluate the effectiveness of bracing systems and shear walls individually and in combination in controlling lateral displacements, inter-storey drift, and base shear. A comparative analysis is carried out using structural analysis software, focusing on different configurations of bracing and shear wall placements. This research highlights the importance of hybrid structural systems in optimizing high-rise building responses to seismic excitations and provides valuable insights for engineers and designers aiming to develop safe, economical, and code-compliant structures in seismic-prone regions.

Key Words : Infill Walls , Base Shear , Storey Drift, Seismic zone.

1.1 Introduction

In India most of the multistoried buildings are found to have open storey at ground floor with masonry infill in the upper stories. This is primarily being adopted to accommodate parking or reception lobbies in the ground floor. Conventional practice is to design these buildings as RC frames considering the masonry infill as nonstructural component, thus neglecting the contribution of the infill in the total structural response. But in reality masonry infills interact with the frame members and make the structure stiffer; resulting stiffness irregularity in buildings with open ground floor. In this thesis, an extensive computational study has been conducted to monitor the response of RC building frames subjected to ground accelerations, and to determine the seismic vulnerability of such building frames in selected seismic zone of India. The numerical investigations performed, in this present study, are meant to evaluate the soft storey effects on a typical interior bay of a RC building frame subjected to earthquake loadings. Infill percentage in the upper stories and number of stories (i.e., total height) of the building frames are considered as the main parameters. In order to get the dynamic response of the frames, time history analyses of the frames have been performed through application of real earthquake time history accelerograms following National Centre for Seismology (NCS), India.

1.2 NEED FOR THE PRESENT STUDY

The present study is essential due to the increasing use of high-rise buildings and the often-overlooked structural impact of infill walls, which significantly influence seismic performance. Traditional design practices neglect their contribution, leading to potential inaccuracies in predicting building behavior under earthquakes. By using nonlinear time history analysis, this study aims to capture the realistic dynamic response of RC frames with varying infill configurations, addressing structural irregularities and enhancing safety, performance-based design, and code development for seismic-prone regions.

1.3 OBJECTIE AND SCOPE OF THE STUDY

The objective of the study is to analyze the seismic behavior of high-rise RC structures with different plan shapes (C, L, Square, T) and varying infill wall percentages (30%, 60%, 90%) using nonlinear time history analysis. The scope includes evaluating the effects of seismic forces on structural responses such as base shear, storey displacement, and peak acceleration across 10, 15, and 20-storey buildings to understand how infill variations and geometry impact structural performance..

2.1 LITERATURE SURVEY

S.T.B. College of Engineering, Tuljapur, Maharashtra (2014): This study analyzes high-rise buildings using STAAD.Pro under various lateral stiffness conditions, including bare frames, brace frames, and shear wall frames. The RSA method is employed to assess the impact of higher vibration modes and force distribution within the elastic range. Key parameters such as base shear, story drift, and deflections are evaluated to determine the most effective lateral load-resisting system.

Apurva Arjun Gaikwad & Atul B. Pujari (2019) : worked on Optimal Design of Tube-in-Tube Systems. Primary objectives of this study were to investigate effects of varying design parameters on the tube action and shear lag behavior of a typical reinforced concrete tube-in-tube building & proposed optimal design approaches for similar tube-in-tube structures. Parametric study was conducted with selected key design variables on the performance

Fasil Mohi ud din (2017) : his study explores the efficiency of various bracing systems in multi-story steel frames using RSA. It evaluates how different steel profiles and bracing arrangements impact lateral displacement and overall structural performance during seismic events

Kamani Kanchan, Pankaj Kumar (2024) : The research compares several bracing systems in a 15- story reinforced concrete structure. It assesses maximum story displacement and base shear under seismic loading, providing insights into the effectiveness of different bracing configurations of a 40 story building. The design variables considered for parametric study included column & beam depth, interior walls of the moment frames. Performance of each model was assessed in terms of overall and critical (maximum) story drifts, and shear lag behavior. Overall effects of column depth on the tube action and shear lag behavior more prominent than the other member dimensions.

