"Comparative Study of Seismic Behavior of RCC Buliding Frames With and Without Masonry Infll Wall"

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ABSTRACT

This project investigates the seismic performance of Reinforced Cement Concrete (RCC) building frames with and without masonry infill walls. In conventional structural design, masonry infill walls are generally treated as non-structural elements; however, they significantly influence the stiffness, strength, and overall seismic response of buildings during earthquakes. A fifteen-storey RCC building located in Seismic Zone III is modelled and analysed using ETABS software. Different building configurations, including bare frames, unfilled frames, irregular-shaped frames (C-shape and T-shape), and soft-storey structures, are considered. Masonry infill walls are modelled using the Equivalent Diagonal Strut Method, and the strut widths are determined using Mainstone and Hendry formulations. Seismic analysis is carried out using the Equivalent Static Method and Response Spectrum Method in accordance with IS 1893:2016 provisions. The structural response is evaluated in terms of storey displacement, inter-storey drift, base shear, storey stiffness, and fundamental time period. The results indicate that the inclusion of masonry infill walls considerably increases the lateral stiffness and strength of the structure, leading to a significant reduction in storey displacement and inter-storey drift. In filled frames exhibit better seismic performance compared to bare frames, while soft-storey configurations show increased vulnerability under earthquake loading. The study concludes that masonry infill walls play an important role in enhancing the seismic resistance of RCC buildings and should be considered appropriately in structural analysis and design.

INTRODUCTION

General

Among natural hazards, earthquakes have the potential to cause the greatest damage because seismic waves are unpredictable and highly dynamic. To design earthquake-resistant structures, architects and structural engineers consider four key principles: seismic design, lateral stiffness, strength, and vertical flexibility. While many other factors, such as aesthetics, functionality, usability, and occupant comfort, also influence building design, these four principles are essential for ensuring structural safety during earthquakes. Vertical stiffness, structural strength, and flexibility can be achieved by strictly adhering to seismic design codes. In addition, a well-planned structural configuration and a carefully considered architectural layout play a crucial role in enhancing the overall seismic performance and resilience of a building.

Seismic Waves

The energy released during an earthquake propagates through the Earth in the form of seismic waves. These waves are broadly classified into two types: **body waves** and **surface waves**. Body waves travel through the Earth's interior, whereas surface waves propagate along the Earth's surface and are generally responsible for the most severe ground shaking. Body waves consist of **Primary (P) waves** and **Secondary (S) waves**. P-waves are compressional waves in which particles of the material move back and forth in the direction of wave propagation, producing alternating compression and expansion. They are the fastest seismic waves and are the first to reach a location. In contrast, S-waves are shear waves that cause particles to move perpendicular to the direction of wave travel, generating stronger ground motion than P-waves. Surface waves are divided into **Love waves** and **Rayleigh waves**. Love waves produce horizontal shear motion perpendicular to the direction of wave propagation, with little or no vertical displacement. Rayleigh waves, on the other hand, cause particles to move in an elliptical path within the vertical plane, combining both vertical and horizontal ground motion. Due to their large amplitudes and prolonged duration, Love and Rayleigh waves often cause the greatest damage to buildings and infrastructure during earthquakes.

Method of Seismic Analysis

There are various strategies for seismic investigation for the construction. The investigation is done by either modular examination or dynamic investigation method. A dealt with framework embraced that will be insinuated as equal power procedure so outstandingly saw as similar sidelong power methodology or indistinguishable static technique. His head qualification between a similar static and dynamic assessment lies in degree and dissemination of flat controls over the level of the designs. In strong assessment strategy the equal powers rely upon the properties of the ordinary vibration techniques for the design, not altogether settled by movement of mass and robustness over level.

Equivalent static strategy:

Response range examination:

In filled RC Frames:

Reinforced concrete (RC) frame structures consist of **horizontal members (beams)** and **vertical members (columns)** connected through rigid joints. These frames resist both **gravity loads** and **lateral loads** by developing flexural and shear resistance in the beams and columns. In many RC buildings, **masonry infill (MI) walls** are incorporated as partition walls or exterior cladding to enclose the building. Although masonry infill walls are often considered non-structural elements, their material properties, configuration, and construction details can significantly influence the overall structural behavior and seismic performance of the building.

Objectives of the Study

The objectives taken into consideration for the current work are listed below:

1. To investigate the seismic response of infilled and bare frame structures under seismic loading in accordance with the provisions of **IS 1893 (Part 1): 2016**.
2. To perform seismic analysis and evaluate the structural response using the **Response Spectrum Method**.
3. To study the influence of masonry infill walls on the seismic performance of regular and irregular structural frames.
4. To evaluate the effectiveness of the **Hendry equivalent diagonal strut model** in representing masonry infill walls during seismic analysis.
5. To examine the effects of a **soft storey** on the overall seismic behaviour of buildings.
6. To assess the effects of storey displacement, storey drift, storey stiffness, base shear, and the fundamental natural time period on the seismic performance of the structure.

