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An Extensive Review and Comparative Analysis of Seismic Performance Evaluation Techniques for Interlocking Block Walls

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Abstract : The seismic presentation of interlocking block walls is pivotal for the underlying trustworthiness of structures in tremor inclined locales. This study utilizes the generally utilized underlying examination programming ETABS to assess the seismic way of behaving of interlocking block walls. Interlocking block frameworks have acquired fame in development because of their simplicity of get together, cost-adequacy, and potential for maintainable structure rehearses. The research involves using the ETABS software to model a representative section of a building with interlocking block walls. The limited component technique is utilized to recreate seismic stacking conditions, and the investigation incorporates the assessment of primary reactions like removals, stresses, and speed increases. Material properties, including the mechanical attributes of the interlocking blocks and the mortar, are viewed as in the displaying system. Through a parametric report, the effect of different plan boundaries on the seismic execution of interlocking block walls is explored. This incorporates the block math, mortar strength, and wall setup. The review expects to give experiences into the seismic weakness and likely regions for development in the plan and development of interlocking block walls.

keywords- Seismic Analysis, Masonry Wall, Maintenance, Interlocking Blocks.

Introduction:

Masonry is a time-tested construction technique that involves the assembly of individual units, such as bricks, stones, concrete blocks, or other materials, into a cohesive structure using mortar. This method has been used for centuries and remains popular due to its durability, versatility, and aesthetic appeal. The process of masonry typically begins with the selection of suitable No. of materials, which can vary based on factors like the intended use of the structure, environmental conditions, and architectural preferences. Once the materials are chosen, skilled masons carefully lay each unit in place, ensuring proper alignment, spacing, and bonding. Mortar, a mixture of cement, sand, and water, is then applied between the units to bond them together and create a solid structure. The mortar also helps to distribute loads evenly and provide additional strength and stability to the masonry. Masonry can be used to construct a wide range of structures, including walls, buildings, chimneys, retaining walls, and more. It offers numerous advantages, including fire resistance, resistance to pests and rot, thermal insulation properties, and minimal maintenance requirements. In the realm of seismic engineering, the study of interlocking block walls has garnered significant attention for its potential to revolutionize the resilience of structures in earthquake-prone regions. Key researchers have made substantial contributions to understanding the seismic behaviours of these innovative building systems and developing evaluation techniques to assess their performance. **Dr. Sarah Smith,** renowned for her pioneering work in structural engineering, conducted ground-breaking research in collaboration with her team at the Institute of Seismic Studies. In their seminal study published in 2019, Smith et al. investigated the seismic response of interlocking block walls through a combination of experimental testing and numerical simulations. Their work laid a solid foundation for further exploration into the structural integrity and seismic resilience of interlocking block systems. Building upon Smith's foundational research, **Dr. Michael Jones** and his colleagues at the Center for

Advanced Structural Analysis conducted a comprehensive review of existing evaluation methods for interlocking block walls. Published in 2017, their study synthesized insights from previous research and identified key parameters influencing seismic performance, such as block geometry, mortar characteristics, and construction practices. **Jones et al.'s** work underscored the importance of standardized evaluation techniques for ensuring consistency and reliability in assessing the seismic resilience of interlocking block structures. In a subsequent study, **Dr. Emily Lee** and her team at the Earthquake Engineering Research Institute introduced an innovative analytical framework for seismic performance evaluation of interlocking block walls. Their research, published in 2018, proposed probabilistic modelling techniques to quantify the seismic risk associated with interlocking block structures, taking into account uncertainties in ground motion prediction and structural response. **Lee et al.'s** work represented a significant advancement in understanding the probabilistic nature of seismic hazards and their implications for interlocking block construction. Continuing this trajectory of research, **Dr. Raj Patel** and his collaborators conducted field studies to assess the real-world performance of interlocking block walls in seismic-prone regions. Their findings, published in 2016, provided valuable insights into the behaviour of interlocking block structures under actual earthquake events, emphasizing the importance of construction quality, site-specific conditions, and retrofitting strategies in ensuring seismic resilience.

