

PERFORMANCE ANALYSIS OF MASONRY BRICK WALLS SUBJECT TO VERTICAL AND DIAGONAL LOADING

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Abstract: *Masonry Bricks are the basic elements of different construction and brick behavior effects on the construction walls behavior. This research is focusing on the behavior of types of bricks such as hollow, engineering brick, fire, and sand-lime bricks under uniform load. Engineering bricks are kind of brick intended to be strong, absorb little water, and withstand extreme weather conditions. The research modelling is performed using ANSYS software V18.5, the parameters of research are different bricks types. Results are ultimate load, drift ratio, ultimate drift ratio, compressive joint strength, and compressive masonry strength. Results shows that fire and hollow bricks has good performance in resisting vertical and diagonal loading. In addition, sand lime has bad performance in resisting vertical and diagonal loading.*

INTRODUCTION

Masonry brick walls have been an essential component of construction for ages, revered for their strength, beauty, and structural integrity. This study intends to investigate the performance of masonry brick walls under uniform loading, which is a prevalent scenario in many structural applications. The key goals are to understand the behavior of these walls under such conditions, to identify the factors that influence their performance, and to provide insights that may be used to improve construction techniques. This study covers numerous types of bricks and mortars, as well as ancient and current construction processes, with a focus on how they affect the structural behavior of masonry walls. The study's significance and help other researchers to discover the effect of material choices, environmental sustainability, financial efficiency, and safety requirements in different projects.

Also, it can be useful for different researcher's in making structural design optimizations and understanding the attitude of different brick types under consistent strain, resulting in more strong and efficient structure techniques. The study of masonry wall has a long history, with many scholars helping us understand their structural performance. Previous research has investigated a variety of topics, including the mechanical properties of various brick and mortar kinds, the implications of construction methods on wall strength, and the behavior of masonry under varying loading circumstances. However, gaps exist, notably in the complete understanding of load distribution mechanisms and the impact of new construction techniques.

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Nebojša studied the strength of unreinforced brickwork under in-plane loading. Using plasticity theory approaches, considering stresses and failure processes are tested, in addition to the in-plane loaded masonry without tensile strength. The in-plane loading considers the slip failure which could be noticed in compression tests and considering the safety of the design according to the current criterion. In addition, the current work provides an outline of an experimental program that contains the compression tests on wall elements made of concrete and calcium-silicate blocks, as well as clay brick masonry, which were conducted at ETH Zurich. In addition to using the concept of the simplified variation of uniaxial masonry strength which validated with the test results, as well as the additional tests made by other researchers. There is a validation and agreement between the proposed simplification and test data [15]. T. Sekar prepared finite element model to study the strengthening of brick masonry in fireworks industries against explosions. He discovered that the brick masonry has good effect against accidental overloading, in addition to resist progressive collapse of the structure, by adding RCC vertical bands at door jambs [18].

D. M. Herbert investigated the effect of out-of-plane hydrostatic loading on masonry walls existing in household or commercial buildings. The researcher performed 1/6th scale model using a geotechnical centrifuge, examines wall panels made using different brick types (autoclaved aerated concrete brick, and brick-block) linked together using two mortar types in addition to using a safe sealing height in the different modelling. The walls were applied to axial load for one storey of load and were simply supported on all four sides. A 3D digital image is used to capture the load out-of-plane, deflection, straining actions. The results showed that when using partial material and load into consider, the results showed that a safe sealing height of 0.9 m was actually incorrect, but a safe sealing height of 0.6 m was not suitable for every example tested. This height lights the need for a proper method for calculating water levels into failure, rather than using fixed numbers stated in public literature [12].

Abraham A.' studied the performance for axial compressive tests on unreinforced masonry walls, as well as extensive comparisons of experimental literature findings based on masonry building methods and affecting parameters. The literature has focused mostly on the masonry elements, design provisions, axial load, slenderness ratio, apertures, and stress-strain response. This study aims to build on previous research by conducting a thorough assessment of these locations, providing new insights that help improve the design and construction of masonry walls [4].

A.Y. Elghazouli studied two groups of masonry wall are used in experimental tests (wall in diagonal compression and vertical positions). the two groups are subjected to cyclic loading. The dimensions of the masonry $d \times h \times t = 1910 \times 1300 \times 110$ mm with mortar thickness of 10 mm and made of these walls were tested in experiments taking consider the wet and dry conditions. Vertical load at three positions (using axial stress = 1 MPa and reversed cyclic loads are applied to vertical walls. Monotonic diagonal compression with 1 mm/min rate are applied to diagonal compression walls in the experimental works. The outputs of the experimental works for vertical loaded wall are ultimate load, drift ratio, ultimate drift ratio, compressive joint strength, and compressive masonry strength. And for diagonal walls are ultimate load, shear strength, tensile strength, shear modulus, compressive joint strength, compressive masonry strength. In addition, a finite element software ANSYS v18 are used to verify the results with experimental test. According to table (1), there are agreements and computability between results from the experimental with the ANSYS [9].