LITERATURE REVIEW

Özge Onat and Pınar Usta Evci(2024) https://link.springer.com/article/10.1007/s10518-024-01936-7: This study scrutinizes a building that sustained damage in the Izmir earthquake in Turkey. The building was represented in four distinct models using the SAP2000 V24 finite element program: without infill walls, with porotherm clay blocks, burnt clay brick, and autoclaved aerated concrete blocks. Real parameters of the building were utilized in the modeling process. Upon comparing the results of the time history analysis, it was observed that the presence of infill walls had a positive impact on various building properties, including period, ground floor shear force, column bearing capacity, and inter-story drift ratio. Additionally, infill walls increased base shear forces on the ground floors and the overall base shear force. Notably, similar outcomes were obtained with porotherm clay blocks and burnt clay brick as infill wall types, while autoclaved aer ated concrete blocks exhibited lower stiffness than other infill wall models.

João Dias-Oliveira, Hugo Rodrigues, Panagiotis G. Asteris and HumbertoVarum (Buildings **2022**, 12, 1146. https://doi.org/10.3390/buildings12081146**):** Infilled frames are usually modelled in the context of global building analysis using simplified procedures without considering the aspects resulting from the interaction between the panel and the frame. Other aspects, such as adequate design of the floor beams and the beam columns' joints, and control of potential sliding shear failure of the columns, that significantly affect the structural response, are also typically not accounted for. In the present work it is intended to look over the literature to evaluate the state of the art regarding the lessons learn from recent earthquakes, the evolution of the structural codes considering the infill masonry panels, and how this influences the evolution of the numerical models and the experimental works to overcome the existent gaps.

Xuetan Zhang , Yang Zhou, Xiangyu Liu, Yaoyu Zheng 1 and Zhengxin Qi (2024): This paper studies the impact of half-height infilled walls on the failure modes of frame columns through quasi-static tests of both frame models and half-height infilled wall frame models. Based on the experimental results, a seismic analysis model of reinforced concrete (RC) frame structures is established, and parametric studies are carried out to analyze the effects of masonry materials and masonry heights on the seismic performance of structures. The results show that the load-bearing capacity and stiffness of the structure are improved, while the ductility of the structure is reduced because of the existence of infilled walls. As the height of infilled walls increases, there is a notable decrease in the free height of frame columns. At a wall-to-column height ratio of 0.2, the masonry walls exert a negligible effect on the frame structure's seismic performance. In contrast, at a ratio of 0.6, there is a transition in column failure modes from bending to shearing. When evaluated at consistent masonry heights, aerated concrete block-infilled walls demonstrate the least impact on the seismic performance of RC frame structures.

Dr. G.D. Awchat and Mr. Jasdeep Singh Rehal (2016) IJSDR|Volume 1, close investigations on seismic conduct of Rcc building genotypes with and with outside stonework "the infill of the block work is considered as a non-considerable element, but has its own unity and strength. Thus, watching for the impact of the block work to become visible as within the assessment of the organization, a great advancement within the energy and robustness of the general creation may be taken under consideration. The current code, IS 1893 (Part-I): 2000 from the guidance prohibits the plan to take into account the impact of the infill. It will usually become obtained that if the infill effect is seen as within the assessment and side plan, the ensuing configuration may be great. Furthermore, the infill, if present in all info gives a important responsibility for limiting the power dissipation, decreasing the most ridiculous moves. In this way, the dedication of the masonry may be very crucial, despite the fact that completely dependent on the first-rate of the ground moves, primarily for strains which have been purposeful without thinking of the seismic forces. When unexpected modifications of energy arise along the level of the structure, the story where this radical change in energy takes place is known as a delicate tale. According to IS 1893(Part-I): 2000, a tender A story is one in which the lateral pressure is less than half that of the story above or below. Within this paper, the power and rigidity of the rock infill is considered and the rock infill is proven using alcove to corner swagger. The main constraints considered within the assess for considering tectonic overall performance are vertical dislodgment, tale waft, base shear, temporal span, and regular repetition.

Kiran Tidke1, Sneha Jangave2/JIRSET (2016) Seismic Evaluation of Structures "Buildings with stone infill walls are the most common type of plan used for multi-story homes in developing countries." Masonry infill walls have been used as both exterior and interior package deal walls in reinforced primary framework constructions. These days, infill walls are typically regarded as non-load-bearing elements. Infill walls are typically considered as unconcealed parts in home design and appraisal. Not noted inside the natural design due to the fact they are taken into consideration to be of no importance for the important response.