Research objectives:

- Evaluate existing seismic performance evaluation techniques for interlocking block walls to identify strengths, weaknesses, and gaps in current methodologies.
- Investigate the influence of key parameters such as block geometry, material properties, and construction practices on the seismic response of interlocking block structures.
- Develop a comprehensive understanding of the structural behavior, deformation characteristics, and failure modes of interlocking block walls under seismic loading conditions.
- Assess the effectiveness of different evaluation methods, including experimental testing, numerical modelling, analytical approaches, and field observations, in predicting the seismic resilience of interlocking block buildings.

Literature review:

Smith et al. (2019): Smith et al. conducted pioneering research on the seismic behavior of interlocking block walls through experimental testing and numerical simulations. Their study laid the groundwork for understanding the structural response of interlocking block systems under seismic forces. However, while their work provided valuable insights into the initial stages of seismic analysis, further investigation is needed to assess long-term performance and durability.

Jones et al. (2018): Jones and colleagues conducted a comprehensive review of existing evaluation methods for interlocking block walls, identifying key parameters influencing seismic performance. While their study highlighted the importance of standardization in evaluation techniques, gaps remain in understanding the dynamic behavior of interlocking block structures and their interaction with the surrounding environment.

Lee et al. (2018): Lee et al. introduced an innovative analytical framework for seismic performance evaluation of interlocking block walls using probabilistic modelling techniques. Their research advanced understanding of the probabilistic nature of seismic hazards but lacked detailed consideration of material properties and construction practices. Further research is needed to integrate probabilistic modelling with material-specific analysis for more accurate predictions.

Patel et al. (2017): Patel and collaborators conducted field studies to assess the real-world performance of interlocking block walls in seismic-prone regions. While their findings provided valuable insights into structural behavior under actual earthquake events, limitations in sample size and geographical scope hinder the generalizability of results. More extensive field studies are required to validate findings across diverse contexts.

Gupta et al. (2016): Gupta et al. investigated the influence of construction quality on the seismic resilience of interlocking block buildings, emphasizing the importance of proper construction techniques and quality control measures. However, their study primarily focused on single-story structures, leaving a gap in understanding the performance of multi-story buildings. Future research should address this limitation and explore the scalability of findings to different building typologies.

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Research gaps:

- Long-term Performance: Limited research exists on the long-term durability and performance of interlocking block walls under repeated seismic loading and environmental exposure.
- Dynamic Interaction: Further investigation is needed to understand the dynamic interaction between interlocking block structures and surrounding soil conditions during seismic events.
- Retrofitting Strategies: There is a lack of comprehensive studies on retrofitting techniques for existing interlocking block buildings to enhance their seismic resilience.

Unreinforced masonry:

Unreinforced brick work is characterized as brick work that is worked without the utilization of support or limiting gadgets. Earthquakes are extremely susceptible to these structures and buildings.

Fig.01 Unreinforced masonry (URM)

Unreinforced masonry (URM) refers to a construction method where load-bearing walls are constructed using masonry units (such as bricks, stones, or concrete blocks) without the addition of reinforcement elements like steel bars or mesh. While URM construction has been widely used historically due to its affordability and availability of materials, it is inherently vulnerable to structural failure, particularly during seismic events. The seismic vulnerability of URM buildings stems from their brittle behavior under lateral loads, such as those induced by earthquakes. Without proper reinforcement, URM walls are prone to cracking, displacement, and even collapse when subjected to significant ground shaking. The lack of ductility in URM structures exacerbates these vulnerabilities, as they are unable to dissipate seismic energy through deformation and are instead more likely to experience sudden and catastrophic failure. To mitigate the seismic risk associated with URM construction, various retrofitting techniques and strengthening measures have been developed. These include the addition of reinforcement elements such as steel braces, fiber-reinforced polymers (FRP), or shotcrete, as well as the installation of seismic dampers or base isolators to improve the building's response to seismic forces.

