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OPTIMIZATION OF STRUCTURAL DESIGN IN HIGH-RISE RCC BUILDINGS:

COMPARATIVE STUDY OF SHEAR WALL AND POCKET SHEAR WALL CONFIGURATIONS USING STAAD. Pro

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ABSTRACT: The design and analysis of multi-storey structures have always posed significant challenges, particularly in balancing structural stability, material efficiency, and cost-effectiveness. One of the key factors in achieving this balance is the inclusion of lateral force-resisting systems, such as shear walls, which provide crucial resistance to wind and seismic forces. This study investigates the performance of three structural models under various loading conditions: a simple frame (Model M1), a frame with a full shear wall (Model M2), and a frame with a shear wall containing pockets (Model M3). The type of analysis done was Equivalent static method. The core objectives of the study were to evaluate the impact of shear wall openings on the structural behaviour of the building, focusing on key parameters such as base shear, axial force, overturning moment, storey drift, storey displacement, torsion, and steel reinforcement requirements by using STAAD Pro software, and results were compared across the three models. The findings of the study revealed that the Model M3, which includes pockets in the shear wall, demonstrated a favourable balance between structural performance and material usage. Model M3 exhibited lower base shear and axial force than Model M2, while maintaining comparable resistance to overturning moments. Although the storey drift and torsion were slightly higher in Model M3, the model demonstrated reduced storey displacement and required similar levels of steel reinforcement as the simple frame (M1), making it a cost-efficient design option. In conclusion, the study confirms that shear walls with pockets (Model M3) can be an effective design choice for optimizing both structural performance and resource efficiency. Future work could expand on this analysis by exploring the impact of different pocket sizes and configurations, as well as the behaviour of such models under varying dynamic loads, particularly seismic forces in high-risk areas.

KEYWORDS: - Shear Wall, Pockets, Staad Pro, Structural Analysis, Cost Effectiveness, Framed Structure, Multistorey Building, Reinforced Cement Concrete, Steel Reinforcement.

I. INTRODUCTION

In contemporary civil engineering, the structural integrity of high-rise buildings is a paramount concern, particularly in regions susceptible to seismic activities or strong wind forces. This study focuses on a comparative analysis of three different structural configurations of a 10-storey reinforced concrete (RCC) building, referred to as Models M1, M2, and M3. These configurationsare examined through software simulations to evaluate their performance under various loading conditions.

Model M1: Basic RCC Structure

Model M1 represents a conventional 10-story RCC building without any additional lateral load-resisting elements such as shear walls. The structure comprises a typical frame system consisting of beams, columns, and slabs, designed to support both vertical loads (such as the weight of the structure and occupants) and horizontal loads (such as wind and seismic forces). This model serves as the baseline for comparison, reflecting the performance of a standard high-rise RCC building without any special modifications to enhance its lateral strength.

Model M2: RCC Structure with Central Shear Wall

Model M2 builds upon the basic configuration of M1 by introducing a centrally located shear wall. The central placement of the shear wall in M2 is strategically chosen to maximize its effectiveness in resisting torsional and translational movements. The shear wall is 200mm thick. This configuration is widely adopted in high-rise buildings to enhance overall stability, as the shear wall provides a direct path for transferring lateral forces to the foundation.

Model M3: RCC Structure with Pocket Shear Wall

Model M3 is an advanced variation ofM2, where the central shear wall is modified to include openings at the centre commonly referred to as a pocket shear wall. Pocket shear walls are often used to accommodate architectural requirements such as doors, windows, or other functional openings. While these openings are essential for building usability and aesthetics, they also introduce complexities in the structural behaviour of the shear wall, potentially reducing its effectiveness in resisting lateral loads. The openings create localized stress concentrations and alter the load transfer mechanisms, which can influence the overall stability and performance of the building. The size of the opening is taken as almost 15% of the overall size of shear wall as per studies conducted.

Comparative Analysis through Software Simulation
The core objective of this thesis is to assess the structural performance of these three models under simulated loading conditions using advanced engineering software named STAAD PRO Each model is subjected to a series of load combinations that mimic real-world scenarios, including dead loads, live loads, and seismic loads. The simulations are intended to provide insights into various performance metrics, such as lateral displacements, inter-story drifts, base shear, axial force generated, torsion in beams, overturning moments & the overall structural stability. The comparison between M1, M2, and M3 is crucial in understanding the impact of shear walls and their configurations on the structural integrity of high-rise buildings. While M1 represents the baseline, M2 and M3 offer insights into the benefits and potential challenges associated with shear walls and pocket shear walls, respectively. The analysis aims to determine whether the addition of a shear wall significantly enhances the building's performance, and if the introduction of openings in the shear wall (M3) affects its efficiency compared to the solid shear wall configuration (M2).