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Practical frame systems supported by means of infill are widely studied as nude frames, doing away with the responsibility for the energy and pressure of the infill. In any case, at some stage in weather and quake, This infill wall contributes to the development's reaction, more electricity, and the edges' immobility. This essay examines the impact of the building's infill wall masonry. The drawings with particular sport plans are dynamically assessed. The body building is displayed for the assessment of a G+7 R. C. The extends aren't all defined through the same eager strut process. The review is provided through SAP2000 program. The foundation shear, Max. Storey elasticity, are not all defined within the gemstone and are considered for all models.

Bhnaupratap R Mehadia Dr. U. P. Waghe | IJSTE (2016) Comparative Study on Design and Analysis of RCC Structures Under Seismic Impacts with and Without Infill Walls In nations like India, where the area is susceptible to seismic events, reinforced concrete homes with block infill partitions are a common practice. The marble infill partitions are typically regarded as non-basis additives in the preliminary evaluations and simplest size stress is considered and the main properties like energy and stiffness are usually no more considered. Designs in great tectonic regions are not proof against crucial damage. In addition to weight masses, the shape has to resist horizontal loads which can motive higher stresses. Built-up practical ends at the moment are the most common in building construction training worldwide. The raised openings in the built-up concrete box inclusive of those made by cutting and shafts are usually crammed by using stones or bricks and are referred to as stop infill walls or slabs. When the box structure is completed, the walls are made from scratchy dust blocks in practical mortar. The walls are generally 2 hundred to one hundred fifteen mm solid. According to practical needs, openings are provided within the cylinder for home windows and entry openings and and many others.

"Tectonic investigation of RCC line with artificial infill dividers the use of ETABS" Jabin James IRJET 2016: "RC collection structures are usually designed with outside considering the principle interest of the existing manufactured infill dividers. These compartments are generally used as parts and are taken into consideration as non-primary parts. However, they affect the principal and non-simple efficiency of RC structures all through tectonic tremors. Numerous investigations have shown that the impact of rock infill slabs on the response of RC lines under seismic activity is frequently noticed. Valuations, at the same time as few attempts to show it medically had been defined. In medical checks, infill compartments are proven to be related to cockiness methodologies, there are various equations determined via researchers and researchers for swagger width and appearance. The infill acts as a pressure swagger between the sections and pubs and the tension force is moved to the subsequent hub from one gateway. The impact of artificial dividers on high systems in this analysis is discussed. Non-linear dynamic weakling inspections are carried out for RC strains with various strategies filler.

Umesh Karadi and Haroon Rashed Tamboli (2012): Walls in embankments are normally taken into consideration as non-primary additives and their strength necessities are generally not noted, such methodology can cause dangerous designs. However, stone infill walls constructed as recommended additives act as basic components of the fundamental form and determine the overall behavior of the layout primarily while subjected to tectonic masses. In this paper, seismic trying out has been executed the use of the Equivalent Lateral Force Method for various structural models made of reinforced concrete (RC) inclusive of unenclosed, filled envelope and open first floor structures. The effects of exposed, stuffed box and opened first floor systems are mentioned and their edges are made. In the case of brick infill tiles, All area fashions are analyzed using the Equivalent Lean Strut approach and the item ETABS.

In 2015, Arulmozhi, Jegidha, Srinivasan, and Dr. Suresh Babu conducted a scientific study on the seismic performance of RCC frames filled with brick walls using E-Tabs. "Large and moderate earthquakes that have caused significant damage have occurred in much of the world." leading to considerable layout demanding situations. Disasters regularly have an effect on the links between major parts and infill paintings of structures. Infill function is frequently used to hood the gaps among the opposing smooth and vertical additives of the structural line. Infill dividers considerably increase the strength and flexibility of the design. It has been located that shells with infill have better power and less bending buildings inside the situation in comparison to the uncovered ends. Thus, an examination of the method 3-D-RC traces behave regardless of rock infill work is essential.

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METHODOLOGY

1. A comprehensive study was conducted to investigate the seismic behavior of reinforced concrete (RC) frame structures with and without masonry infill walls, including the effect of a soft storey.
2. Structural models of the building, with and without masonry infill walls, were developed and analyzed using ETABS.
3. A 15-storey three-dimensional RC building model was created by considering dead loads, live loads, and earthquake loads. The equivalent diagonal strut width for the masonry infill walls was determined using the Mainstone and Hendry formulations.
4. Response Spectrum Analysis was performed to evaluate the dynamic behavior of the building. The analysis included the determination of base shear, storey displacement, inter-storey drift, storey stiffness, floor stiffness, and the fundamental natural time period.
5. The analysis results were compiled, compared, and discussed, and appropriate conclusions were drawn based on the observed seismic performance of the different structural models.