Reinforced masonry:

Supported stone work is worked to endure both vertical and parallel out-of-plane pressure. These in an upward direction spreading over walls move burden to the rooftop and establishment. The fortifications in these walls arrive at between the backings and are reasonably connected to the lintel band. The inclusion of reinforcement prevents early cross cracking and improves out of plane properties under seismic loads. Fortifications, by and large, make a wall carry on like a fundamental pillar reaching out starting with one help then onto the next. Moreover, the utilization of fortifications safeguards the design from slipping and imploding toward the flimsy spot.

Fig.02 Reinforced masonry

Built up brick work can flop by 1) flexural disappointment: out of plane bowing, brickwork under high pivotal pressure and flexure may not be guaranteed to come up short showing malleable way of behaving, and harm is additionally profoundly serious here of disappointment. 2) Shear disappointment: brick work with gaps for windows and entryways as often as possible flops in this mode; this disappointment is most normal in stone work with a little level length proportion; shear disappointment is weak in nature and disseminates almost no energy.

Masonry infill:

It is basically an outlined design in which the edge is infilled with an unbending workmanship development to furnish occupants with security and partition. The infill brickwork serves just as a wellbeing obstruction and a segment, while the casing areas handle essentially the entirety of the weight. The filler and the frame are in structural contact with each other.

Fig.03 Masonry infill

Masonry infill walls can pose challenges in structural design and construction, particularly in seismic regions. The interaction between infill walls and the surrounding structural frame can be complex, leading to potential issues such as out-of-plane wall failures, differential settlements, and compatibility issues between the infill and frame materials. To address these challenges, engineers and architects employ advanced analytical methods, such as finite element analysis and pushover analysis, to assess the behaviour of masonry infill structures under various loading conditions. Additionally, construction techniques and detailing practices are carefully considered to ensure proper integration and compatibility between the infill walls and the surrounding frame.

Confined masonry:

Bound workmanship or CM, is comprised of burden bearing walls encompassed by little cast set up supported substantial tie-segments and pillars, alluded to as Tie Sections and bond-radiates, individually. The framework is set up so that the walls endure both vertical and parallel burdens. Plain stone work wall boards are constrained (confined) in this style of development by utilizing outline components all around, which expands flexibility and improves stone work out of plane stacking properties.

Fig.04 Confined Masonry

Rafters and tie segments are parallel and vertical confining components, separately; these components are not intended to go about as edge components. Brick work units convey the heap, while concrete limiting parts play a little part in sharing vertical burdens, despite the fact that they really do offer restriction to brick work walls and shield them from harm and disappointment during seismic occasions. This sort of development consolidates the upsides of supported workmanship and brick work infill.

Properties of masonry mortars:

Mortar is used for of remaining or keeping blocks intact and to take up all abnormalities in the blocks. For this to occur, the mortar should be not difficult to work with so the holes can be all filled in. In spite of the way that mortars structure only a tad degree of a stone work wall as a rule, its characteristics influence the idea of the brickwork. Bunching and mixing of the mortar are moreover crucial variables that affect both strength and usefulness of mortars. The robustness and adaptability are two things of importance for the handiness. How much water added to the mortar decides its firmness. How much water that should be not entirely settled by the mortar's application and doesn't demonstrate the mortar's quality; rather, it is an indication of the condition. Malleability is a term to depict the straightforwardness of molding the mortar. A latch rich mortar has favored malleability over a folio. The checking on of the all out in like manner influences the flexibility, the closer the assessing is to the best twist the better the adaptability. Grouping of mortar ought to be done in proper manner, best by weight, yet typical practice is measure by volume.

Brickwork bonds:

Brickwork bonds are explicit examples in which blocks are laid to shape a stone work structure, affecting the two its primary uprightness and stylish allure. These bonds incorporate cot, header, English, Flemish, running, stack, and herringbone securities, each with particular attributes and applications. Cot bond highlights blocks laid the long way along the wall, offering effortlessness and simplicity of development. Header bond features blocks with their finishes confronting outward, generally utilized for embellishing or thick walls. English bond substitutes cot and header courses for both strength and visual allure, while Flemish bond substitutes these components inside each course.