II. LITERATURE REVIEW

In this Study by **Ritesh J. Raut et-al., [2023]**Analysis and Design of Earthquake Resisting Building with Shear Walls by Using ETAB Software. It presents a comprehensive study on the seismic behaviour of buildings equipped with shear walls. Seismic Behaviour Analysis: The research focuses on understanding how buildings respond to earthquake loads through Non-linear Static analysis. Objective of the Study: The primary aim is to identify the optimal location for shear walls within a building and to evaluate the performance of the most effective shear wall configuration for reinforced concrete (RCC) structures. The study considers both G+13 and G+5 RCC buildings across seismic zones I to IV, applying appropriate load combinations. Methodology: The analysis is conducted using ETABS software, which allows for detailed modelling of the structural system. The shear walls are designed to extend from the foundation level to the top of the building, ensuring maximum resistance against lateral forces. Findings: The results indicate that shear walls significantly reduce lateral displacement and story drift, enhancing the overall stability of the structure during seismic events. The study also compares the performance of buildings with and without shear walls, demonstrating that the presence of shear walls leads to a marked improvement in seismic resilience. Conclusion: The paper concludes that strategically placed shear walls are essential for the design of earthquake-resistant buildings, as they provide the necessary strength and stiffness to withstand lateral forces. The findings underscore the importance of shear wall configuration and placement in optimizing the seismic performance of RCC structures. **V.Samyuktha et al., [2023]**this study investigates the impact of staggered openings in shear walls on the response reduction factor of building frames. Shear walls, crucial for resisting lateral forces, are typically made of reinforced concrete and vary in thickness from 150 to 400 mm. The research analyses four different shear wall positioning scenarios across buildings of heights 56, 72, and 88 m, both with and without openings. The models are evaluated using ETABS for storey displacement and drift, focusing on regular vertical and staggered shear wall openings in square and rectangular shapes. Results indicate that shear walls with staggered openings outperform those with vertical openings in terms of maximum lateral deflections and lateral drift, leading to a better performance under seismic loads. **Hala Mamdouhet[2022**] Performance of Strengthened, Reinforced Concrete Shear Walls with Opening. this study investigates the performance of reinforced concrete (RC) shear walls with openings, which are common due to architectural requirements. The study addresses the challenges posed by these openings, such as reduced wall stiffness and potential failure points. It presents both experimental and analytical findings on ten RC shear walls, initially tested without any strengthening and subsequently retested after being reinforced with glass-fibre-reinforced-polymer (GFRP) sheets around the openings. The positioning of openings also affected load capacity, with mid-height openings performing worse than those at the top or bottom. **Rajesh Kumar et al., 2022** Effect of Shape and Size of Openings in Shear Walls on Lateral Deformations in Shear Walled Framed Structures. This paper examines the impact of the shape and size of openings in shear walls on the lateral deformations of multi-storeyed framed structures. reduce the stiffness of these walls. The study employs finite element analysis using SAP2000 to evaluate various configurations of shear walls with triangular, square, and circular openings, considering 20% and 25% opening sizes. A ten-storey building model is analyzed under seismic loading conditions, specifically the El-Centro earthquake. Results indicate that the shape and size of openings greatly influence lateral displacements, with circular openings performing better under earthquake loads compared to triangular and square openings**. Prof. V. R. Harne, et al., [2023]**Seismic performance of high-rise building having a shear wall with opening and without opening**.** This Study focuses on understanding how structures respond to horizontal forces, especially in high-rise buildings, which must be sufficiently rigid to withstand forces generated by earthquakes. To resist these horizontal forces, also known as lateral loads, shear walls are integrated into the building's design, enhancing its rigidity.These walls may include functional openings, such as doors and windows, whose size and placement can vary based on the design requirements. The positioning and dimensions of shear walls are critical factors in a building's performance during seismic events. This study employs Response Spectrum Analysis to evaluate the effects of earthquake forces on a G+10 multi-story residential building and optimize the placement of shear walls. Key parameters examined include story drift, story shear, maximum allowable displacement, and overall stiffness. The analysis and modelling are conducted for Seismic Zone V, in compliance with IS 1893 (Part-1) 2016, using the FEM-integrated software Etabs. The dynamic analysis focuses on an irregular structure built on medium soil. The study concludes that structures incorporating shear walls demonstrate improved seismic performance compared to those without shear walls or with shear walls featuring openings.Ganapathi Pawar et al., 2024 Effect of Openings in Shear wall on Seismic Behaviour of RC Buildings. This paper examines the influence of openings in shear walls on the seismic performance of reinforced concrete (RC) buildings. It highlights how shear walls positioned along the building's exterior enhance resistance to seismic forces, while the presence and placement of openings can significantly affect structural stiffness and seismic response. The study analyses 15-storey RC building models with various inline and staggered openings using commercial **software STAAD**, applying seismic coefficient and response spectrum methods. Results indicate that shear walls with staggered openings exhibit more uniform stress distribution compared to those with inline openings, impacting parameters such as time period, base shear, and storey displacement.