The Building's Modelling and Analysis

Description about the Model:

SL no	Model Name	Descriptions
1	M1	Bare frame
3	M2	Mainstone-designed frame with an infill wall.
3	M3	Hendry's idea for a frame with an infill wall
4	M4	C shape bare frame
5	M5	Mainstone created a C-shaped frame with an infill wall.
6	M6	According to Hendry, a C-shaped frame with an infill wall
7	M7	T shape bare frame
8	M8	Mainstone created a T-shaped frame with an infill wall.
9	M9	Hendry designed a T-shaped frame with an infill wall.
10	M10	Infill wall with soft storey designed according to Mainstone.
11	M11	Infill wall with soft storey designed according to Hendry

INPUT DETAILS

No. of stories	G+15
Beam size	230mm x 450mm
Column size	500mm x 500mm
Slab thickness	150mm
Storey height	Ground floor 4m, Typical floor 3m
Wall thickness	230mm
Zone	III
Soil	Medium
Zone factor	0.16
Importance factor	1
R (reduction factor) OMRF	3

Material Property

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Column	M25
Beam	M25
Slab	M25
Concrete's density	25kN/m^3

Details of the load case

Dead load: According to 875-1987(part-1), determined by the material's density and section size According to IS 875-1987 (part-2).

Live load: designed to transfer or vary loads based on occupancy. Live load on the floor is equal to 2kN/m^2, whereas live load on the roof is equal to 1.5kN/ m^2.

Quake loads: in accordance with **IS 1893-2016**, zone III is taken into consideration; as a result, zone factor is 0.16 in table (2), the soil type is medium, the damping ratio is 5%, and the important factor is 1.

RESULTS AND DISCUSSION

Equivalent Static Method

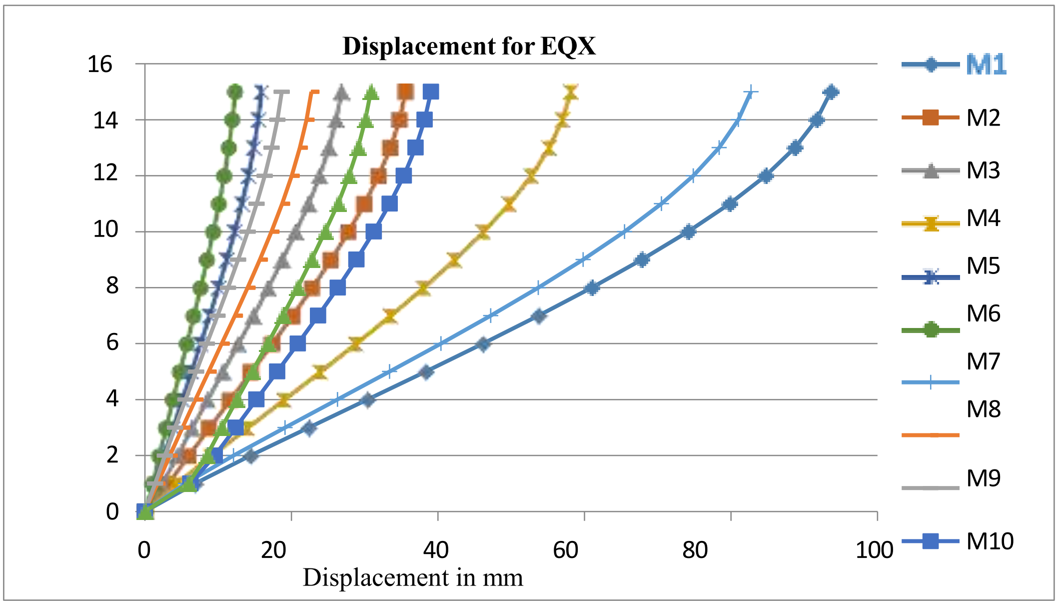

Fig 5.1 EQX displacement graph

1. A significant reduction in storey displacement was observed across the analyzed models.
2. Model M1 exhibited the maximum storey displacement, whereas Model M6 exhibited the minimum storey displacement.
3. Compared with the reference model, Models M5 and M9 exhibited an 80% reduction in storey displacement.
4. Model M3 exhibited a 70% reduction in storey displacement.
5. Models M11 and M2 each exhibited a 60% reduction in storey displacement.
6. Model M10 exhibited a 58% reduction in storey displacement.
7. Model M4 exhibited a 38% reduction in storey displacement.
8. Model M7 exhibited an 11% reduction in storey displacement.