Nimmy (2015) studied the seismic performance of tube-in-tube structures. Three different models were developed in SAP2000 software by varying location of the inner tubes. Structures were analyzed using continuum approach in which the horizontal slabs and beams connecting vertical elements were assumed as continuous connecting medium having equivalent distributed stiffness properties. Equivalent static, Response spectrum analysis and Time-history analysis was done and the output of three models were evaluated to compare their seismic performance. It was concluded that time-history analysis predicts structural response more accurately than equivalent static analysis. It was seen that for a regular structure with seismic loading, the model with core located at the corners yielded better results. Large displacements were seen in which positioning of the inner cores were not exactly at middle nor at corner. Hence this type of arrangement was least recommended.

Yogendra (2015) studied Lateral load Resisting Systems for Multi-Storey Building. Structural system can be visualized as consisting of two components 1) Horizontal Framing consisting of Slab and Beams which is primarily responsible for transfer of vertical load to the Vertical framing system and 2) Vertical Framing System consisting of Beams and Column which is primarily responsible for transfer of Lateral load to Foundation. Framed, Shear-Wall, Frame-Shear wall system, Framed Tube System, Tube in Tube System and Modular Systems were compared.

Navin R Amin et.al studied the Design of Multiple Framed Tube High Rise Steel Structure in Seismic Region carried out analysis and design of Multiple tube for governing load cases and finally concluded that the Multiple Framed Tube concept can be effectively utilized in seismic region. Also proper proportioning of framed members will result in good consistent in terms of strength, stiffness etc.

Khanetal discussed the analysis and design of framed tube structures for tall concrete buildings. The behavior of framed tube structures was discussed from an overall structural system point of view. The influence of various structural parameters was emphasized for achieving better tubular behaviors. Also the concept of the equivalent reduced plane frame modeling technique was used for developing a series of influence curves for the preliminary analysis and design.

A.M. Chandler suggested the application of strut and- tie method on outrigger braced core wall buildings. This is to enhance practicing engineers to understand the general structural behavior of outrigger braced core wall system.

B.N.Sarath strut and-tie method is applied to analyze the whole lateral structural system. The complete load transfer mechanism between the outrigger brace and the core wall is displayed. Many practical concerns in design including the structural behaviors of different configuration of our triggers, the effect of openings through the core wall adjacent to the outrigger brace, the arrangement of shear studs on outrigger brace and the shear link arrangement in core wall are briefly discussed.

Jiemin Ding introduced the design and research for a tall building of concrete filled square steel tube. The braced - frame system was adopted to reduce the torsion effect brought by architectural irregularities of plan and elevation. The modal analysis, response spectrum analysis and time history analysis was carried out by several software. The period, displacement and story shearing force etc. were obtained and compared with each other.

3.1 LATERAL LOAD RESISTANT STRUCTURAL SYSTEMS

Safety and minimum damage level of a structure could be the prime requirement of all buildings. To meet these requirements, the structure should have adequate lateral strength, lateral stiffness, and sufficient ductility.

Structural systems may be classified as follows

- Moment-Resisting Frames
- Flexural (Shear) Walls Systems
- Dual Systems

3.1.1 Moment Resisting Frames

It is a system in which members and joints are capable of resisting vertical and lateral loads primarily by flexure i.e. Moment resisting frame is a space frame designed to carry all vertical and horizontal loads, by developing bending moments in the members and at the joints. Elevation of moment resisting frame is shown in Figure 3.1.

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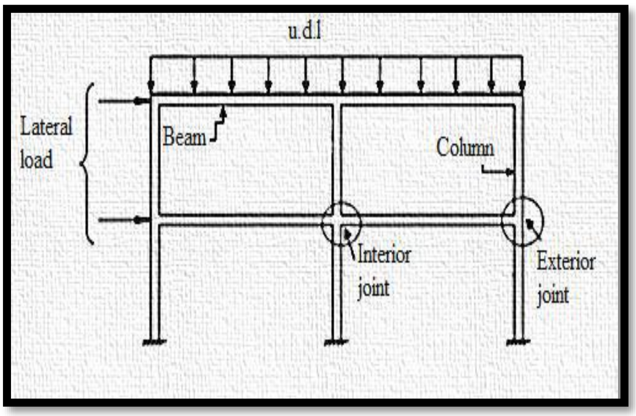


Figure 3.1: Elevation of Moment Resisting Frame

Moment resisting frames have rigidly joined beams and columns. Loads are resisted mainly by bending and shear in beams and columns. Due to the overturning moment acting on the frames, the columns experience compression and tension forces in addition to their gravity loads. Frames may be designed using concept of strong column-weak girder proportions to perform well during strong ground shaking.

