IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684, p-ISSN: 2320-334X, Volume 22, Issue 6 Ser. 1 (Nov - Dec 2025), PP 58-64
www.iosrjournals.org

Experimental And Numerical Evaluation of Shear Performance in Brick Masonry Walls

Sachin Gajananrao Raut[1], Dr. Nitin Y. Patil[2]
[1,2] *Department of Civil Engineering, Mansarovar Global University, Sehore, MP, India*

Abstract
To meet the latest environmental and sustainability standards, most modern masonry systems use highly insulating hollow clay bricks. A dearth of experimental and numerical data on the structural behaviour of sustainable masonries under lateral in-plane stresses is evident, despite their increasing application in seismically vulnerable nations. Using both experimental testing and numerical modelling, this study delves into the shear behaviour of brick masonry walls. Masonry wall specimens were subjected to shear tests in compliance with SNI 03-4166-1996 in order to ascertain the rigidity, ductility, displacement properties, and failure processes associated with shear strength. On average, the shear strength was 0.207 MPa, the shear modulus was 21.99 MPa, and the maximum load was 16.39 kN, according to the testing data. There was strong agreement between the deformation and fracture patterns seen experimentally and the calculated displacement and stress contours.
Keywords: *Brick masonry, Shear strength, Masonry walls, Crack, Displacement*

I. INTRODUCTION

The abundance of inexpensive, easily accessible materials, and relative simplicity of construction make masonry constructions among the most popular types of buildings in human history. The majority of the population in many emerging nations still calls brick houses home. In addition, historic landmarks like the Great Wall, the Roman Colosseum, and Notre Dame Cathedral are mostly masonry constructions, making them a vital part of heritage preservation efforts. Though researchers and designers must pay close attention to masonry constructions' shortcomings. Masonry buildings have shown time and time again that they are weak and not very ductile in seismic events. These shortcomings, when added to the fact that materials degrade over time in use, create substantial risks to structural safety. There is an immediate requirement for credible studies on masonry strengthening and repair due to the prevalence of urban redevelopment initiatives.

Due to its simple construction, fast building cycles, and dependable bonding with the original structure, near-surface mounted (NSM) strengthening technology has garnered a lot of interest. Following the "minimal intervention" philosophy in historic building restoration, it is crucial that the original surface qualities of the reinforced structure be kept mostly unmodified. This technique entails making grooves in the surface of the structure, inserting reinforcing materials with high strength (e.g., FRP bars, steel bars, or steel strands), and then using mortar or glue to create a composite load-bearing system. Structural components' flexural, shear, and seismic resistance are all improved by this method. Importantly, "structural repointing" (SR) is another name for the process when NSM grooves are limited to mortar joints in brickwork. This method enhances ductility and mechanical performance without causing any harm to the brick units. Additionally, it allows for the targeted reinforcement of important wall areas in engineering, leading to more efficient and effective structural improvement.

Traditional NSM reinforcement, on the other hand, is a passive strengthening technique that makes very little use of material strength and is defined by stress lag effects between the original structure and the reinforcing materials. A novel and beneficial technological technique is the use of prestressed NSM reinforcement. Brick walls reinforced with prestress NSM had far higher load-bearing and deformation capacities than those of brick walls reinforced with nonprestressed NSM. Extensive construction area, high prices, and intricate installation processes are typical characteristics of traditional prestressing systems, which normally depend on external tensioning equipment and elaborate anchoring systems. The idea of structural self-prestressing by means of smart materials has arisen as a result of developments in material science. Due to their one-of-a-kind shape memory effect, shape memory alloys (SMAs) have emerged as a leading candidate for self-prestressing materials. A lot of the first studies concentrated on NiTi SMAs, or nickel-titanium shape memory alloys. Unfortunately, the widespread use of NiTi SMAs in civil engineering has been greatly impeded by their expensive cost, higher activation temperature, low thermal hysteresis, and poor recovery-stress stability. An attractive substitute that has arisen in recent years is shape memory alloys (Fe-SMAs), which are iron-based and quite inexpensive. They are a new generation of smart materials that have the potential for broad implementation in civil engineering due to their stable and dependable recovery-stress features and acceptable activation-temperature range.

