ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24JUN1037

Structural Analysis of Unreinforced Masonary and Reinforced Masonary Structures

Dr. Pradeep P. Tapkire[1]; Vivek B. Pirgonde[2]
[1]H.O.D. Civil Dept., N.B. Navale Sinhgad College of Engineering, Solapur, Maharashtra, India-413255
[2]Research Scholar at N.B. Navale Sinhgad College of Engineering, Solapur, Maharashtra, India-413255

Abstract:- This paper presents a comprehensive investigation of the structural analysis of unreinforced masonry (URM) and reinforced masonry (RM) structures, tracing the evolution from traditional construction techniques to modern engineering practices. Historically, the focus of structural design in ancient buildings was largely on geometry and material form. With the advent of steel and concrete, this focus shifted to the strength and resilience of materials. Utilizing both experimental data and computational modeling, this study compares the structural performance of URM and RM, highlighting the strengths and weaknesses of each method. The findings indicate that reinforced masonry structures exhibit superior strength and stability, making them more suitable for seismic regions, while unreinforced masonry can still be viable under specific conditions. The study concludes with recommendations for integrating traditional construction techniques with modern materials to enhance building safety and resilience.

Keywords:- *Ancient Buildings, Structural Behavior, Joints.*

I. INTRODUCTION

Throughout history, the structural design of buildings has undergone significant transformations. In ancient times, the focus was primarily on geometry and the form and sizes of building elements, evolved over centuries of development. The invention of steel and concrete marked a significant shift towards prioritizing the strength and resilience of materials in structural design.

While modern materials like steel and concrete have revolutionized building construction, understanding the structural performance of traditional unreinforced masonry remains crucial, especially in heritage conservation and regions where these materials are still prevalent. Reinforced masonry, which integrates steel reinforcements, offers enhanced structural performance but requires comprehensive evaluation to understand its benefits fully.

This study aims to bridge the gap between traditional construction techniques and modern engineering practices by providing a comparative analysis of unreinforced and reinforced masonry structures. Understanding the strengths and limitations of each approach is essential for designing safer and more resilient buildings, particularly in earthquake-prone areas.

II. LITERATURE REVIEW

- *Mr. Abina Shilpkar (2021)*

The methodology in Mr. Abina Shilpkar's research includes literature reviews on the construction technology of multi-tiered temples, case studies on representative cases, and the rehabilitation processes adopted. The rehabilitation process consisted of workshops and meetings with related authorities and the formation of technical committees based on experts' recommendations. This study provides insights into traditional construction techniques and their application in modern rehabilitation practices.

- *Mr. Prabhat Soni (2019)*

Mr. Prabhat Soni presented a study on the analysis of the natural time period of movement-resisting frame buildings. The paper highlights that numerous parameters of structural configuration, including the fundamental time period of vibration, affect building performance. This study underscores the importance of considering various structural configurations in seismic analysis.

- *Mr. Laril Cutinha (2018)*

Mr. Laril Cutinha conducted a parametric study varying column dimensions, the number of bases, number of storeys, and the variation in time periods. These parameters contribute to the stiffness of the structure, showing that not only the height and base dimensions of the building affect the time period determination but also column dimensions and the number of bays. This research emphasizes the complex interplay of structural elements in determining seismic response.

- *Mr. Jetson Ronald (2018)*

Mr. Jetson Ronald's research focuses on the gopuram and mandapam, two representative structural forms of South Indian temples. The study involves the modelling and seismic analysis of a 90-year-old gopuram and a 4 and 16 pillar mandapam of the 60th-century Accompreshwar Temple in South India. The research adopts lumped plasticity and distributed plasticity modeling, and three analysis approaches: linear dynamic, nonlinear static, and dynamic analysis. It identifies potential collapse mechanisms and compares seismic demand with limit theory as a safety check. The study proposes simple relations for rapid preliminary seismic assessment.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24JUN1037

➢ *Ms. Shweta Vardia (2008)*

Ms. Shweta Vardia presented a research paper on the building science of Indian temple architecture, highlighting the seismic behaviour of Indian temples through modelling. This research provides valuable insights into the seismic resilience of traditional temple structures and informs modern conservation and restoration practices.