Yuwei Zhang et al., [2022]. This study investigates the seismic behaviour of reinforced concrete (RC) shear walls with multiple post-construction openings through experimental tests and finite element simulations. The research includes quasi-static tests on one shear wall without openings and three shear walls with identical total opening areas but varying arrangements. Specifically, the wall without openings and the wall with two vertically arranged openings exhibited flexural shear failure at the base, while shear walls with one opening in the middle or two horizontally arranged openings experienced shear failure at the wall limbs adjacent to the openings. The presence of openings led to a redistribution of strains, with maximum strain concentrations occurring at the corners of the openings rather than at the wall base, causing the vertical reinforcement near the openings to yield earlier than in walls without openings. The study quantitatively assessed the residual bearing capacity, ductility, and energy dissipation capacity of the shear walls, finding that the wall with two horizontal openings had the lowest performance metrics, while the wall with two vertical openings demonstrated the highest. **Hossein Alimohammadi et al., [2024]** This study investigates the seismic behaviour of concrete shear walls with various shaped openings while maintaining a constant cross-section. Key findings reveal that the presence of openings significantly affects ductility, stiffness, energy absorption, and ultimate load. Specifically, shear walls with openings exhibited reduced seismic performance, with a notable decrease in safety and structural integrity compared to solid walls. The research emphasizes the importance of performance objectives in seismic design, highlighting how different opening shapes influence the overall resilience of shear walls.

III . METHODOLOGY

In this study three models of G+10 storey high are being modelled, analysed & design as per equivalent static method of structural analysis.

- Model M1 -simple framed building
- Model M2 - RC framewith shear wall at centre.
- Model M3- Shear wall has pocket in it.

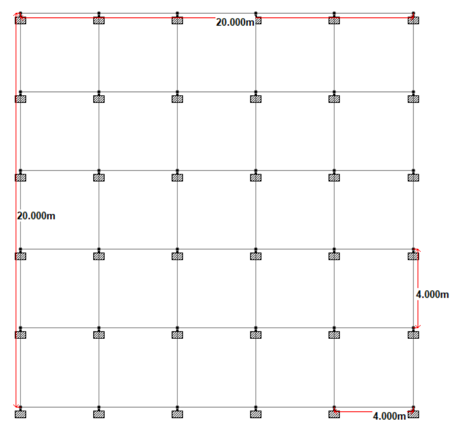


Fig. 1. Structural Framming details:

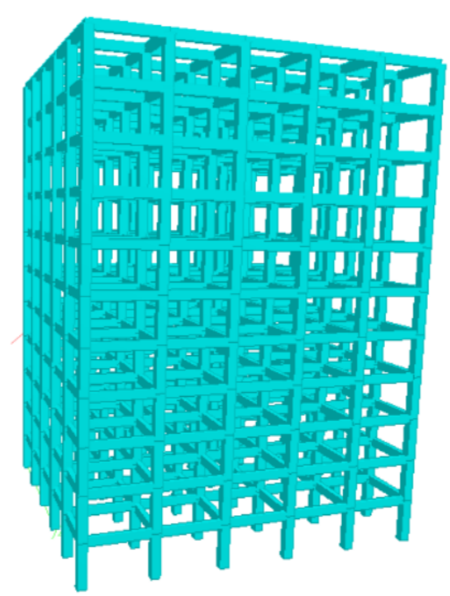


Fig. 2: Model M1 - Building with the beam and column

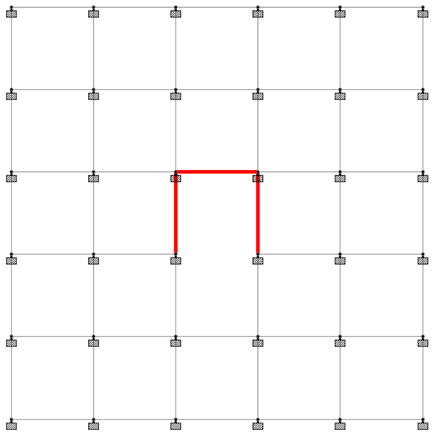


Fig. 2 Shear wall location in frame

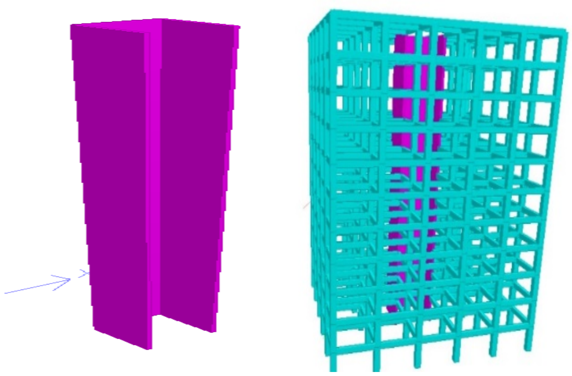


Fig. 3: Model M2 - RC frame with shear wall at centre.

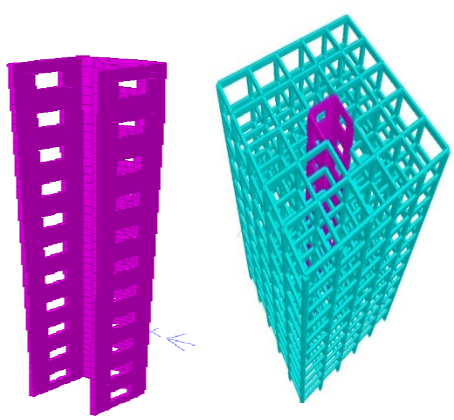


Fig.4: Model M3 - Shear wall has pocket in it.

All the three models have been used for finding out the efficiency of the pockets/opening in the shear wall. Later on, all the concerned parameters like Story drift, Base Shear, Overturning Moment, bending moment, shear force etc. has been compared.

Table 1. Frame details

PARAMETER	VALUE
Beam sizes:	300x600 mm
Column Sizes:	500x500 mm
Shear wall thickness:	200 mm
Grade of concrete: [20]	M25
Grade of Rebar:	Fe500
Isotropic Concrete & Steel bars are	Assigned
Shear wall opening	~15%.
Shear wall size:	4m x 3m
Shear Opening size:	1.6x1.2 m

Table 2: Model Description

PARAMETER	VALUE
No. Of Story	G+10
Floor Plan Dimensions	20m x 20m
Bays	4x4
Floor Height	3m
Thickness of the shear wall	200 mm
Size of Beams and Columns	300x600 mm
Grade of beams, columns and Slab	M25
Opening Size	1.6 x 1.2 m
Shear Wall Dimensions	4 x 3 m

Table 3Load Parameters

Parameter	Values
Dead Loads on all beams	10 kN/m
Dead Loads on Floor	2.5 kN/m2
Live Loads on Floor	4 kN/m2

Table: 4 Earthquake Load

Response Reduction Factor	5
Importance Factor	1.2
Rock & Soil Site Factor	2 (Medium)
Type of Structure	1 (SMRF)
Damping Ratio	0.05
Seismic Zone	II (0.1)

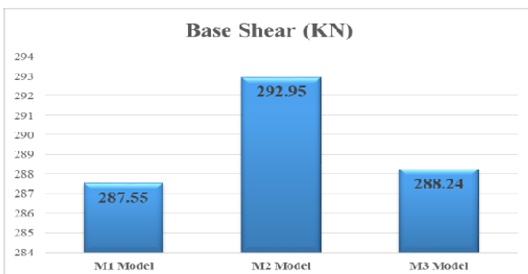
Table 5: Load Combinations

S.No.	Load Combinations
1	1.5(D. L+L.L)
2	1.2(D. L+L.L+Ex+)
3	1.2(D. L+L.L+Ex-)
4	1.2(DL+L.L+Ez+)
5	1.2(D.L+L.L+Ez-)
6	1.5(D.L+Ex+)
7	1.5(D.L+Ex-)
8	1.5(D.L+Ey+)
9	1.5(D.L+Ey-)