Three main goals of moment resisting frames are -

1. To achieve strong column-weak beam design.
2. To avoid shear failure.
3. To provide details that enable ductile flexural response in yielding regions.

Moment resisting frames may be Ordinary Moment Resisting Frames (OMRF) or Special Moment Resisting Frames (SMRF).

Ordinary Moment Resisting Frames (OMRF) is those frames which designed and detailed as per IS 456:2000 only and not meeting special detailing requirements for ductile behavior. Value of response reduction factor is 3 for ordinary moment resisting frames.

Special Moment Resisting Frames (SMRF) is those frames which specially detailed to provide ductile behavior and comply with the requirements given in IS 4326 or IS 13920 or SP6. These frames required in the higher seismic zones. Value of response reduction factor is 5 for special moment resisting frames.

3.1.2 Flexural (Shear) Walls Systems

Special Moment Resisting Frames are generally efficient up to 10-15 storey‟s only. Taller moment resisting frames are undesirable for earthquake resistance as large inter-storey displacements can cause severe damage to non-structural components. Therefore in areas of high seismic risk, RC shear walls have been widely used as the main lateral load resisting system in medium and high-rise buildings because of their high lateral stiffness.

Shear wall is a reinforced concrete wall designed to resist lateral forces parallel to the plane of the wall acting in its own plane and detailed to provide ductility conforming to IS13920-1993. It can be used up to a height of 70m, if and only if, flexural walls in any plane do not resist more than 33% of the earthquake design force including torsional effects.

Shear walls as shown in Figure 3.3 have considerable stiffness in their own plane, but very little stiffness in the perpendicular direction and their satisfactory performance depends on the stiffening effect of floor diaphragms, which prevent buckling of walls. All the longitudinal seismic loads are resisted by RC shear wall. Recent earthquakes shown that only properly designed shear walls can withstand strong earthquake forces with no or minor damage.

3.2.1 Dual Systems

In high rise building, dual systems may be used where walls and frames together resist the horizontal loads. In present contest many buildings are provided with more than one type of lateral load resisting systems. Usually in these days structures are designed in such a way that its lateral force resistance is provided by frames and shear walls or infills or bracings. This combined system can be said as dual system. Dual system may combine the advantages of the constituent elements. Frames with bracing, infill and shear wall are shown in Figures 3.4 (a), 3.4 (b) and 3.4 (c) respectively.

Buildings with dual system consist of shear walls or braced frames and moment resisting frames such that:

• The two systems are designed to resist the total design lateral force in proportion to their lateral stiffness considering the interaction of the dual system at all floor levels; and

• The moment resisting frames are designed to independently resist at least 25 percent of the design base shear.

3.3 HIGH RISE TUBULAR SYSTEMS

In 1960s and 1970s Dr. Khan became the most prominent innovator in the area of high rise buildings, both in concrete and steel. He introduced the tubular design concept. This concept assumes that façade structure responds to lateral loads as a closed hallow box beam cantilevering out of ground. The exterior walls resist all or most of the time dependent load. Therefore, costly interior diagonal bracing or shear-walls are eliminated.

The tube walls consist of closely spaced columns around the perimeter of the building tied together by deep spandrel beams. This façade looks like a perforated wall. The stiffness of the façade wall may be further increased by additional diagonal braces causing truss like action. The rigidity of the tube is so high that it resist all lateral loading similar to cantilever beam. The exterior tube alone can resist all lateral loads entirely, or it can be further stiffened by adding interior bracing of some kind. Different applications of tubular design have been made upto date. These may be sub-divided into following types:

1) **Hollow tube**
   - (i) Framed tube or Vierendeel tube.
   - (ii) Deep spandrel tube.
   - (iii) Perforated shell tube.
   - (iv) Trussed tube (column diagonal trussed and lattice trussed tube).
2) **Interior braced tube**
   - (i) Tube with parallel shear-walls.
   - (ii) Tube in tube (including multiple tubes like triple tube).
   - (iii) Modified tube (tube with rigid frames, tube in semitube).
   - (iv) Modular tubes or bundles tubes.
3) **Hybrid tube**
   - (i) Partitioned tube.
   - (ii) Ruptured or partial tube.
   - (iii) Stressed skin tube.
   - (iv) Mixed construction tube.
4) **Hollow megatube (i.e. effect of building form)**

3.4 EARTHQUAKE RESISTANCE DESIGN CRITERIA

3.4.1 Seismic Zones in India

The varying geology at different locations in the country implies that the like hood of damaging earthquakes taking place at different locations is different. Thus, a seismic zone map is required so that buildings and other structures located in different regions can be designed to withstand different level of ground shaking.