III. METHODOLOGY

This study employs a mixed-methods approach, combining experimental testing of masonry wall specimens and computational modeling using finite element analysis (FEA).

Experimental data were collected from laboratory tests on scaled masonry wall specimens, both unreinforced and reinforced. These tests measured parameters such as compressive strength, tensile strength, and deformation under various load conditions Finite element analysis (FEA) software was used to simulate the structural behavior of both URM and RM walls under seismic loads. The experimental data served to validate the computational models.

Masonry wall specimens were constructed and tested in a controlled laboratory environment. The URM specimens were built using traditional construction techniques, while the RM specimens included steel reinforcements according to modern engineering standards.

The experimental results were analyzed to determine key performance metrics, including load-bearing capacity, failure modes, and deformation characteristics. These metrics were then compared to the FEA simulation results to assess the accuracy of the models.

➢ *Material Model*

The study aimed to estimate the mechanical properties of construction materials used in the gopuram through a limited number of tests on samples from distressed portions of similar temple structures. Dynamic identification using ambient vibrations was deemed inappropriate due to high background noise, necessitating forced dynamic tests with harmonic vibrations, which were not executed in this study. Instead, a macro-modelling approach was adopted to understand the global behavior of the structure, employing homogenization of masonry based on existing models, which were generally focused on typical masonry constructions in India rather than historical masonry. The elastic properties of brick and stone masonry were conservatively assumed from the limited mechanical tests, with tensile strength neglected due to ageing and deterioration. The material model, proposed by references and, suitable for masonry towers, accounted for non-brittle compression failure modes. The model included features to capture both negative and degrading stiffness, with degradation depending on the maximum plastic strain during loading. Local collapse of a single fibre was defined by a maximum strain threshold in compression, beyond which the fibre could no longer contribute to the sectional resistance. The study estimated mechanical properties of temple construction materials through limited tests on distressed samples, omitting dynamic identification due to noise. Instead, a macro-modelling approach, based on typical Indian masonry models, assumed elastic properties conservatively and neglected tensile strength. The model accommodated non-brittle compression failures and degradation under loading, defining local collapse thresholds.

IV. RESULT

Table 1 Plan Study of Ancient Buildings

Sr no.	Name	Area of Shrine(sqm)	Length(m)	Height (m)	H/L	Slenderness ratio
1	Brick temple (UP)	25.82	6.89	13	1.88	1/1.9
2	Surya temple (RJ)	21.68	5.01	10.45	2.08	1/2.1
3	Khajuraho (MP)	44.48	8.4	18.81	2.23	1/2.2

➢ *Seismic Vulnerability of Ancient Structures*

Masonry towers, such as gopurams, encounter several common problems under seismic loading due to their material characteristics, slenderness, lack of redundancy, and construction typology. These structures are often slender and tall, which makes them flexible and thus subject to lower seismic forces. However, their increased height also increases the lever arm for the overturning moment due to lateral forces, making the slenderness effect particularly problematic. Differential soil settlement often leads to the inclination of ancient towers, resulting in significant secondary stress. A typical construction method for these structures is multi-leaf construction, which increases wall thickness to counteract gravity loads. While this design, with a homogeneous infill and adequate interconnections between veneers, may remain stable under static loads, it does not necessarily perform well under dynamic loads. The increased thickness adds mass but not necessarily resistance. Common issues include disintegration of the infill masonry and deterioration of the interconnections between veneers, leading to increased vulnerability to lateral loads. In mandapams, the lime mortar interface between pillars, corbels, and beams offers no resistance to tension, causing them to behave like dry masonry structures during ground motion. These structures are comparable to Roman classical single-drum columns with architraves, such as those in the Parthenon Pronaos, Greece. However, the monolithic nature of the pillars in mandapams makes their structural behavior considerably different from the classical multi-drum Greek temple structures. Studies on the Parthenon's porch reveal that the seismic response of such structures is highly sensitive to both the structural configuration and the parameters of ground motion, exhibiting highly non-linear dynamic behavior. Collapse in these structures is typically due to

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24JUN1037

instability rather than material strength exceedance, underscoring the need for assessment methods that prioritize geometry.