S.NO.	FRAME	BASE SHEAR IN X & Z DIRECTION (KN)
1	M1	287.55
2	M2	292.95
3	M3	288.24

IV . RESULT & DISCUSSION

Table 6: Base Shear (KN) values in M1, M2 & M3 model

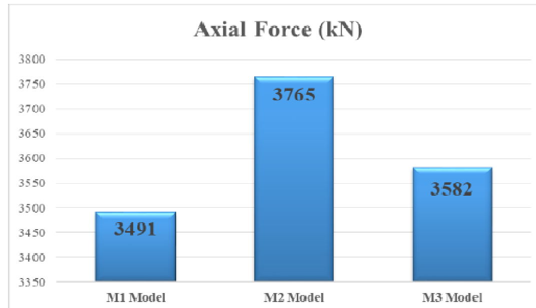


Graph 1. Comparison of Base shear (in KN) among M1, M2 &

FRAME	AXIAL FORCE (kN)
M1	3491
M2	3765
M3	3582

M3 Models

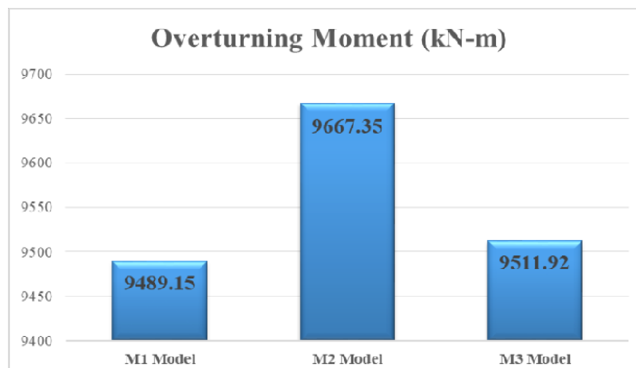
Table 7: Axial Force (kN) values in M1, M2 & M3 model



Graph 2. Axial Force (in kN) among M1, M2 & M3 Models

FRAME	OVERTURNING MOMENT (kN-m)
M1	9489.15
M2	9667.35
M3	9511.92

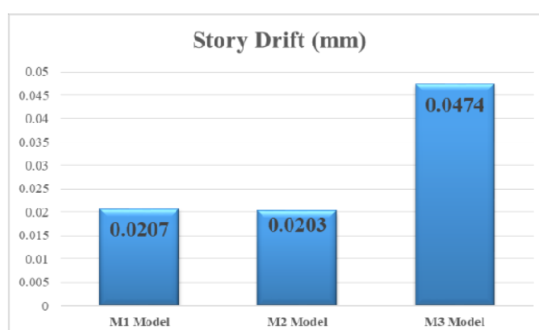
Table 8: Overturning Moment (kN-m) values in M1, M2 &M3 model



Graph 3. Overturning Moment (in kN-m) among M1, M2 & M3 Models

FRAME	STORY DRIFT IN X & Z DIRECTION (mm)
M1	0.0207
M2	0.0203
M3	0.0474

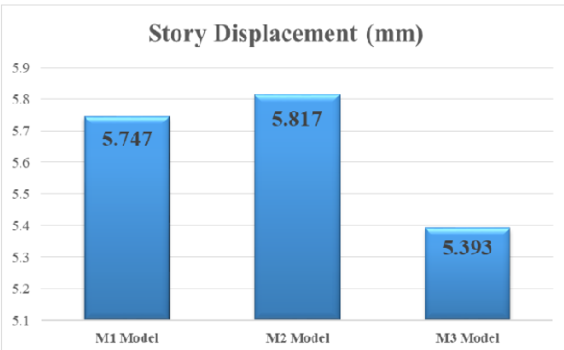
Table 9:Story Drift (in mm) values in M1, M2 & M3 model



Graph 4. Story Drift (in mm) among M1, M2 & M3 Models

FRAME	STORY DISPLACEMENT (in mm)
M1	5.747
M2	5.817
M3	5.393

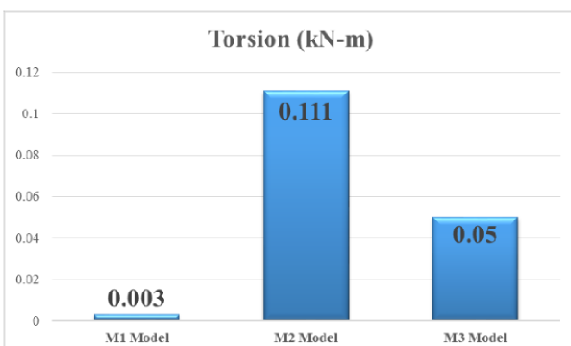
Table 10:Story displacement (in mm) values in M1, M2 & M3 model