commonly utilized in both historic and modern structures. Concrete bricks, on the other hand, have benefits like as cost-effectiveness and ease of production, however they may have different thermal and mechanical qualities than clay bricks. Other types, such as fly ash bricks and calcium silicate bricks, provide distinct advantages such as increased environmental sustainability and strength, respectively. Furthermore, Hollow bricks which chosen for specified applications due to their lighter weight, better thermal insulation, and cost-effectiveness compared to solid bricks, and Engineering Bricks. They are widely utilized in applications that require durability and strength, such as foundations, load-bearing structures, and exposed masonry work. In addition, Sand-Lime Bricks which commonly known as calcium silicate bricks, are a form of brick composed mostly of sand, lime, and water. They are cured via a chemical process combining pressure and steam, giving them distinctive features. Fire Bricks, also known as refractory bricks, are specially built to withstand high temperatures and are utilized in extreme heat conditions. They are widely utilized in fireplaces, kilns, furnaces, and other high-temperature applications [2, 3, 5-7, 16, 17, 20]. Below are the tables (1), (2), (3) & (4) which describe the properties of the bricks studied in the paper:

Table 2: Properties of Hollow Bricks.

Hollow Bricks	
Young's Modulus	15 GPa
Density	1000 kg/m ³
Poisson's Ratio	0.15

Table 3: Properties of Engineering Bricks.

Engineering Bricks	
Young's Modulus	30 GPa
Density	2200 kg/m ³
Poisson's Ratio	0.15

Table 4: Properties of Fire Bricks.

Fire Bricks	
Young's Modulus	40 GP
Density	2300 kg/m ³
Poisson's Ratio	0.15

Table 5: Properties of Sand-Lime Bricks.

Sand-Lime Bricks	
Young's Modulus	20 GPa
Density	2000 kg/m ³
Poisson's Ratio	0.15

Finite Element Modelling

This research aims to test the performance of the analytical modeling of clay brick used in an experimental test for A.Y. Elghazouli which discussed in literature. The analytical modelling was conducted using ANSYS software V18.2 [1]. The results of experimental test for A.Y. Elghazouli are compared by ANSYS modelling as shown in table (1). There results showed the agreements and computability between results from the experimental with the ANSYS.

In addition, more investigation is used by the ANSYS v18 through modelling the other four types of like hollow bricks, engineering bricks, fire bricks, and sand-lime bricks. These bricks are modelled with the same experimental condition used in Elghazouli. These bricks are used in dry conditions and applied to both vertical load

position and diagonally load position as performed in the experiment before. The results of these bricks are shown in table (6) and figures from (2) to (12).

Table 6: Results of Vertical Load Position and Diagonally Load Position for Different Brick Using ANSYS.

load Position	Property	Fired Clay Bricks (A.Y. Elghazouli)	Engineering Bricks	Hollow Bricks	Fire Bricks	Sand-Lime Bricks
(Vertically Loaded)	Ultimate Load kN	110.6	110.25	100.48	115.12	105.47
	Drift Ratio	0.406	0.34	0.51	0.37	0.48
	Ultimate Drift Ratio	0.625	0.51	0.73	0.55	0.65
	Compressive Joint Strength MPa	2.24	2.4	2.14	2.35	2.15
	Compressive Masonry Strength MPa	4.34	4.66	4.15	4.76	4.25
	Ultimate Load kN	26.9	27.35	241.44	30.21	26.34
(Diagonal Loaded)	Shear Strength Mpa	0.24	0.24	0.224	0.28	0.25
	Tensile Strength Mpa	0.17	0.175	0.151	0.23	0.16
	Shear Modulus MPa	665	705.53	604.57	755.34	685.17
	Compressive Joint Strength Mpa	1.29	1.375	1.34	1.578	1.48
	Compressive Masonry Strength Mpa	3.68	4.53	3.57	4.25	3.77

For Vertical Load Results

Fire and Hollow Bricks Shine: Both fire and hollow bricks demonstrated the highest ultimate load capacities (around 115 kN and 100 kN, respectively). This suggests they are strong contenders for resisting vertical compression.

Clay and Engineering Bricks in the Middle: Clay and engineering bricks performed reasonably well, but with slightly lower ultimate load capacities than fire and hollow bricks.

Sand-Lime Bricks Lag Behind: Sand-lime bricks showed the lowest ultimate load capacity (105 kN). This indicates they might not be the best choice for applications where high vertical loads are expected [10].

For Diagonal Load Results

Hollow Bricks Take the Lead: Interestingly, hollow bricks showed a significant jump in strength under diagonal loading, achieving the highest ultimate load capacity (241 kN) by far. This suggests their internal structure might be particularly effective at resisting diagonal forces [11].