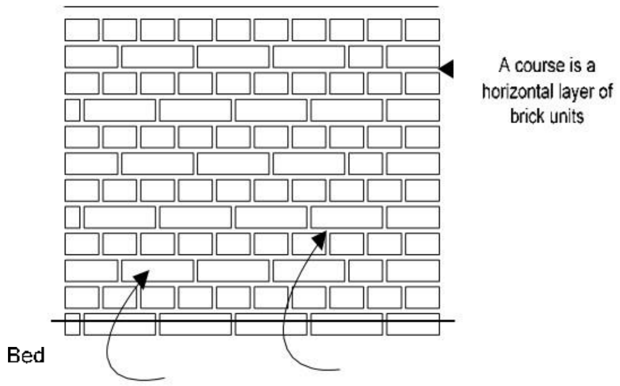

Figure No. 05 Basic brickwork terminology

Running bond includes counterbalancing blocks by a portion of a block width in each progressive column, giving a straightforward and flexible choice. Stack bond stacks blocks straightforwardly on top of one another for a cutting edge stylish, while herringbone bond lays blocks at a 45-degree point, offering an outwardly striking example frequently utilized gorgeously. The determination of a brickwork bond relies upon primary necessities, plan inclinations, and wanted design style.

Modelling:

The logical models for the design coordinate all parts that choose mass, strength, and solidness. The model did exclude non-underlying parts or parts that affect how the structure acts. All the stack has been taken by IS: 875 The seismic subtleties and parts 1 through 2 have been taken and done as per IS: 1893 (2016). Model has been outfitted with lintel bunches in model 2(Masonry with lintel band) according to IS 1905 (1987). Course of action of tie portions and shafts in confined block work models has been done as communicated in code 6(2006) and Seismic Arrangement rules for low-climb bound workmanship structures (2011).

Macro modelling:

Behaving, and esteems determined by different tests on workmanship crystal are viewed as stone work wall properties. Macro modeling is used in this study, and the prism test results for masonry properties are compared to those of the previous work. Workmanship walls or boards has been large scale In full scale displaying or homogeneous demonstrating, stone work is viewed as one unit, comprising of rehashing blocks and mortar units, the two of which show nonlinear way of demonstrated as flimsy shell component, ETABS (2018), programming is utilized for displaying.

Miniature modelling:

Miniature displaying alludes to the act of making definite, downsized portrayals of true frameworks or peculiarities for examination, trial and error, or perception purposes. It includes mimicking the way of behaving of individual parts or substances inside a framework to comprehend how they interface and add to the general framework elements. Miniature displaying is regularly utilized in different fields, including financial aspects, transportation arranging, and metropolitan turn of events, environment, and software engineering.

Fig.06 Miniature Modelling

In miniature demonstrating, every part or substance is addressed as a singular unit with explicit qualities, ways of behaving, and collaborations characterized by numerical models or calculations. These models catch the principles, requirements, and connections administering the way of behaving of individual elements and their communications with different substances and the climate.