II. REVIEW OF LITERATURE

Yusof, Mohammed et al., (2024). One way the construction industry may develop sustainably is by finding new uses for old materials. Discovering novel use for waste products is one step toward achieving environmental sustainability. Research is also needed to encourage the recycling of garbage into building materials that are both sustainable and economically feasible. Instead than fixating on rapid expansion as the project's end goal, it would be wise to adopt the idea of practicing environmental consciousness. Scientists have discovered that incorporating natural fibres into bricks enhances their strength development. In this study, we investigate how adding pineapple fibres to masonry bricks changes their mechanical properties. Following the guidelines laid out by the ASTM C67-17 Standard (2017), tests were conducted to determine the water absorption rate and compressive strength of masonry bricks treated with pineapple fibre at concentrations of 0, 0.25%, 0.50%, and 0.75%. According to studies, the strength properties of masonry bricks are significantly improved when 0.5% pineapple fibres are added. Based on the results of this study, the optimal fibre content for masonry bricks reinforced with pineapple leaf fibre is 0.5% for optimal performance in the construction industry.

Javed, Kamran et al., (2024). Masonry prisms were built using a variety of materials, including cement mortar (CM), fly ash mortar (FAM), bagasse ash mortar (BAM), and calcined clay cement mortar (C3M). Manufactured clay bricks (MB), fly ash bricks (FB), and handmade clay bricks (HB) were also used. Compressive strength tests were conducted on brick units and cube specimens of masonry mortar. We measured the compressive strength of five-brick prisms and the flexural bond strengths of seven-brick prisms. The masonry triplets were employed for the purpose of assessing the shear bond strength of brick masonry. Researchers tested the effects of curing age on prism and triplet babies at14, 28 and 90 days postpartum. We also compare the compressive strength of masonry prisms to that of bricks and mortar. The compressive strength of HB was much higher than that of FB and MB. C3M has a substantially greater compressive strength than other types of mortar. Compressive, shear, and flexural bond strengths were all better in HB-C3M prisms compared to other kinds of masonry prisms during the whole curing process. Due to the progressive development of its compressive strength, masonry prisms made from BAM demonstrated increased performance with increasing age.

Almssad, Asaad et al., (2022). In construction, many parts are brought together to create a finished structure. Masonry is the backbone of every successfully constructed structure. The Colosseum, Central American monuments, ancient Greek and Roman structures, and Mycenaean structures all include this material. The first variety involved the use of dried stones with irregular shapes. Modern concerns about sustainable design have resurrected the use of masonry as a green building material owing to its healing qualities, low environmental effect, and the massive wall's capacity to control the environment around it. This article follows the evolution of masonry as a primary construction material from ancient structures to modern skyscrapers. This article will teach you the basics of masonry building so you may build structures with it in whichever style you want. Masonry is a vital representation of human creation in architectural history. Masonry will be emphasised as an important building component and its role in the evolution of building materials in this essay that aims to offer a historical overview.

Raheel Shah, Syyed Adnan et al., (2019) Examining how different cement-to-mortar ratios affect interface behaviour and the formation of brick-based masonry bonding over the long term is the primary objective of this research. To find out how the varied brick bonding behaved in the long run, we put the five brick masonry structures that were made using four different mortar ratios through a battery of tests. The design was followed for the execution of the shear bond, bond wrench, prism triplet, and brick masonry strength tests. The purpose of doing the prism triplet test was to get insight into the bonding behaviour of mortar. The results showed that the mix ratio that yielded the greatest strength was 1:3, with a value of 0.21 MPa, while the mix ratio that yielded the lowest strength was 1:8, with a value of 0.095 MPa. The bond wrench test revealed that a mortar ratio of 1:3 resulted in a maximum bond strength of 0.0685 MPa, while a mortar ratio of 1:8 produced a minimum bond strength of 0.035 MPa. It was found that masonry buildings with an English bond formation and a mortar ratio of 1:3 had their highest compressive strength (0.786 MPa) and flexural strength (0.352 MPa). Here we provide the findings of our study on the correlations between different material characteristics, mortar mixes, and bond kinds, together with the outcomes of our artificial neural network (ANN)-based compressive and flexural strength prediction efforts. When considering this design for new home construction, it may be easier to choose sustainable brick masonry forms.