At present the zone map has four seismic zones – II, III, IV, and V. Seismic zone II and zone III are major zones, covering more percentage of land area in India. Geographical statistics of India show that almost 54% of the land is vulnerable to earthquakes. Eastern India has higher seismic intensity hence falls under zone V and North-East India falls under zone IV. Figure 3.12 show the Map for various seismic zones in India.

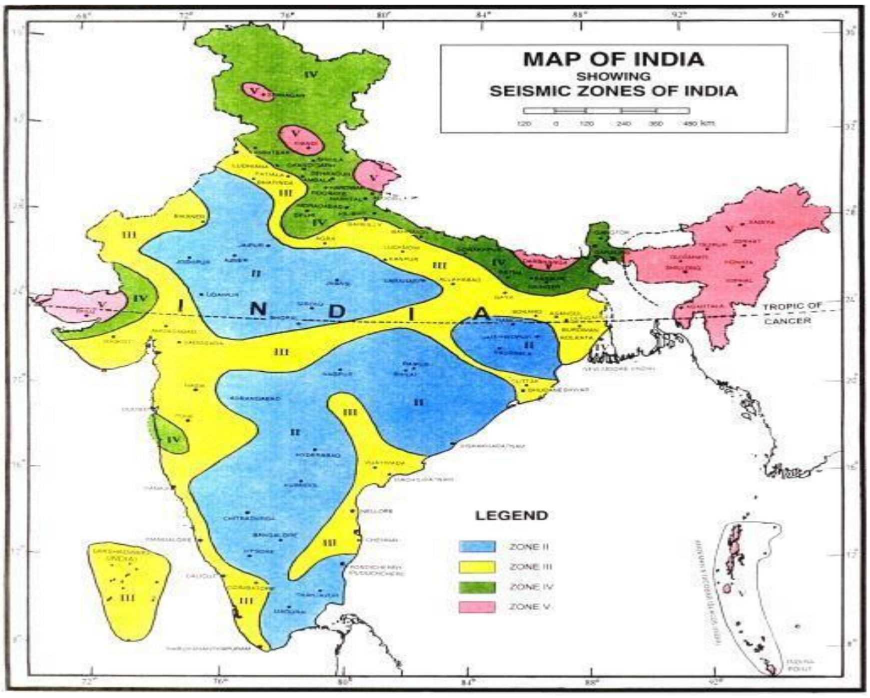


Figure No 4: Map showing various seismic zones of India

3.4.1.1 Zone Factor (Z)

Seismic Zone	II	III	IV	V
Seismic Intensity	Low	Moderate	Severe	Very Severe
Zone Factor	0.10	0.16	0.24	0.36

Table 1: Zone Factor (Z) as per IS 1893 (Part 1): 2016

3.4.2 Response Reduction Factor (R)

Lateral load-resisting system	Response Reduction Factor (R)
Ordinary RC moment resisting frame (OMRF)	3.0
Special RC moment resisting frame (SMRF)	5.0