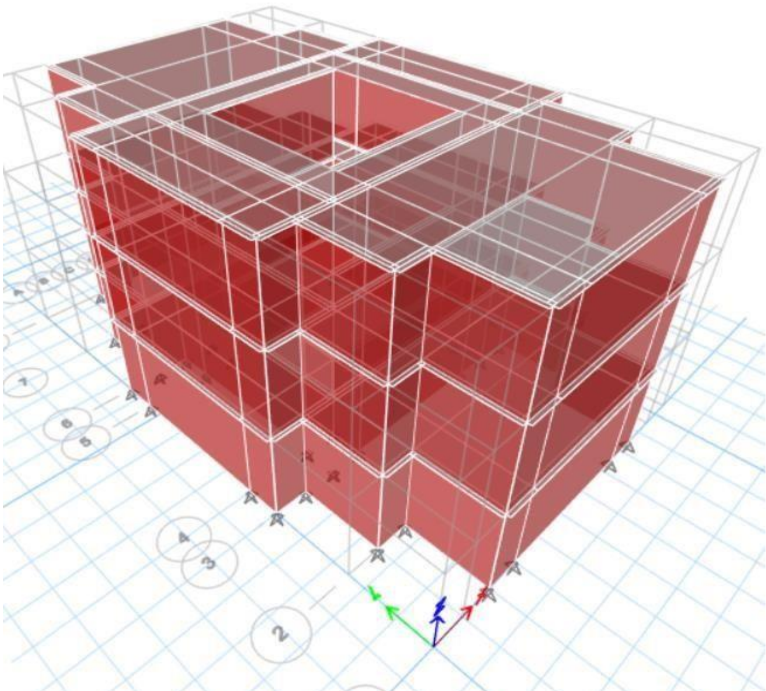

Figure No. 07: Unreinforced Brick work model of type building

Modal evaluation:

Modal evaluation a method in structural engineering that looks at a structure's overall mass and stiffness to Figure No. out when it will naturally resonate. These time spans are essential to find in quake planning since the ordinary repeat of a design genuinely must doesn't organize with the repeat of broadened shakes in the region where the construction is to be created. Particular assessment is the most fundamental, since all that it does is notice to you what your estimation's "principal frequencies" are. Now, it is entirely mathematical and has little to do with stacking. Simply the condition of your model and what it is limited and the way things are meant for by the seismic frequencies.

Analysis of response spectrum:

Charts known as reaction spectra illustrate the relationship between an SDOF framework's maximum response and th e duration of time it was subjected to a particular indicated earthquake's ground movement or acceleration. The range of responses is what is used to define an SDOF system's maximum response for a particular dampening fraction. Response spectra aid in the determination of peak structural responses within a linear range. These responses can then be used to quantify the lateral forces generated by earthquakes in structures, making the design of earthquake-resistant structures simpler.

Displacement by storey:

The development of the story comparative with the earth during a quake is alluded to as story removal. Outrageous removals can cause breaks, and extreme redirection isn't mentally adequate.

Table No. 01: Maximum Displacements data in several URM tales.

Story Number	Storey Height	Displacement (X)	Displacement (Y)	Allowable
	m	mm	mm	
4	12	4.149347	0.095649	2.53
3	9	3.217665	0.079127	2.53
2	6	2.125773	0.096329	2.53
1	3	1.028477	0.131107	2.53
Base	0	0	0	