Oti, Jonathan et al., (2010). Sustainable masonry mortars were developed for use in brick joints and plastering by blending powdered granulated blast furnace slag with Portland cement. A control mortar composed of Portland cement was used for this purpose. One goal of the testing program was to find a link between the flow value of mortar and the water demand for different mix compositions. Using standard briquet towing and testing equipment, the lab determined this value, even though brickwork mortar is rarely stressed in action. Because of this, tensile strength is not a crucial property of mortar. Under extreme conditions containing sulphate, we tested the chemical durability of both the control and blended mortar. After curing in either water or a sodium sulphate solution at room temperature (20 ± 2°C) for 30 to 120 days, there was a correlation observed in the compressive strength of the mortar. The results showed that the control mortar lost a significant amount of weight and strength after a long length of time. The hydration of Portland cement results in the formation of calcium hydroxide. This, in turn, alters the mortar's shape, suppresses reaction species, and, ultimately, disrupts the matrix, causing the mortar to age and lose strength and weight. According to the results, crushed granulated blast furnace slag and Portland cement may be used to make eco-friendly mortars that survive for a long time in the UK.

III. RESEARCH METHODOLOGY

The protocol for conducting wall shear tests is SNI 03-4166-1996. Up until it is crushed, the sample is analysed. Equation (1) may be used to determine the wall's shear strength:

$$f_{vd} = \frac{0.707x\left(P_u + W\right)}{A}\left(1-\mu\right) \quad (1)$$

where Pu is the maximum load in Newtons, A is the shear surface area in millimetres squared, W is the mass in Newtons, and μ is the friction coefficient, assumed to be 0.3.

Simulation model

We then compare the results of the experiment to a model created in the SAP2000 program. The goal of this model is to recognize whether the experimental and model results are similar in cases of displacement and fracture pattern, which can be determined from the stress in the plane. Table 1 displays the material parameters of the masonry.

Table 1. Material properties for the masonry

Properties		Value
Density	550 fi	1,276.53 kg/m3
Compressive strength (fi)		2.30 MPa
Modulus of elasticity (E)		1,266.06 MPa
Poisson ratio		0.208

The shear stress will be the basis for the model. The analysis made use of a shell-membrane with dimensions of 42 cm in width and 42 cm in height, and a thickness of 10 cm. The item was tilted at 45° and a point load was applied to the top for the shear model. The outcome of the shear test experiment will determine the load. The model for simulating shear is shown in Figure 1.

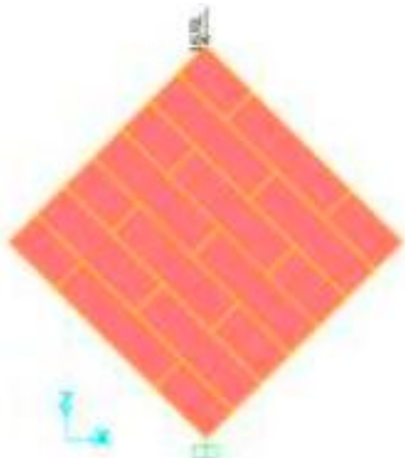

Figure 1: Object for shear model

IV. RESULTS AND DISCUSSION

Shear test result

When evaluating brick walls for shear, it is necessary to tilt the wall at a 45-degree angle and apply a horizontal load to the wall. The load is measured using a load cell. You may view the results of the shear tests, which assess the wall's shear strength properties, in figures 2-4 and in Tables 2 and 3.

Figure 2: Shear test specimens for DG 01

Figure 3: Shear test specimens for DG 02

Figure 4: Shear test specimens for DG 03

The shear test results for samples DG 01, DG 02, and DG 03 appear to be comparable, with crack patterns developing in the horizontal and vertical perpendicular directions, as seen in the aforementioned figures. According to the findings, the primary factor limiting the shear strength of brick masonry is the strength of the perpendicular connection to the brick.