Fire Bricks Remain Strong: Fire bricks maintained their good performance under diagonal loading as well, exceeding both clay and engineering bricks [19].

Sand-Lime Bricks Still Struggle: Sand-lime bricks, again, exhibited the lowest ultimate load capacity under diagonal loading (26 kN), reinforcing the idea that they are more vulnerable to this type of force [8].

Additional Observations

Drift and Ultimate Drift Ratios: While the table provides these values, it's difficult to draw firm conclusions without comparing them to established performance

criteria or limits. Further analysis would be needed to assess the implications of these values for structural safety and serviceability [14].

Strength Parameters: The table also lists values for compressive joint strength and compressive masonry strength. These values provide more detailed insight into the behavior of the different brick types under different loading conditions, highlighting the interplay between brick-and-mortar properties [13].

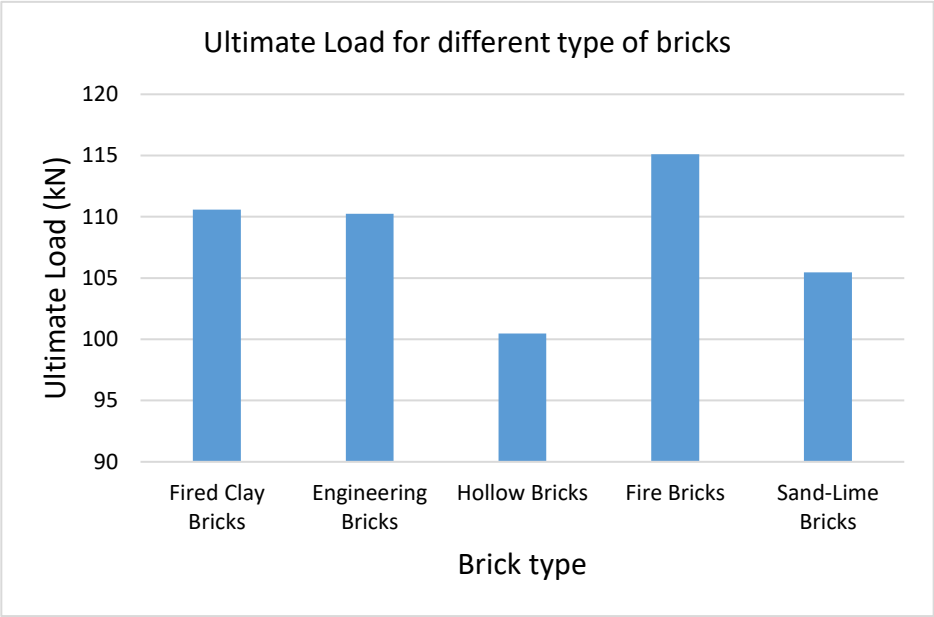


Figure 2: Ultimate Load for Different Type of Bricks.

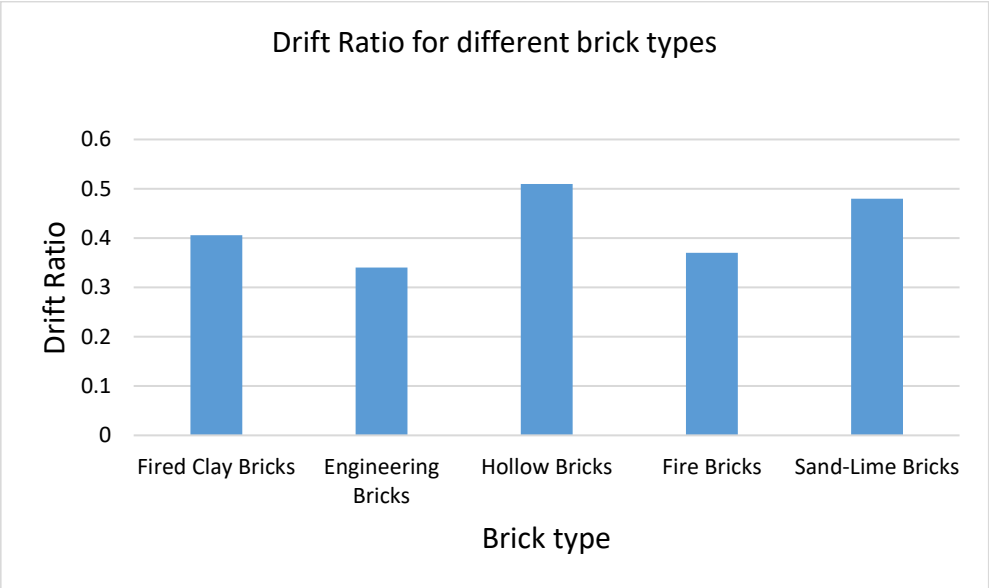


Figure 3: Drift Ratio for Different Brick Types.