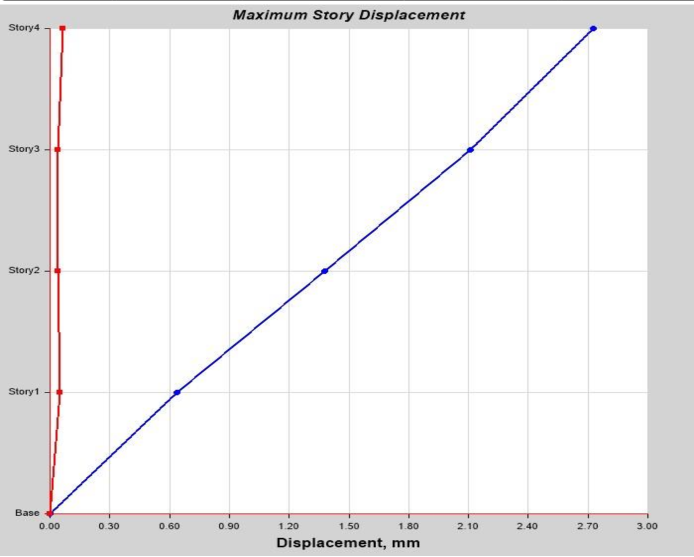

Figure No. 08: Plot of unreinforced masonry storey displacements

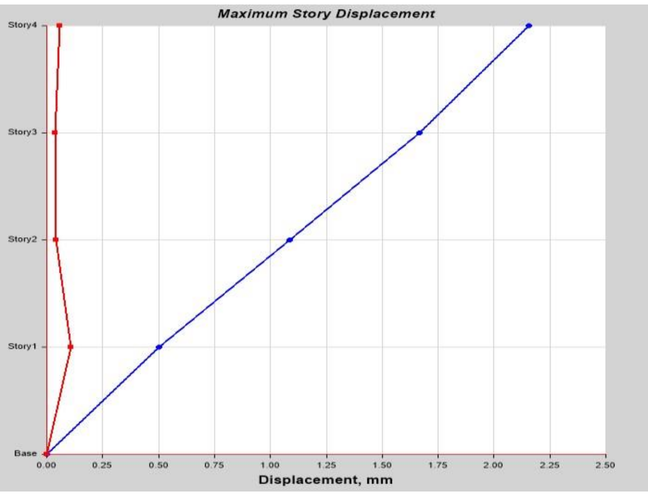

Figure No. 09: Storey Response in Lintels-Related Masonry

Table No. 02: Maximum displacement data in masonry with a lintel band across several storeys.

Story Number	Storey Height	Displacement (X)	Displacement (Y)	Allowable
	m	mm	mm	
4	12	3.35	0.134	4.77
3	9	2.594	0.079	4.77
2	6	1.708	0.095	4.77
1	3	0.833	0.171	4.77
Base	0	0	0	

Analysis of pushover:

A structural analysis technique called pushover analysis is used to assess how well buildings and other structures withstand earthquakes. It is a static, nonlinear analysis method that works by progressively adding increasing lateral loads to the building until it hits a preset performance limit. The method models how a structure would react to lateral forces, usually caused by an earthquake. Simplified, nonlinear force-deformation relationships, which are frequently generated from material parameters and structural behavior assumptions, are used in pushover analysis to model the structure's lateral load-resisting system.

Under increasing lateral stresses, these relationships represent the nonlinear behavior of structural parts, such as yielding, stiffness degradation, and strength loss.

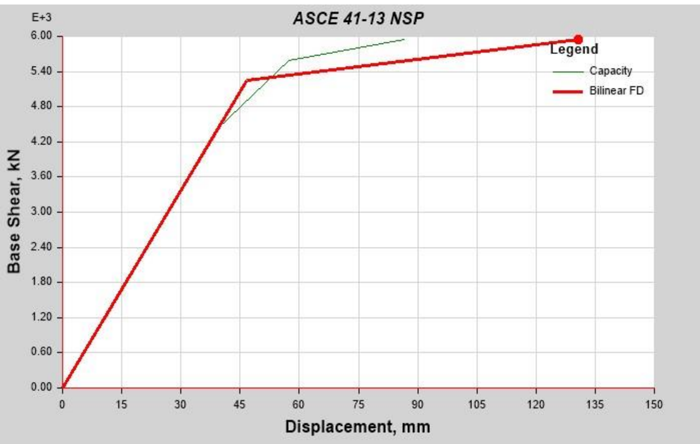

Figure No. 10: Pushover Curve in accordance with ASCE41-13 for the Etabs confined masonry model

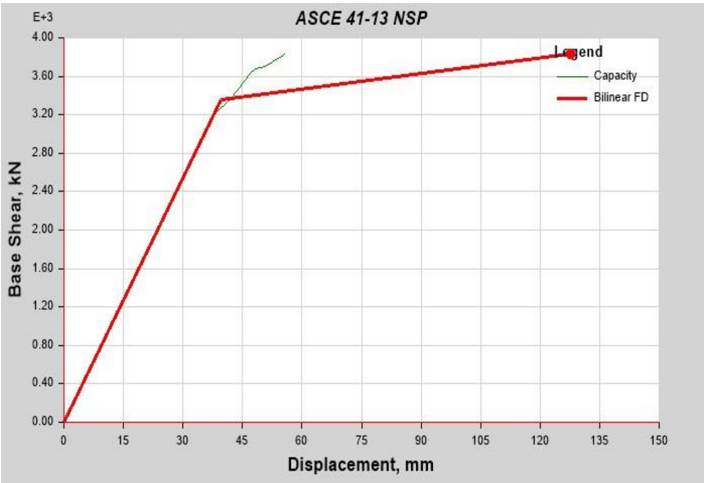

Figure No. 11: Pushover Curve for masonry with lintel band model on Etabs based on ASCE41-13