Table 2: Response reduction factors (R) as per IS 1893 (Part 1): 2002

3.5 LOAD COMBINATIONS CONSIDERED

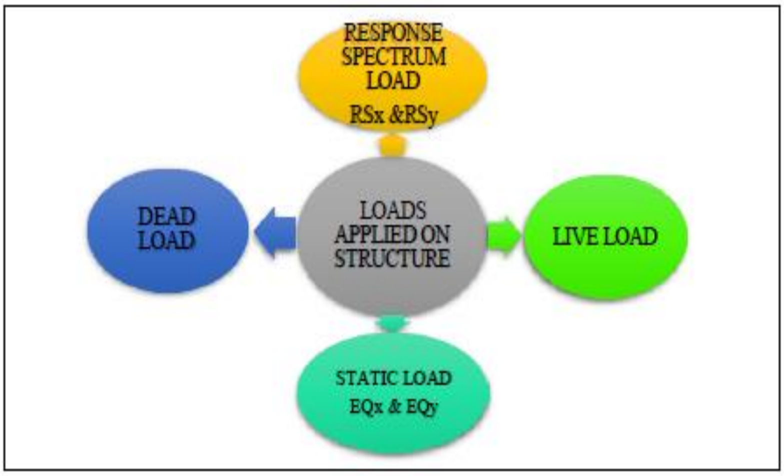


Figure 5: Types of Load

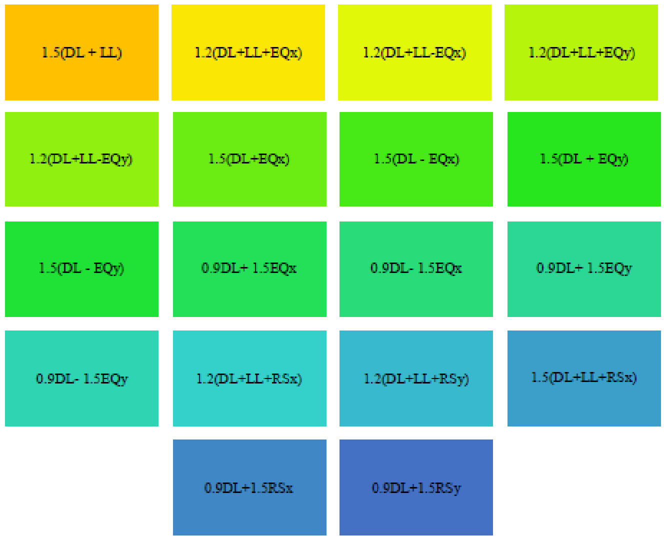


Figure 6: Load Combinations

Table No 3: Description of various Models considered

Model No	Name of Structural System
I	C-Shape in plan
II	L-shape in plan
III	Square Shape in plan
IV	T-Shape in plan

Table No 4: Detailed Specifications Required for the Structures

Sr.No	Structural Element	Dimension
1	Plan Dimensions	21 X 21 m
2	Spacing in X-Direction	3 m
3	Spacing in Y-Direction	3 m
4	Number of Bays in X-Direction	7
5	Number of Bays in Y-Direction	7
6	Number Stories	10, 15 and 20
7	Grade of Concrete	M25
8	Grade of Steel	Fe500
9	Support Conditions	Fixed
10	Typical Storey Height	3.2 m
11	Bottom Storey Height	2 m
12	Total Height of Structure	37.2m,53.2m &69.2m
13	Thickness of Slab	0.15 m
14	Thickness of Wall	0.230 m

Table No 5: Detail Description of Loads Applied on Structure

Sr. No	Type of Load	Intensity
1	**Dead Load** Self-Weight of Slab Self-Weight of Beam Self-Weight of Column Floor Finish	1 kN/m2
2	Live Load	2.5 kN/m2
3	Wall Load	(Height of Wall – Depth of beam) x Density of Masonary x Thickness of Wall Eg : (3.2 -0.45) x 20 x 0.23 =12.65 KN/m

Table No 6: Detailed Specifications for Seismic Analysis

DETAILED SPECIFICATIONS FOR SEISMIC ANALYSIS (ACC TO IS 1893- 2002)		
1	Zone	V
2	Zone Factor **(Z)**	0.
3	Importance Factor **(I)**	1
4	Response Reduction Factor **(R)**	5
5	Soil Type	I, II and III
6	Method of Analysis	Response Spectrum Analysis

4.1 ANALYSIS RESULTS FOR MODULE – 01 (FOR 30% INFILL WALL)

4.1.1 BASE SHEAR COMPARISON

Structure	C-Shape		L-Shape		Square Shape		T-Shape	
	VBx	VBy	VBx	VBy	VBx	VBy	VBx	VBy
10	58996	60028	44328	43355	74481	74480	20520	25161
15	53209	65758	48411	42267	85890	74892	36653	34780
20	55870	72715	56936	55893	88518	83519	48418	41798