Displacement in Y-Direction

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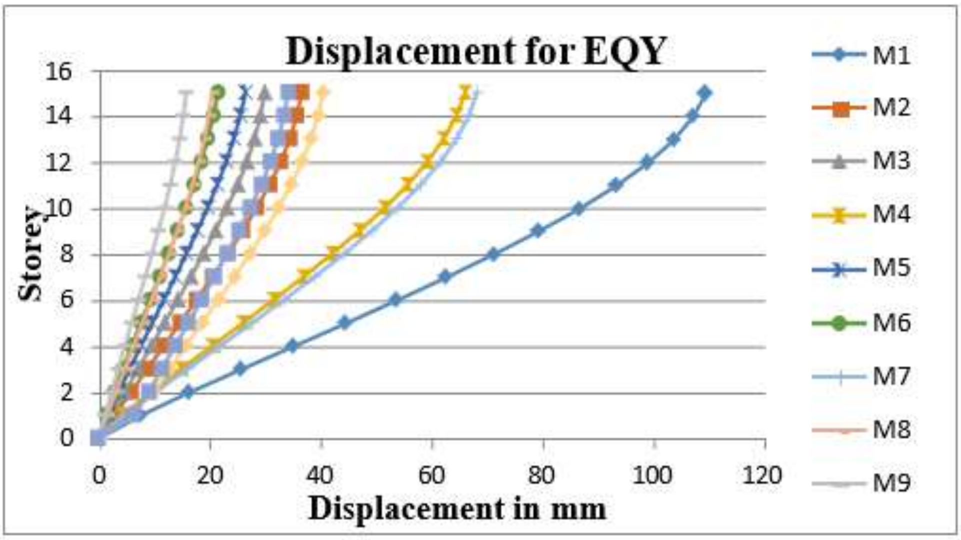

Fig 5.2 EQY displacement graph

1. Model M1 exhibited the maximum storey displacement, whereas Model M9 exhibited the minimum storey displacement.
2. Compared with Model M1, Model M9 exhibited an 85% reduction in storey displacement.
3. Model M8 exhibited an 81% reduction in storey displacement.
4. Model M6 exhibited an 80% reduction in storey displacement.
5. Model M5 exhibited a 76% reduction in storey displacement.
6. Model M3 exhibited a 72% reduction in storey displacement.
7. Model M11 exhibited a 68% reduction in storey displacement.
8. Model M2 exhibited a 66% reduction in storey displacement.
9. Model M10 exhibited a 63% reduction in storey displacement.
10. Model M4 exhibited a 40% reduction in storey displacement.
11. Model M7 exhibited a 38% reduction in storey displacement, compared with Model M1.

Drift Interstorey

Inter-story drift in the X direction

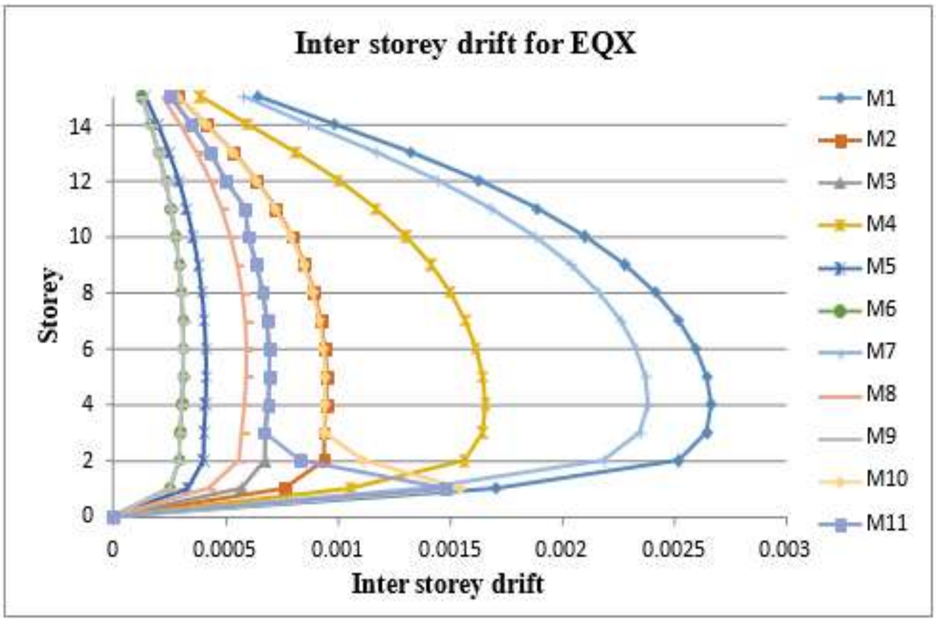

Fig.5.3: Inter storey drift graph for EQX

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The maximum **inter-storey drift** was observed in models with **column discontinuity (floating columns)**, except in the **soft storey** model.