Table 2: Shear Test Sample Properties

Properties	DT 01	DT 02	DT 03	Average
Length (mm)	420	420	420	420
Thickness (mm)	94.43	94.43	94.43	94.43
Max load (kN)	13.42	18.95	16.81	16.39
Load displacement (mm) – Vertical	4.76	6.18	5.72	5.55
Load displacement (mm) – Horizontal	0.71	0.54	0.62	0.62

Max displacement (mm) – Vertical	5.02	6.63	6.21	5.95
Max displacement (mm) – Horizontal	0.92	1.13	1.27	1.11
Stiffness (kN/mm) – Vertical	2.82	3.07	2.95	2.95
Stiffness (kN/mm) – Horizontal	18.90	35.24	27.81	27.32
Ductility – Vertical	1.05	1.07	1.09	1.07
Ductility – Horizontal	1.30	2.09	2.05	1.81

The shear test findings show that the specimen dimensions are consistent; all samples are 420 mm long and 94.43 mm thick. Very good load-carrying ability was demonstrated by the highest load, which ranged from 13.42 kN to 18.95 kN and averaged out to 16.39 kN. Deformation was mostly vertical, with an average vertical displacement of 5.95 mm and a horizontal displacement of 1.11 mm; the average load displacements were 5.55 mm and 0.62 mm, respectively. Stiffness measurements indicate adequate resistance to deformation, with an average of 2.95 kN/mm for the vertical direction and 27.32 kN/mm for the horizontal direction. The average horizontal ductility of 1.81 and the average vertical ductility of 1.07 both point to steady deformation behaviour prior to collapse.

Table 3: Shear Test Results

Properties	DT 01	DT 02	DT 03	Average
Cross-sectional area (mm²)	39,661.44	39,661.44	39,661.44	39,661.44
Max load (N)	13,420	18,950	16,810	16,393
Mass of tools (N)	67.17	67.17	67.17	67.17
Shear strength (MPa)	0.169	0.239	0.212	0.207
Strain	0.0080	0.0105	0.0096	0.0094
Shear Modulus (MPa)	21.13	22.76	22.08	21.99

All of the specimens maintained a consistent cross-sectional area of 39,661.44 mm², according to the shear test findings. The highest load averaged 16,393 N and varied between 13,420 N and 18,950 N. All of the specimens showed similar shear resistance, with an average shear strength of 0.207 MPa. The shear modulus is 21.99 MPa, which indicates strong resistance to shear deformation, and the average strain is 0.0094, which indicates mild deformation before failure.

Simulation modelling result

The model allows us to see the damage that has occurred due to the wall's stress. The shear model stress diagrams may be seen in figures 5 and 6.

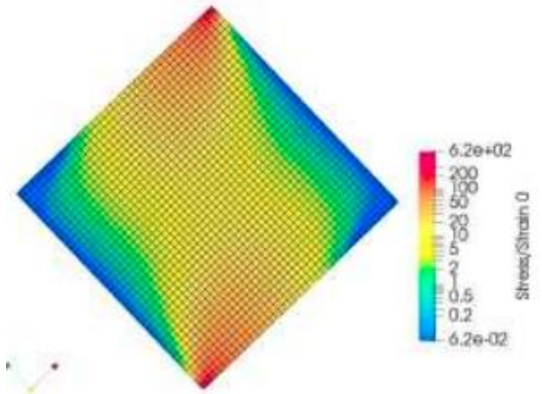

Figure 5: Stress diagram for shear model S11

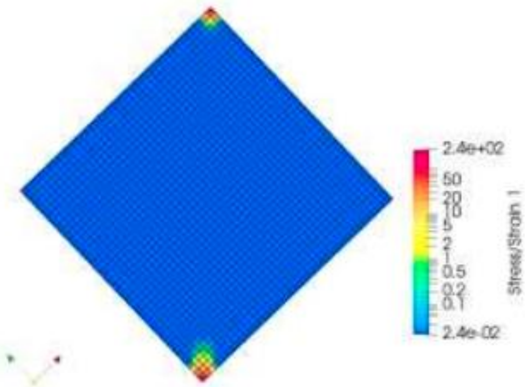

Figure 6: Stress diagram for shear model S22

According to the figures, S22 acts on the positive and negative 2 face in the Z-axis direction while S11 acts on the positive and negative 1 face in the X-axis direction, indicating direct shear. The numerical study indicates that the shear model can withstand loads up to 53 kN. Results are greater than experimentally possible due to the inclusion of macro-modelling procedures in the model. The following figures show the positive stress diagram that formed in the brick (perpendicular) connection. The model might also tell us how far things have moved. The displacement that results from the shear model is seen in Figure 7.