Graph 5. Story Displacement (in mm) among M1, M2 & M3 Models

FRAME	TORSION (kN-m)
M1	0.003
M2	0.111
M3	0.050

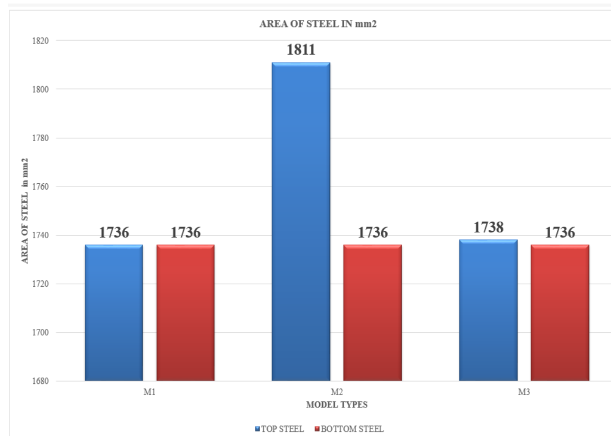
Table 11: Torsion (in kN-m) values in M1, M2 & M3 model



Graph 6. Comparison of Torsion (in kN-m) among M1, M2 & M3 Models

Table 12: Steel requirement (in mm2) values in M1, M2 & M3 model

Area of Steel in mm2		**M1**	**M2**	**M3**
	TOP STEEL	**1736**	**1811**	**1738**
	BOTTOM STEEL	**1736**	**1736**	**1736**



Graph 7. Comparison of Steel requirement (mm2) among M1, M2 & M3 Models

IV. CONCLUSIONS

The comparison covers key structural aspects such as base shear, axial force, overturning moment, story drift, story displacement, torsion, and steel reinforcement requirements. The focus of this report is on the advantages and limitations of Model M3 relative to Model M1 and Model M2.

1.Base Shear: Model M3 with pocket shear walls exhibited a slightly lower base shear (288.24 kN) compared to the full shear wall Model M2 (292.95 kN), while Model M1 (287.55 kN) had the lowest base shear overall.

2.Axial Force: Model M3 generated an axial force of 3582 kN in the test column, which is lower than Model M2 (3765 kN) but higher than Model M1 (3491 kN).

3. Overturning Moment: Model M3 exhibited a slightly higher overturning moment (9667.35 kN-m) than Model M2 (9511.92 kN-m), while Model M1 had the lowest (9489.15 kN-m). Despite the presence of pockets, Model M3 demonstrates a slight increase in overturning moment.

4. Story Drift: Model M3 resulted in the highest story drift at 0.0474 mm in both the X- and Z-directions, compared to Model M2 which had less drift (0.0203 mm).

5. Story Displacement: Model M3 demonstrated the least story displacement (5.393 mm) compared to Model M1 and M2 which had higher displacement values.

6. Torsion: Model M3 showed less torsion in the test beam (Beam No. 926) than Model M2, while Model M1 had the least torsion (0.003 kN-m).

7. Area of Steel Used: Model M3 required 1738 mm² of steel in the top part and 1736 mm² in the bottom part of the test beam, which is comparable to Model M1 and slightly less than Model M2 (1811 mm²).

Overall Conclusion on the Use of Model M3:

Model M3, which incorporates openings (pockets) in the shear wall, proves to be a highly viable structural solution in comparison to Models M1 and M2. It offers a good balance between structural performance and material efficiency.

- **Base shear and axial forces are lower in Model M3, suggesting that it can effectively manage lateral forces while distributing vertical loads more uniformly.**
- **The overturning moment is slightly higher but within acceptable limits, indicating sufficient stability against lateral loads.**
- **While story drift is higher in Model M3, it remains within tolerable limits, especially in environments requiring a degree of flexibility, such as in seismic design.**
- **The reduced story displacement and lower torsion values further highlight the advantages of using Model M3 in terms of both stability and material savings.**

Additionally, the steel reinforcement requirements for Model M3 are comparable to the simpler frame (M1), indicating that the use of pockets in the shear wall does not significantly increase the need for additional reinforcement, thus contributing to a cost-effective design.

In conclusion, Model M3 with pocket shear walls offers a structurally sound, material-efficient, and cost-effective alternative to the full shear wall (M2) and simple frame (M1). It is highly recommended in scenarios where lateral force management, structural flexibility, and resource optimization are critical design considerations.

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