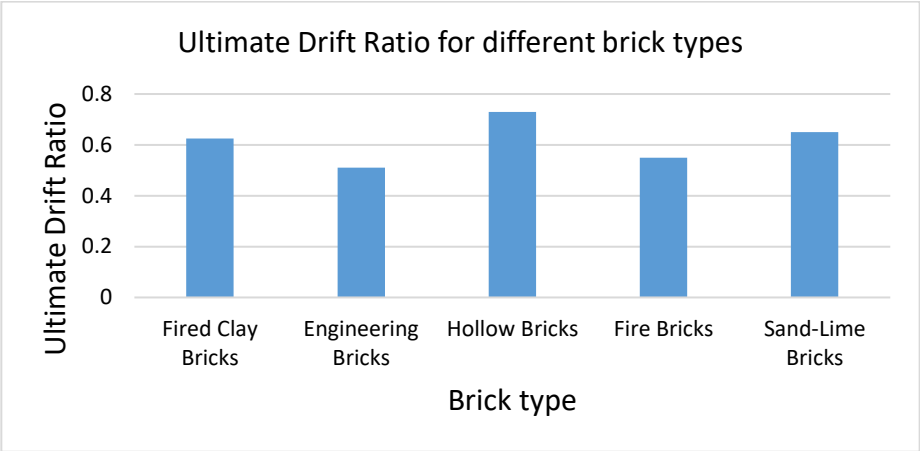


Figure 4: Ultimate Drift Ratio for Different Brick Types.

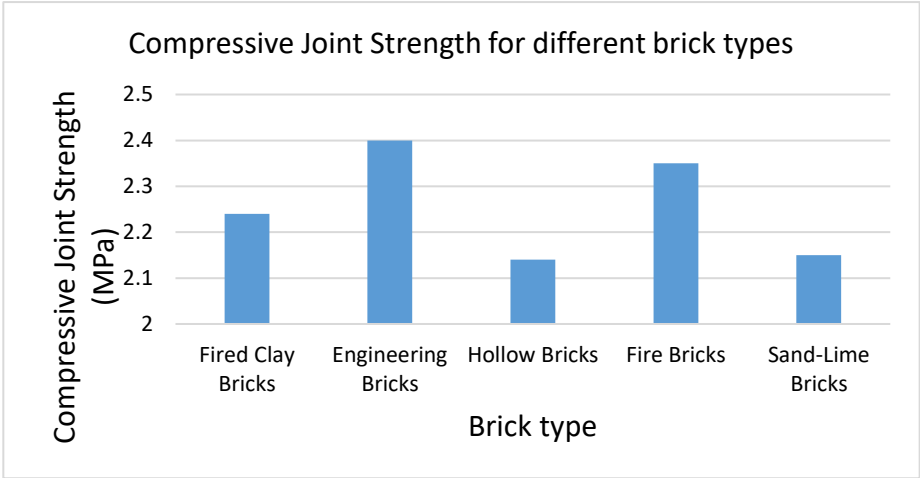


Figure 5: Compressive Joint Strength for Different Brick Types.

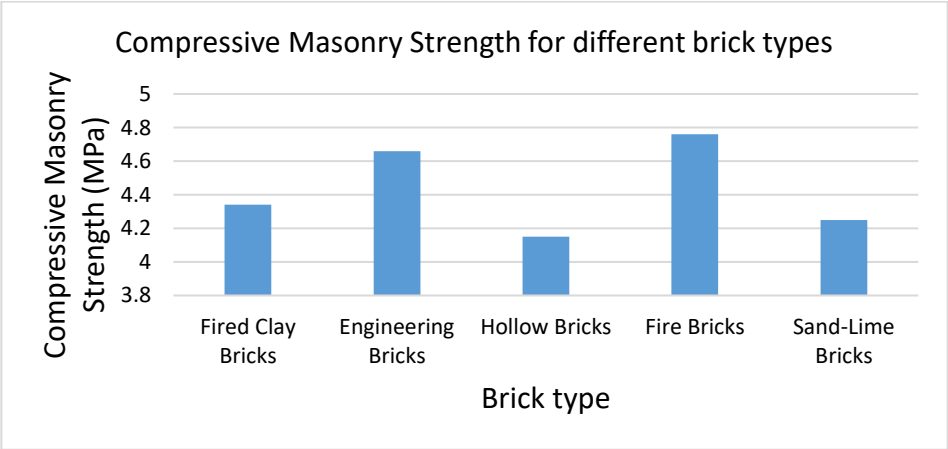


Figure 6: Compressive Masonry Strength for Different Brick Types.