Table 7: Base Shear in X & Y direction for Different Shapes of structure in plan

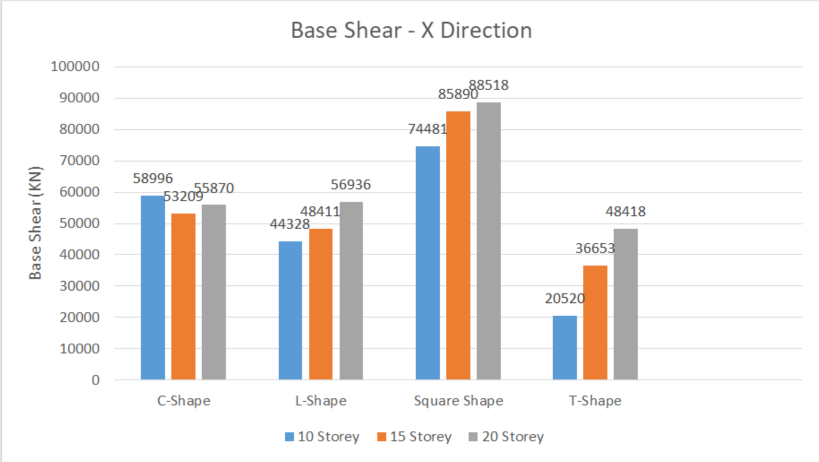


Chart 1: Base Shear in X direction for various heights and shapes for 30% infill wall

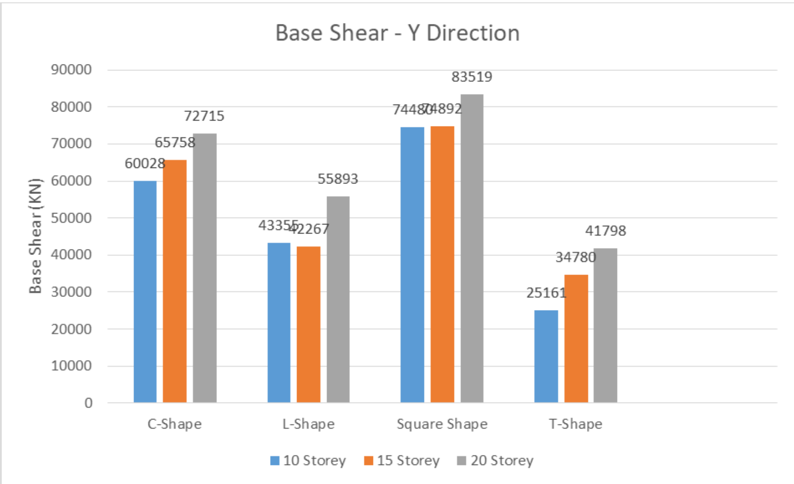
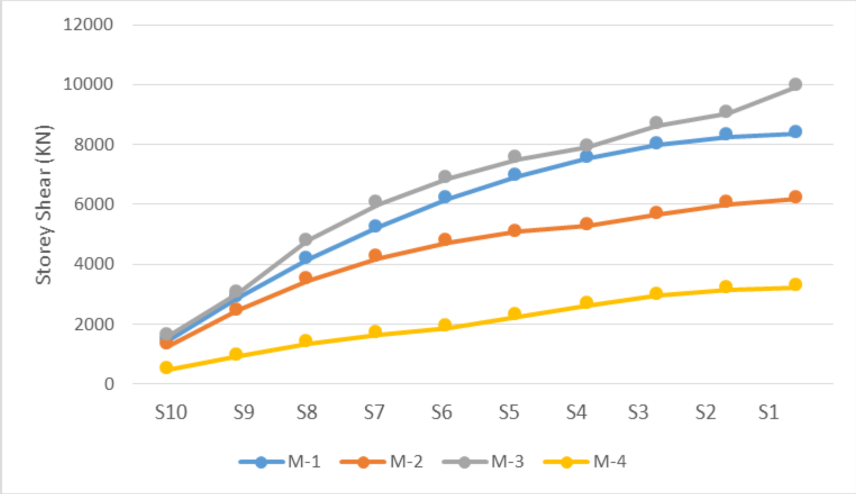


Chart 2: Base Shear in Y direction for various heights and shapes for 30% infill wall