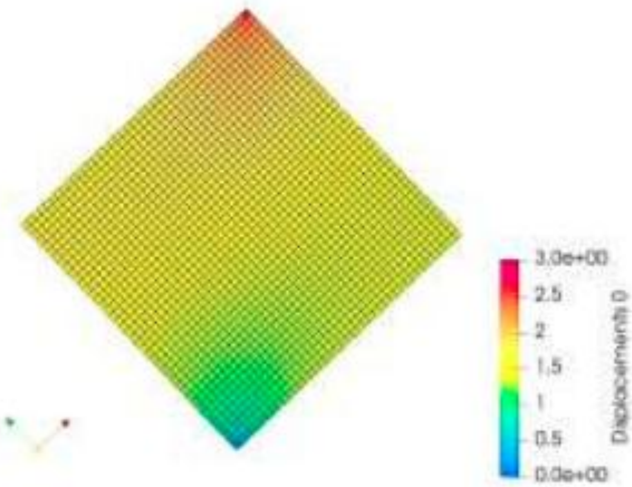

Figure 7: Z-axis displacement shear model

The displacement along the Z-axis as a result of the shear model in the upper center is 6.85 mm.

V. CONCLUSION

Failure mostly happened at the brick-mortar joints, according to the testing results, which also showed consistent deformation, shear strength, and stiffness. Although the experimental results showed lower load-carrying capacity, the SAP2000 numerical model accurately reproduced the overall stress distribution and displacement behaviour, owing to its macro-modelling assumptions. In sum, the results show that the experimental-numerical method works well to evaluate the shear loading behaviour of brick masonry and gives useful information for designing and evaluating robust, long-lasting masonry buildings.

REFERENCES: -

[1] M. Yusof, M. Yahya, V. Munikanan, and Z. Rosli, "Mechanical Properties of Masonry Brick Using Pineapple Fibre," *Jurnal Kejuruteraan*, vol. 36, no. 2, pp. 13–18, 2024.

[2] K. Javed, M. Irfan-ul-Hassan, M. A. Farooq, and M. Sharif, "Detailed Investigation of Compressive and Bond Strength for Sustainable Brick Masonry Developed by Using Various Types of Bricks and Green Mortars," *Journal of Building Engineering*, vol. 84, pp. 1–18, 2024.

[3] Almssad, A. Almusaed, and R. Homod, "Masonry in the Context of Sustainable Buildings: A Review of the Brick Role in Architecture," *Sustainability*, vol. 14, p. 14734, 2022.

[4] Behera, H. Khan, and R. Nanda, "Geosynthetic as a Strengthening Material for Brick Masonry Wall," *Materials Today: Proceedings*, vol. 4, no. 1, pp. 1–14, 2020.

[5] S. A. R. Shah, H. Arshad, M. Farhan, S. Raza, M. Khan, S. Syeda, G. Shahzadi, M. Qurashi, and M. Waseem, "Sustainable Brick Masonry Bond Design and Analysis: An Application of a Decision-Making Technique," *Applied Sciences*, vol. 9, no. 5, Art. no. 4313, 2019.

[6] V. Umamaheswari, K. Settu, P. Krishnan, and K. Baskar, "Strengthening of Brick Masonry with Welded Wire Mesh," *International Journal of Engineering and Technology*, vol. 7, no. 1, pp. 133–136, 2018.

[7] S. Abbas, M. Saleem, S. M. S. Kazmi, and M. Munir, "Production of Sustainable Clay Bricks Using Waste Fly Ash: Mechanical and Durability Properties," *Journal of Building Engineering*, vol. 14, no. 3, pp. 7–14, 2017.

[8] V. Krishnappa, "Sustainable Units for Structural Masonry," *Indian Journal of Science and Technology*, vol. 9, no. 3, pp. 1–7, 2016.

[9] P. Foytong, M. Boonpichetvong, N. Areemit, and J. Teerawong, "Effect of Brick Types on Compressive Strength of Masonry Prisms," *International Journal of Technology*, vol. 7, no. 1, p. 1171, 2016.

[10] J. Oti, J. Kinuthia, and J. Bai, "Sustainable Masonry Mortar for Brick Joint and Plaster in the UK," *Construction Materials*, vol. 163, no. 5, pp. 87–96, 2010.

[11] D. Martens, G. van Zijl, and A. Vermeltfoort, "Brick-Mortar Interface Effects on Masonry Under Compression," *Canadian Journal of Civil Engineering*, vol. 34, no. 1, pp. 1475–1485, 2007.