For Diagonally Loaded Wall

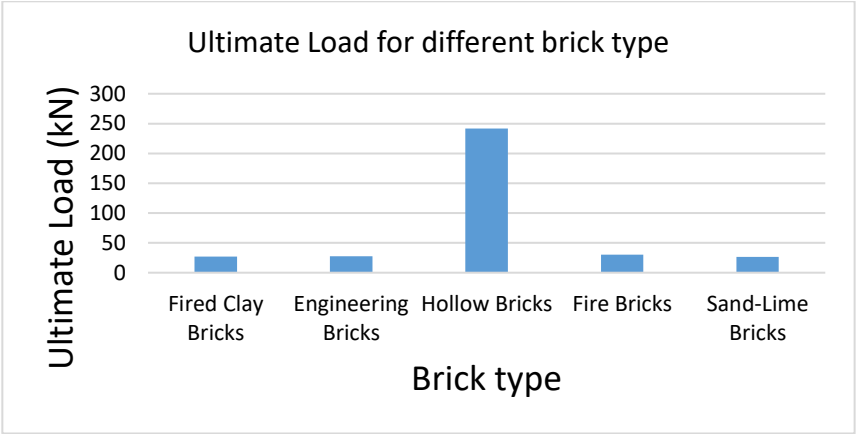


Figure 7: Ultimate Load for Different Type of Bricks.

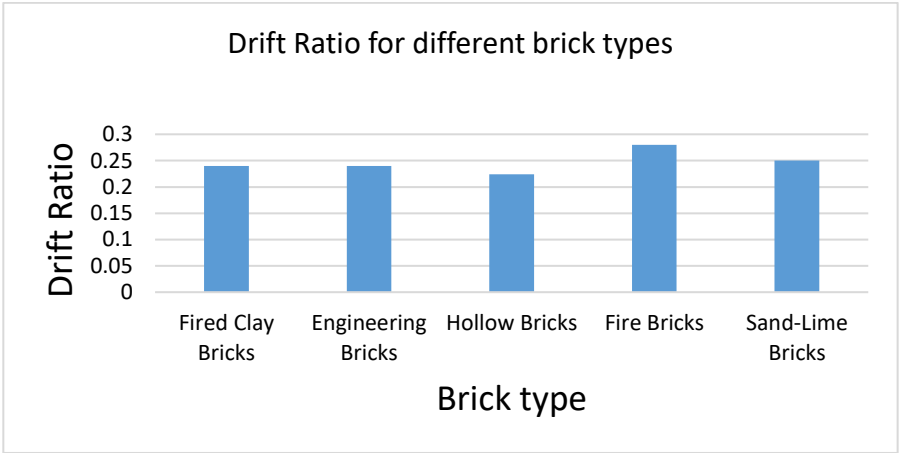


Figure 8: Drift Ratio for Different Brick Types.

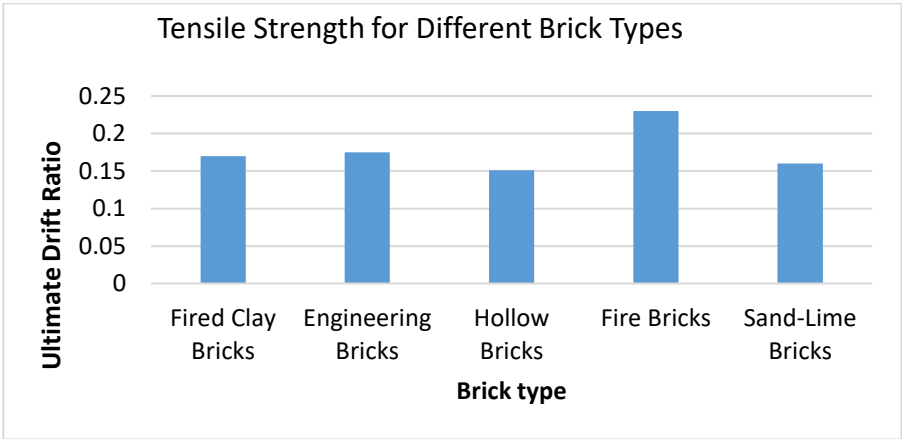


Figure 9: Tensile Strength for Different Types of Brick.

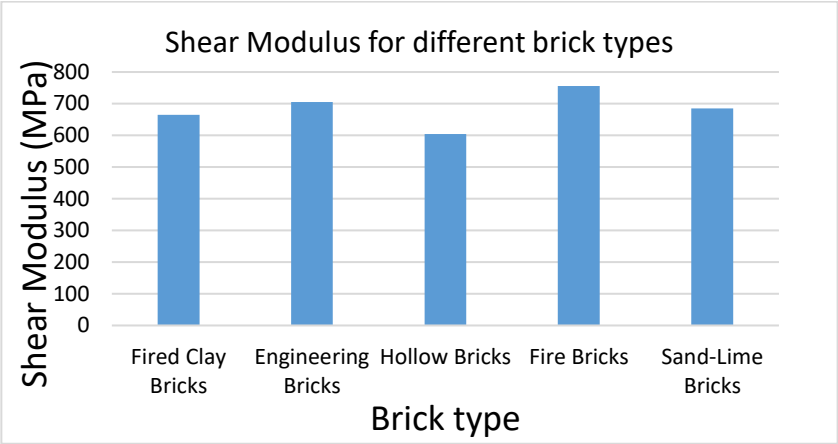


Figure 10: Shear Modulus for Different Types of Bricks.