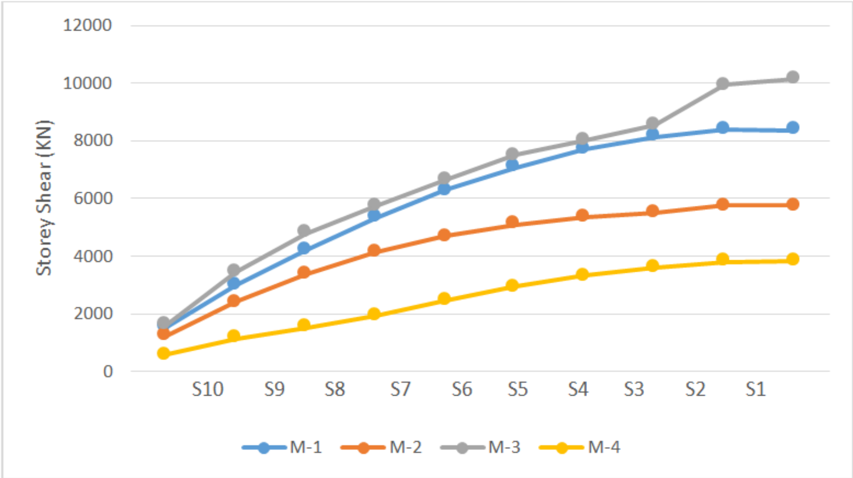
4.1.2 STOREY SHEAR COMPARISON

Storey	C-Shape (M-1)		L-Shape (M-2)		Square Shape (M-3)		T-Shape (M-4)	
	Qx	Qy	Qx	Qy	Qx	Qy	Qx	Qy
10	1468	1555	1273	1244	1600	1635	476	593
9	2899	3013	2469	2418	3025	3456	948	1136
8	4157	4192	3447	3389	4786	4796	1345	1533
7	5246	5326	4198	4149	6005	5722	1656	1923
6	6167	6285	4729	4703	6853	6632	1881	2456
5	6926	7072	5081	5087	7501	7514	2251	2939
4	7528	7690	5299	5341	7923	7996	2635	3335
3	7974	8129	5646	5499	8633	8534	2946	3622
2	8266	8409	6013	5762	9043	9943	3159	3799
1	8366	8356	6173	5763	9953	10143	3224	3825

Table No 8: Storey Shear in X & Y direction for Different height of structure and structural provisions-10 storied building



Graph 1: Storey Shear in X direction for various heights and shapes for 30% infill wall



Graph 2: Storey Shear in Y direction for various heights and shapes for 30% infill wall

4.1.3 STOREY DISPLACEMENT COMPARISON

Storey	C-Shape		L-Shape		Square Shape		T-Shape	
	δx	δy	δx	δy	δx	δy	δx	δy
10	3.2	6.77	8.2	8.65	1.7	1.7	17	10.02
15	7.06	9.1	13.72	13.64	7.96	11.46	19.11	10.79
20	7.78	8.52	13.98	10.63	25.11	25.11	19.4	10.75

Table 9: Storey Shear in X & Y direction for Different height of structure and structural provisions-10 storied building

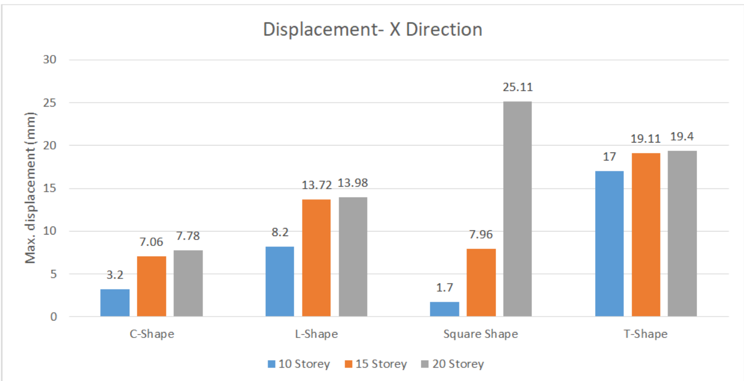


Chart 3: Storey Displacement in X direction for Different height of structure and structural provisions