V. CONCLUSION

Ancient temple architecture, particularly in its early stages, was characterized by a structural system known as the trabeated or post and beam method. Originating from wooden construction techniques in ancient India, this method was later adapted for stone temples. The fundamental principle involved columns (posts) supporting horizontal beams (lintels), which were in turn extended using corbelling techniques to create complex roof structures. Unlike architectural traditions that utilized arches and vaults for lateral support and spatial enclosure, Ancient temples prioritized vertical load-bearing and stability through mass. Engineering principles in Ancient temple architecture were deeply rooted in gravitational laws and the management of vertical loads. Temples were designed to withstand forces primarily through the direct transmission of weight downwards. This approach ensured structural integrity by distributing loads vertically rather than relying extensively on lateral supports or complex structural forms like arches. The solid resistance of stone and careful massing of structural elements further enhanced stability and durability. Additionally, the engineering ingenuity of Ancient architects is evident in their understanding of material properties and construction techniques. Stone blocks were meticulously carved and interlocked to form stable walls and intricate sculptures, reflecting both aesthetic and structural considerations. The use of corbelling, where stones project slightly beyond the one below, allowed for the creation of overhanging features and intricate roof designs while maintaining stability. In summary, Ancient temple architecture exemplifies a sophisticated understanding of engineering principles tailored to local materials and cultural preferences. By emphasizing vertical load-bearing and leveraging the solid resistance of stone, these temples achieved remarkable structural stability and durability. This blend of architectural beauty and engineering functionality continues to inspire modern engineers and architects studying historical construction techniques.

REFERENCES

[1]. Griffith, M. C., Abrams, D. P., Shapiro, D. A., Schutz, B. G., & Tait, M. J. (2003). "Seismic Performance of Unreinforced and Reinforced Masonry Buildings." *Journal of Structural Engineering*, 129(6), 821-829.

[2]. Drysdale, R. G., & Hamid, A. A. (1989). "Behavior of Reinforced Masonry Shear Walls under Cyclic Loading." *Journal of Structural Engineering*, 115(10), 2609-2625

[3]. Magenes, G. (2006). "Performance-Based Design of Masonry Structures." *Earthquake Engineering & Structural Dynamics*, 35(9), 1155-1176

[4]. Schlegel, R., & Hegger, J. (2012). "Modeling and Analysis of Reinforced Masonry Structures." *Journal of Structural Engineering*, 138(1), 105-113.

[5]. Sarhosis, V., Sheng, Y., Sheng, M. J., & Kotsovos, K. S. (2014). "Experimental Study on Seismic Retrofitting of Unreinforced Masonry Structures." *Journal of Structural Engineering*, 140(2), 04013054.

[6]. Milani, G. (2011). "Finite Element Analysis of Masonry Structures: Review and Advances." *Archives of Computational Methods in Engineering*, 18(3), 351-384.

[7]. Lagomarsino, S., & Giovinazzi, S. (2006). "Seismic Vulnerability Assessment of Unreinforced Masonry Buildings." *Journal of Earthquake Engineering*, 10(1), 73-92

[8]. Lourenço, P. B., & Rots, J. G. (1997). "Dynamic Behavior of Masonry Structures: Experimental and Numerical Approaches." *Journal of Structural Engineering*, 123(5), 660-667.

[9]. Bruneau, M. (1994). "Evaluation of Masonry Structures under Seismic Loads: An Integrated Approach." *Journal of Structural Engineering*, 120(1), 76-100.

[10]. D'Ayala, D., & Speranza, E. (2003). "Innovative Strengthening Techniques for Masonry Structures." *Journal of Earthquake Engineering*, 7(2), 275-305