1. In the soft storey model, the maximum inter-storey drift occurred at the soft storey level itself.
2. The highest inter-storey drift was recorded in Model M1 at Storey 4, whereas the lowest inter-storey drift was observed in Models M6 and M9 at Storey 6.
3. Model M6 exhibited an 88% reduction in inter-storey drift at Storey 6 compared with Model M1 at Storey 4.
4. Model M9 exhibited an 88% reduction in inter-storey drift at Storey 6 compared with Model M1 at Storey 4.
5. Model M5 exhibited an 84% reduction in inter-storey drift at Storey 5.
6. Model M8 exhibited a 77% reduction in inter-storey drift at Storey 6.
7. Model M3 exhibited a 73% reduction in inter-storey drift at Storey 5.
8. Model M2 exhibited a 64% reduction in inter-storey drift at Storey 5.
9. Model M11 exhibited a 44% reduction in inter-storey drift at Storey 1.
10. Model M10 exhibited a 40% reduction in inter-storey drift at Storey 1.
11. Model M4 exhibited a 38% reduction in inter-storey drift at Storey 5.

12. Model M7 exhibited the least reduction in inter-storey drift, recorded at Storey 4.

Inter-story drift in the Y direction

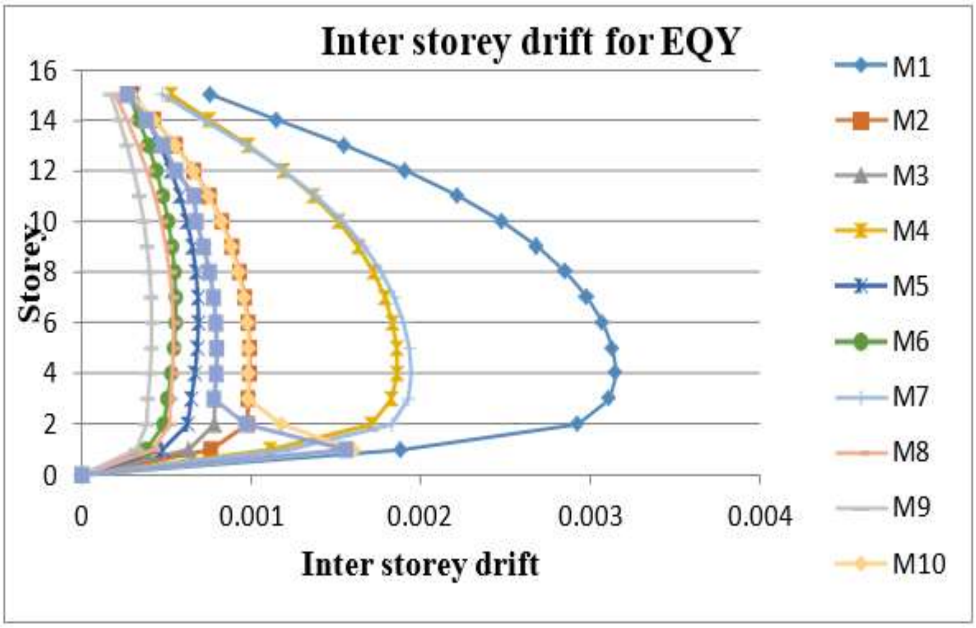

Fig.5.4: EQY Inter-story drift graph

1. The maximum storey stiffness was observed in Model M9 at Storey 4.
2. The minimum storey stiffness was observed at Storey 6.
3. Model M5 exhibited a 78% reduction in storey stiffness at Storey 6 compared with the reference model.
4. Model M3 exhibited a 74% reduction in storey stiffness at Storey 5.
5. Model M2 exhibited a 56% reduction in storey stiffness at Storey 5.
6. Model M11 exhibited a 56% reduction in storey stiffness at Storey 1.
7. Model M10 exhibited a 5% reduction in storey stiffness at Storey 1.
8. Model M4 exhibited a 40% reduction in storey stiffness at Storey 4.
9. Model M7 exhibited a 38% reduction in storey stiffness at Storey 4.

Base **Shear:**

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5.3.1 Base shear in kN in the directions of X and Y:

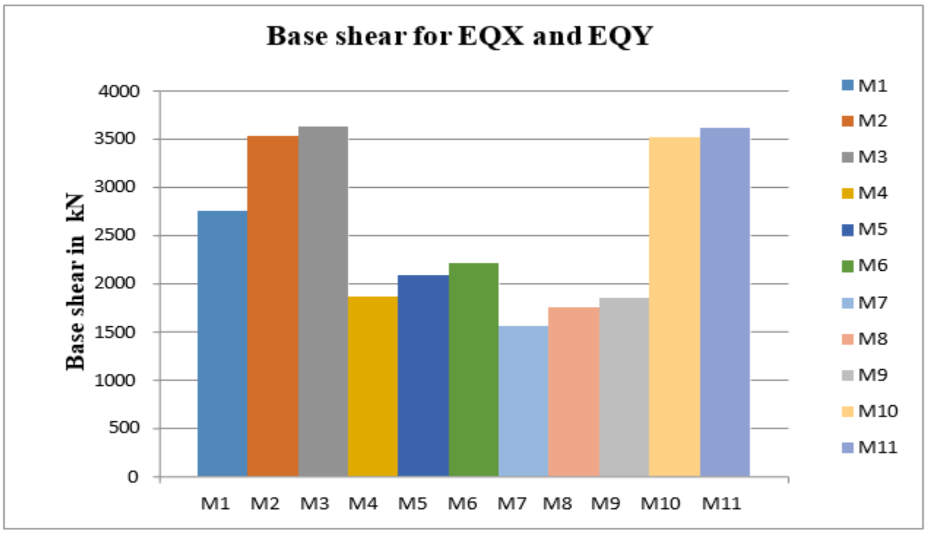

Fig.5.5: EQX and EQY base shear graph

The middle friction results in the following:

1. The infilled frame exhibited higher base shear than the bare frame.
2. The results indicate that Model M3 exhibited the highest base shear, whereas Model M11 exhibited the lowest base shear.
3. Model M7 exhibited a 60% lower base shear than Model M3.
4. Model M4 exhibited a 50% lower base shear than Model M3.
5. Model M9 exhibited a 50% lower base shear than Model M3.
6. Model M5 exhibited a 42% lower base shear than Model M3.
7. Model M6 exhibited a 38% lower base shear than Model M3.
8. Model M10 exhibited a 3% lower base shear than Model M3.
9. Model M2 exhibited a 2.5% lower base shear than Model M3.
10. Model M11 exhibited a 1% lower base shear than Model M3.

Storey Stiffness

Storey stiffness ratio in the X-direction

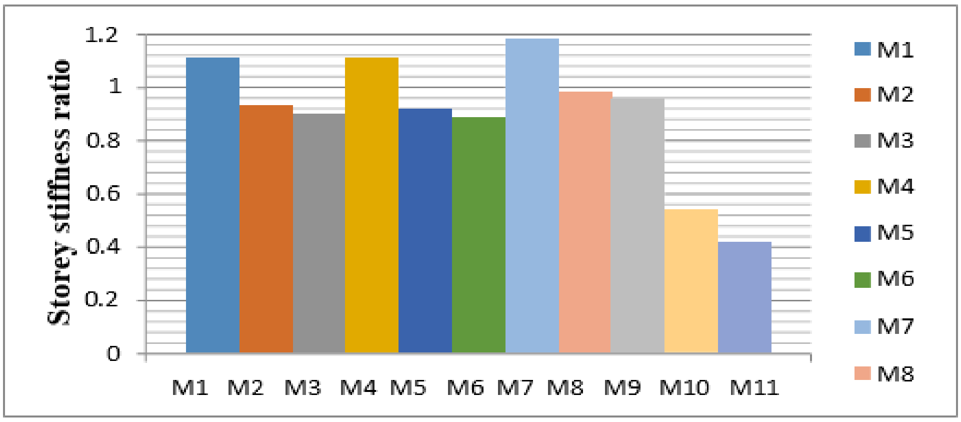

Fig.5.6: Comparison graph of storey stiffness at bottom floor level

The results from measuring flooring stiffness are as follows.

1. The bare frame exhibited significantly lower floor stiffness than the infilled frame.

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2. Compared with the reference model, Model M11 showed a 50% reduction in floor stiffness at the ground floor and a 56% reduction at the first floor.
3. Model M3 exhibited a 19% reduction in floor stiffness.
4. Model M5 exhibited a 7% reduction in floor stiffness.
5. Model M8 exhibited a 2% reduction in floor stiffness.
6. Model M1 exhibited 12% higher floor stiffness than Model M4.
7. Model M1 exhibited 18% higher floor stiffness than Model M7.
8. Model M10 exhibited 10% higher floor stiffness than Model M1.