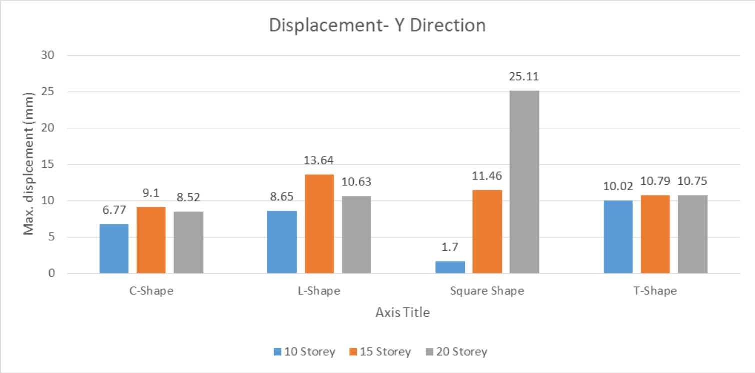


Chart 4: Storey Displacement in Y direction for Different height of structure and structural provisions

5.1 SUMMARY OF WORK AND COMMON OBSERVATIONS FROM MODULE-I, MODULE-II AND MODULE-III

Following are the observations that drawn from the present study. Here we have considered 10, 15 and 20 storey buildings. The different structure.

Different shapes in plan are considered for the study with variation in the elevation height.. The Infill wall percentage is decided with respect to total number of bays in plan area ie. in Square Shape plan total 180 number of bays are there. 30% of 180 number of bays will be around 54: means we provided/distributed infill wall in plan counting with 54 bays with infill. Likewise calculated in the same way for 60% and 90%.

The models that is created has been examined for the Hard soil. The Tables and charts mentioned above and the common observation are mentioned in next point:

1. Base shear observed to be more for the Square Shape and C Shape observed to be nearly same and those to be 35% more than L Shape and 45% more than T Shape. This trend is same for all percentage of infill wall
2. More the height of structure more is the base shear.
3. 60% infill shows 8 to 10% more base shear and 90% infill provision shows 10 to 12% more base shear compare to 30% infill provision.

As the percentage of infill wall increases, Lateral stiffness get increases which leads to increase the base shear acting on the structure. Hence stroey shear will also get increases respectively. If we say K as lateral stiffness, Vb as base shear and Δ as lateral deformation, we can have relation,

$K = Vb \cdot \Delta$

So base shear is directly proportional to stiffness of the structure where infill walls enhances the lateral stiffness of the structure. So it is recommended to consider the Infill efeect appropriately to reduce lateral deformation.

The C shape leads to torsional irregularity, meaning when lateral loads act on the structure, it doesn't just move side-to-side but also twists**.** Discontinuous mass or stiffness distribution leads to one side of the C often moves more than the other.

Here the lateral displacement of top floor of structure in X direction seems to be uniform whereas it is non-uniform in Y Direction, So leads to Generate Torsional Effect. So it is necessary to achieve distribution of centre of mass and centre of stiffness as close as possible in the designing stage only.

4. Lateral Displacement is seems to be more for T-Shape structure compare to other types of structures. As it can be say that the lateral stiffness is less than other structures.
5. 60% infill provision shows 3 to 5% more peak accelaration and 90% infill provision shows 4% to 6% more peak acceleration compare to 30% infill provision. Hence to reduce the acceleration response of the structure, the appropriate infill walls shall be considered which is termed as partition wall in practice.

6.1 CONCLUSION

This study has comprehensively analyzed the influence of various infill wall configurations and geometrical layouts on the seismic performance of high-rise RC frame buildings using nonlinear time history analysis. Key parameters such as base shear, storey displacement, storey shear, and peak acceleration were examined across multiple building shapes and heights to assess structural response under dynamic earthquake loading.

- The findings reveal that **infill walls significantly improve the lateral stiffness** and reduce inter-storey drifts and displacements. As the infill percentage increases (from 30% to 90%), the overall structural performance improves, indicating better seismic resistance.
- The study also shows that **building shape plays a vital role** in determining seismic behavior. Regular shapes like square and rectangular plans exhibit more uniform responses, while irregular shapes like L and T create torsional effects and uneven stress distribution, potentially leading to weak zones in the structure.
- **Time history analysis proves to be an effective method** for understanding real-time structural behavior under seismic forces. It enables accurate modeling of nonlinear interactions and highlights critical zones requiring design attention, making it more suitable than linear or static methods for high-rise buildings.
- These insights are valuable for structural engineers and designers aiming to create safer, code-compliant, and performance-oriented buildings in seismic-prone areas. The study emphasizes the need to include infill wall behavior and plan irregularities in the early design phase to prevent structural failures during earthquakes.

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