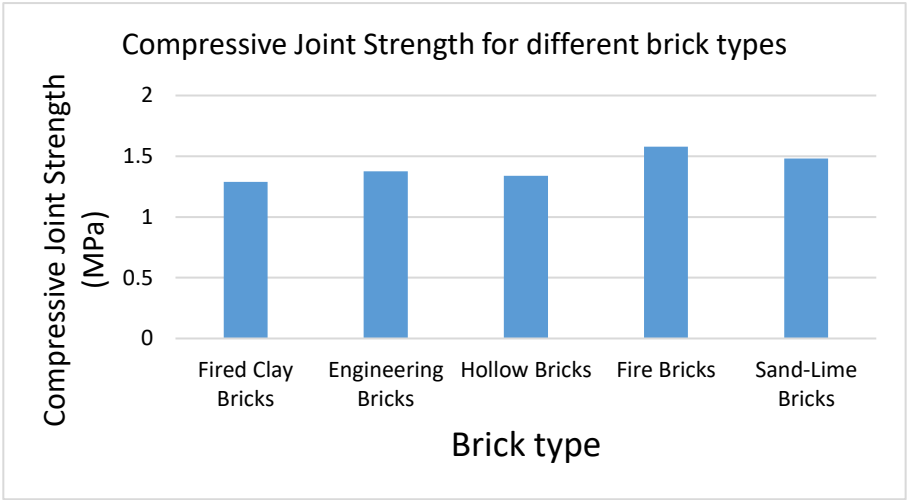


Figure 11: Compressive Joint Strength for Different Types of Brick.

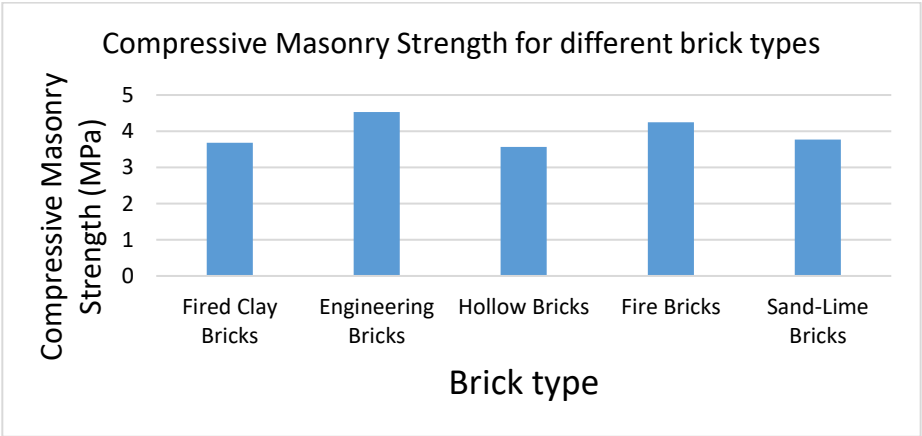


Figure 12: Compressive Masonry Strength for Different Brick Types.

For diagonally position of wall

From figures (13), (14) we can discover the following:

Stiffness and Strength: The curves demonstrate that clay, hollow, and engineering bricks exhibit similar stiffness and strength under diagonal loading, regardless of the moisture condition. Fire bricks show slightly lower values, while sand-lime bricks exhibit significantly lower stiffness and strength, indicating their vulnerability to this loading mode.

Moisture Influence: Comparing the dry and wet condition curves, a consistent trend emerges: moisture reduces both stiffness and strength, although the overall shapes of the curves remain comparable. This observation is consistent with previous findings about the detrimental effects of moisture on masonry performance.