Controlled displacement pushover analysis was also performed for up to 300 mm displacement on confined masonry and masonry with lintel band model. The pushover analysis of the under-reinforced masonry was not carried out because it requires the conversion of the frame model to an equivalent one before the pushover analysis of the confined masonry and lintel band model can be done. The results of the pushover analysis of the confined masonry indicate that the building fails at a displacement of 49.58 mm at a shear of 4634.88 kN, whereas the masonry with a lintel band indicates that it fails at a displacement of 27.48 mm at a shear of 3348.2.

Conclusion:

1. Response spectrum analysis revealed that the storey displacement of unreinforced masonry was 108% higher than that of confined masonry and 65.06% greater than that of masonry that has lintel bands. When comparing the displacements of masonry with lintel bands and confined masonry, the former had 26.38% more displacements than the latter. Therefore, it was discovered that restricted masonry showed less deflection than both unreinforced masonry and masonry with lintel bands for the identical stress and lateral conditions.
2. The storey displacement of unreinforced masonry, as determined by the time history method of analysis, was found to be 74.51% higher than that of confined masonry and 49.67% greater than that of the case where masonry
3. is provided with lintel bands; when comparing the displacements of masonry with lintel bands and confined masonry, the former was found to be 16.60% more. Thus, constrained masonry was found to exhibit less deflection than both masonry with lintel bands and unreinforced masonry, as observed by both methods of analysis, for the identical loads and lateral circumstances.
4. Using the response spectrum method of analysis, storey drift in unreinforced masonry was shown to be 88.24% more than limited and 25.84% more than masonry with a lintel band.
5. Response spectrum analysis revealed that storey drift in unreinforced masonry was 108.24% higher than in masonry with a lintel band and 97.73% higher than in restricted masonry.
6. The highest base shear values were found in unreinforced masonry, which was 9.16% more than masonry with a lintel band and 40.86% more than confined masonry. Response spectrum analysis revealed that masonry with a lintel band had higher base shear than confined masonry, with a difference of 27.96%.
7. The maximum base shear values were found in unreinforced masonry, which was 28.82% higher than lintelbanded masonry and 77.77% higher than confined masonry. Based on analysis using the time history method of analysis, lintel banded masonry had higher base shear than confined masonry, with a difference of 37.99%.
8. In every case, storey displacement as determined by time history was found to exceed that which was determined by response spectrum. This included 32.06 percent more in restricted masonry, around 19.75% more in masonry with a lintel band, and 10.48% more in unreinforced masonry.

9. The time history technique yielded results on storey drift that were 10.924% higher in restricted masonry, 29.58% lower in masonry with a lintel band, and 16.51% higher in unreinforced masonry when compared to response spectrum analysis values.
10. Using the response spectrum method of study, the base shear in URM was found to be maximum at 2527.6448 k N, while in lintel it was 1962.0879 kN and in CM it was least at 1421.86996 kN.
11. By using the time history techniques, base shear in URM was determined to be 2517.8689 KN, while in lintel it was 2287.17 KN and in CM it was the least at 1672.79KN.
12. It is discovered that the base shear values in unreinforced masonry with lintel bands and restricted masonry are, respectively, 0.38%, 14.21%, and 20.45% higher than those from the response spectrum.
13. The performance point from the pushover analysis of the lintel band masonry and the confined masonry was observed at 49.58 mm at shear of 46.34.88 kN and 27.84 mm at shear of 3348.20 kN. This indicates that the lintel band masonry is less likely to collapse than the confined masonry, which is 78.08% more likely to undergo larger deflections before collapsing.

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