Stiffness of the storey in the Y direction

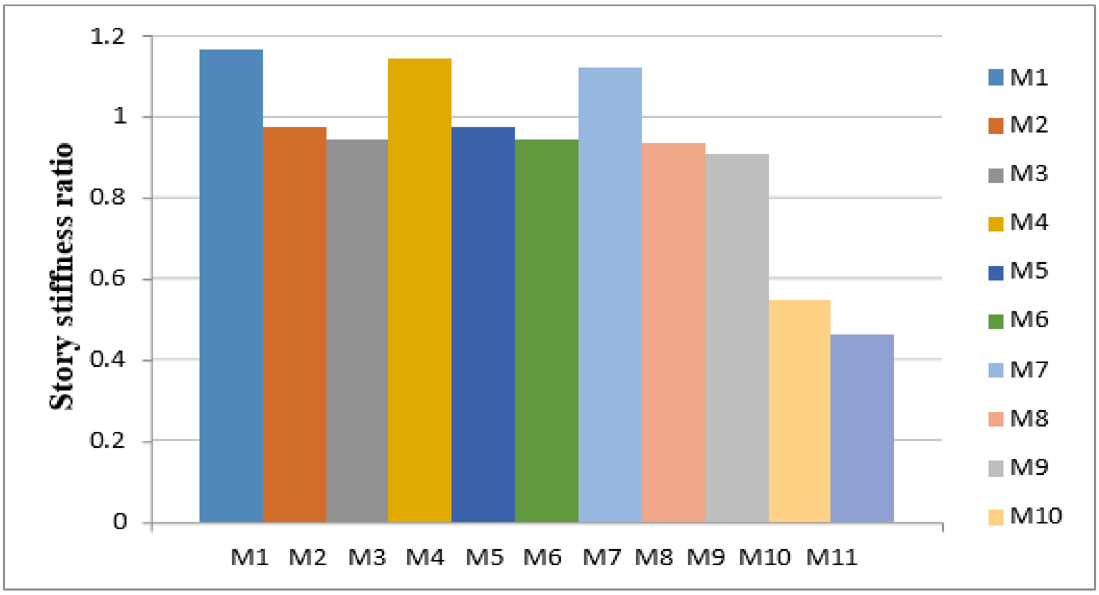

Fig.5.7: Ground floor comparative graph of storey stiffness

1. Model M11 exhibited a 56% reduction in floor stiffness from the ground floor to the first floor.
2. Model M9 exhibited a 46% reduction in floor stiffness.
3. Model M8 exhibited a 7% reduction in floor stiffness.
4. Models M3 and M6 each exhibited a 6% reduction in floor stiffness.
5. Models M2 and M5 each exhibited a 33% reduction in floor stiffness.
6. Model M1 exhibited a 16% increase in floor stiffness between the ground floor and the first floor.
7. Model M4 exhibited a 14% increase in floor stiffness between the ground floor and the first floor.
8. Model M10 exhibited a 12% increase in floor stiffness between the ground floor and the first floor.

Scope for Further Study

Common conclusions from this function were reported within the confines of this work. However, research can also be done in the following locations.

1. In the present study, all building models were analyzed using the **Response Spectrum Method**.
2. Further research can be carried out using **Time History Analysis** and **Pushover Analysis** to evaluate the seismic performance of the structures under different loading conditions.
3. In this study, the beam and column dimensions were kept constant for all models. Future work may focus on optimizing the beam and column sizes to achieve improved structural performance and economy.
4. A similar study can be conducted to investigate the effect of openings (such as doors and windows) in masonry infill frames on the overall seismic behavior of buildings.
5. Further research can also be undertaken by considering different types of masonry infill walls and construction materials to evaluate their influence on the structural response under seismic loading.

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CONCLUSION

1. The lateral displacement of the infilled frame is significantly lower than that of the bare frame. Among the analytical approaches, the Hendry and Mainstone methods provide reduced displacement due to the increased stiffness contributed by the equivalent diagonal struts.
2. The inter-storey drift of the infilled frame is lower than that of the bare frame because the masonry infill increases the overall stiffness of the structure.
3. The maximum inter-storey drift occurs at the soft-storey level, showing a significant contrast with the adjacent storeys. This confirms that the soft storey is the most critical location and requires careful evaluation during structural design.
4. The inter-storey drift values for all the models are within the permissible limit of **h/250** as specified in **IS 1893 (Part 1): 2016**
5. The base shear obtained for the infilled frame is higher than that of the bare frame because the presence of masonry infill increases the seismic weight and stiffness of the structure.
6. The stiffness ratio between two consecutive storeys is an effective parameter for identifying and assessing the soft-storey effect in multi-storey buildings.
7. The study indicates that buildings with masonry infill and a soft ground storey exhibit a pronounced soft-storey effect. Therefore, special attention should be given to the design of beams, columns, and other lateral load-resisting members at the soft-storey level.
8. The fundamental natural period obtained using the empirical equation of **IS 1893 (Part 1): 2016** does not closely match the values obtained from modal analysis for either bare-frame or infilled-frame models. Hence, modal analysis provides a more realistic estimate of the dynamic characteristics of infilled buildings.
9. The fundamental natural period of the bare-frame model is higher than that of the infilled-frame model because the absence of masonry infill results in lower lateral stiffness.
10. The soft-storey model exhibits a higher fundamental natural period than the fully infilled-frame model due to the reduction in lateral stiffness at the ground storey.
11. The Mainstone equivalent diagonal strut model yields a slightly higher fundamental natural period than the Hendry model because the Mainstone method generally predicts a smaller equivalent strut width, resulting in comparatively lower stiffness.
12. The empirical expression recommended in **IS 1893 (Part 1): 2016** for estimating the fundamental natural period is not fully consistent with the results obtained from modal analysis. Therefore, response spectrum analysis based on a realistic infill-frame model should be adopted for the seismic analysis and design of buildings with masonry infill.

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