Model Validation: The good agreement between numerical and experimental data for fired clay bricks (mentioned in the text) validates the model's accuracy and reliability for predicting the behavior of different brick types

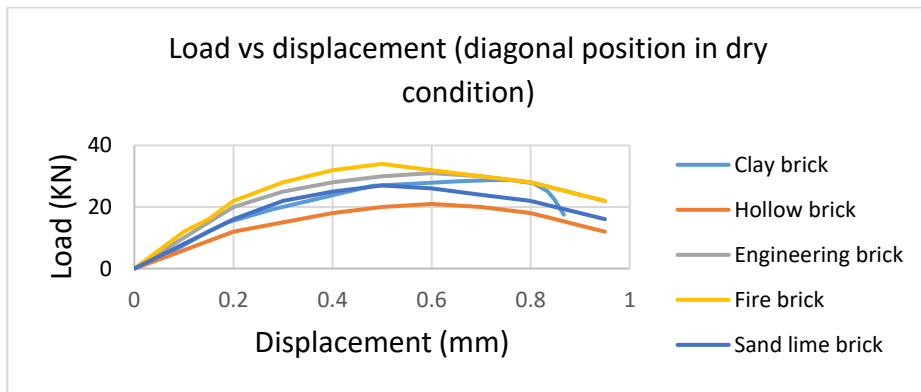


Figure 13: Load-Displacement Response of Diagonal Panels: for the Different Brick Types in Dry Condition.

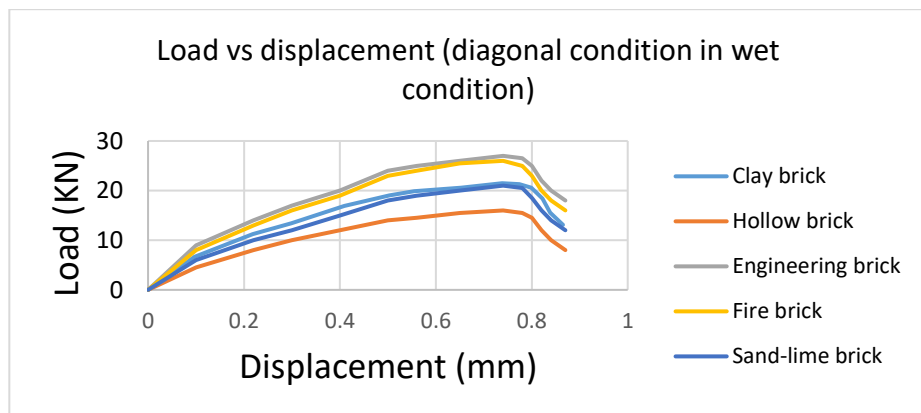


Figure 14: Load-Displacement Response of Diagonal Panels: for the Different Brick Types in Wet Condition.

The load vs drifts envelopes are shown in fig (15), (16). Comparing the wet and dry specimens we found the following:

The Performance Differences: These curves reveal significant differences in performance among the different brick types. Fire and hollow bricks consistently demonstrate higher peak loads (ultimate strength) and better ductility (gradual softening post-peak) under both dry and wet conditions. Engineering bricks exhibit moderate performance, while sand-lime bricks show the lowest peak loads and a more brittle failure behavior with a sharp drop in load after peak.

Moisture Effect: Similar to the diagonal loading case, moisture consistently reduces the peak load and stiffness of all brick types under vertical loading. However, the relative performance ranking remains consistent, suggesting that moisture does not fundamentally alter the relative strength characteristics of each brick type.

Failure Mode Implications: The shapes of the curves, particularly the post-peak behavior, offer insights into the underlying failure modes. The brittle behavior of sand-lime bricks indicates a sudden, catastrophic failure likely associated with crushing or cracking. The gradual softening of fire and hollow bricks suggests a more ductile failure mechanism potentially involving gradual yielding or deformation of the material.

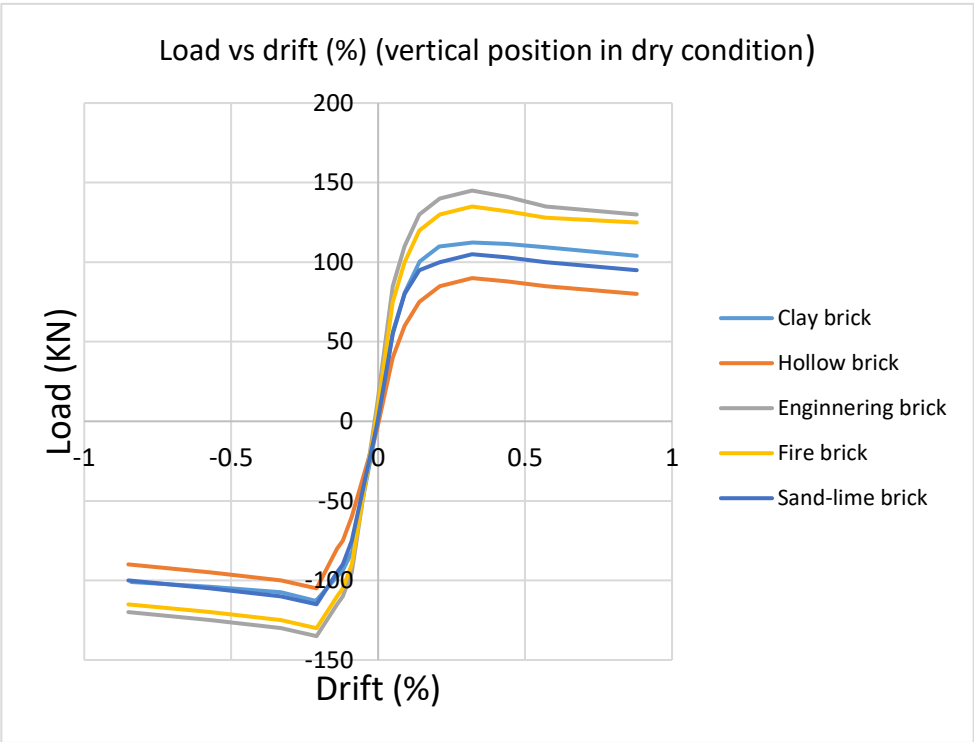


Figure 15: Comparative Load-Drift Envelope Response for Different Brick Types in Dry Condition.

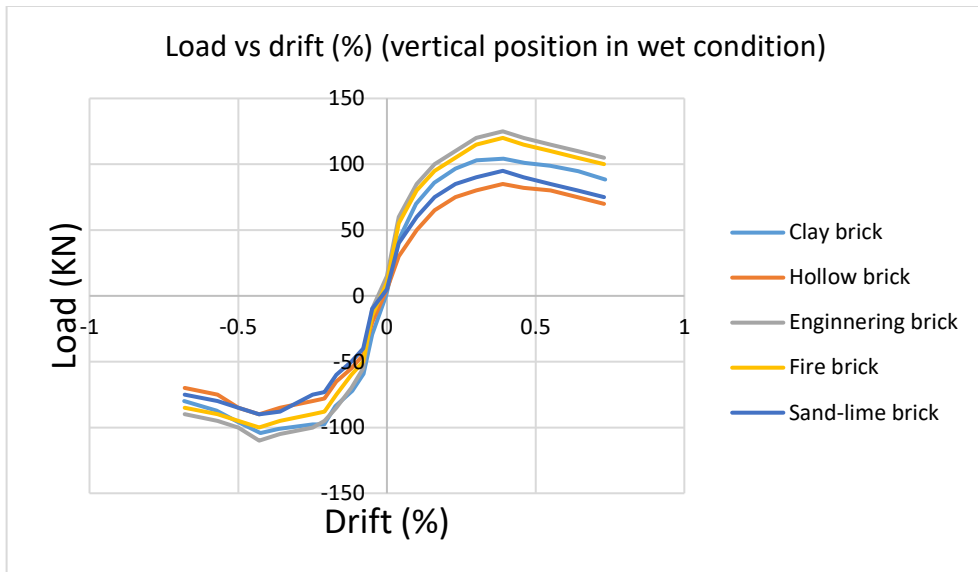


Figure 16: Comparative Load-Drift Envelope Response for Different Brick Types in Wet Condition.

CONCLUSION

We studied the behavior of wall clay bricks in vertical and diagonal loadings using the experimental results and varied the results with ANSYS V18 software. In addition, the research considered also the other brick types like hollow, engineering, fire, and sand-lime bricks.

Brick Type Significantly Impacts Performance: The type of brick used drastically affects how a masonry wall behaves under load. Some bricks are inherently stronger, some are better at handling specific types of force (like diagonal pushing or pulling), and some are more sensitive to moisture.

Fire and Hollow Bricks: These brick types consistently demonstrate high strength and good ductility under both vertical and diagonal loading conditions, even when wet. They are strong candidates for load-bearing walls in a variety of applications.

Sand-Lime Bricks: consistently exhibit lower strength and a more brittle failure behavior, making them less suitable for load-bearing walls, especially under diagonal loads. Their use might be best reserved for non-structural applications or situations with minimal loading.

Engineering bricks: are strong not quite as impressive as fire or hollow bricks. They're a solid choice for most construction projects, but fire or hollow bricks are suitable high strength especially in diagonal forces.

Sand-lime bricks, on the other hand, are the ones that make you go, "Hmm, maybe not." They're consistently the weakest of the bunch, both when pushed straight down and when pushed diagonally. They also tend to break suddenly

without much warning, which is definitely not ideal for a building! It seems like they're better suited for things like decorative walls or fences where they don't have to hold up a lot of weight.

Moisture Weakens All, But Preserves Relative Strength: Moisture consistently reduces the strength and stiffness of all brick types. However, the ranking of the bricks relative to each other remains largely unchanged, meaning that some bricks are simply stronger than others, regardless of moisture levels.

Balance Between Brick and Mortar is Key: The interaction between brick strength and mortar strength significantly influences how a wall fails. A strong brick with weak mortar, or vice versa, may lead to unexpected failure modes. Careful consideration of this balance is crucial for designing durable masonry structures.

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