

Development of Lightweight Interlocking Bricks Using Fly Ash, Cement, Lime and Soil for Sustainable Construction

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ABSTRACT-The construction industry consumes a large amount of natural resources and contributes significantly to environmental issues, mainly due to the use of conventional materials like burnt clay bricks and cement. To address this present work focuses on developing lightweight interlocking bricks using locally available materials such as fly ash, soil, cement, and limestone. The bricks are designed with an interlocking (tongue-and-groove) arrangement, which removes the need for mortar during construction. This not only simplifies the construction process but also helps in reducing both time and cost. Experimental tests were carried out to study the compressive strength and water absorption of the bricks. The results show that the developed bricks achieved a compressive strength of around 8 N/mm^2 , which is higher than that of conventional clay bricks. In addition, the water absorption was found to be less than 12% indicating better durability. Another important observation is that the interlocking system completely eliminates the use of mortar and reduces overall material consumption to a significant extent. This makes the construction process faster and economical. Based on the results, it can be said that interlocking bricks made from fly ash and other locally available materials provide a practical, cost-effective, and environmentally friendly alternative for modern construction, especially in low-cost housing.

Key Words: Interlocking Bricks, Fly Ash, Mortar less Construction, Sustainable Construction, Water Absorption, Lightweight Bricks.

GRAPHICAL ABSTRACT

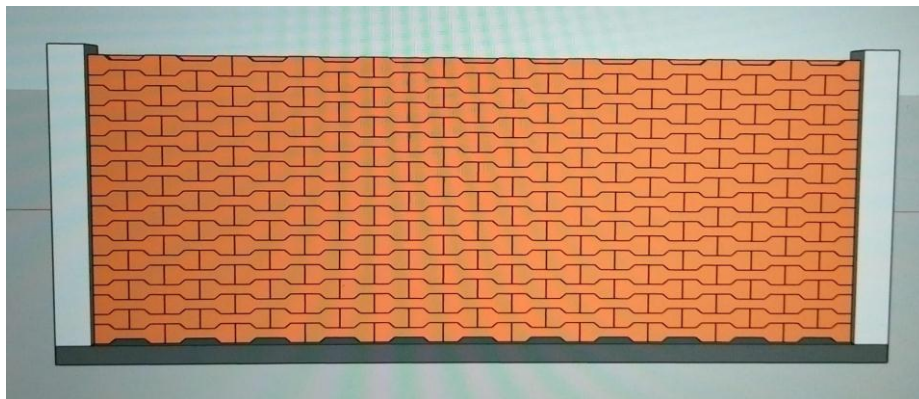


Fig.1: Graphical representation of Interlocking Brick

1. INTRODUCTION

The construction industry is essential for infrastructure development, but at the same time, it puts a heavy load on natural resources and the environment. Conventional materials such as burnt clay bricks require a large amount of energy for manufacturing and also use fertile topsoil, which leads to environmental imbalance. Moreover, the use of cement mortar in traditional construction increases both the overall cost and carbon emissions. Because of these issues, there is a need to find alternative building materials that are economical as well as environmentally friendly.

Interlocking brick technology is one such solution that has gained attention in recent years. These bricks are specially designed so that they can fit into each other through a tongue-and-groove arrangement. Due to this feature, there is no need for mortar while constructing walls. This method not only speeds up construction work but also reduces the requirement for skilled labor and excess cement usage. As a result, it becomes a more efficient and cost-effective construction technique.

At the same time, the use of industrial byproducts in construction has become an important area of research. Fly ash, which is obtained from thermal power plants, is widely available and has good binding properties due to its pozzolanic nature. It helps in improving the strength and durability of bricks. Using such materials also helps in reducing waste disposal problems and supports sustainable construction practices.

In this study, lightweight interlocking bricks are developed using locally available materials such as fly ash, soil, cement, and limestone. The main aim is to study their strength, water absorption, and overall cost efficiency. This approach can provide a practical and eco-friendly alternative to traditional construction methods, especially for low-cost housing and rural applications.

1.1. PROBLEM STATEMENT

In present construction practices, burnt clay bricks are widely used, but their production requires a large amount of energy and natural resources. The process involves the use of fertile topsoil and fuel for kiln burning, which leads to environmental problems such as loss of soil quality and increased air pollution. This makes conventional bricks less sustainable in the long run.

Another issue with traditional masonry is the use of cement mortar. It increases the overall cost of construction and also requires more time and skilled labor. For large projects or fast construction work, this method becomes less efficient and more expensive.

At the same time, materials like fly ash are produced in large quantities from thermal power plants, but they are not fully utilized. Improper disposal of such materials creates environmental concerns. If these materials can be used effectively in construction, it can help reduce waste and improve sustainability.

Because of these reasons, there is a need to develop an alternative building material that is economical, easy to use, and environmentally friendly. Interlocking bricks made from fly ash, soil, cement, and limestone can be a suitable option. These bricks reduce the use of mortar, save time during construction, and still provide the required strength and durability.

1.2. OBJECTIVES OF THE STUDY

The main aim of this study is to develop lightweight interlocking bricks using fly ash, soil, cement, and limestone, and to evaluate their suitability as a sustainable construction material. The specific objectives of the study are as follows:

1. To prepare lightweight interlocking bricks using fly ash along with soil, cement, and limestone in suitable proportions.
2. To study the feasibility of using fly ash as a partial replacement for conventional brick-making materials in order to promote sustainable construction practices.
3. To evaluate the compressive strength of the developed interlocking bricks and compare it with conventional clay bricks.
4. To determine the water absorption characteristics of the bricks to assess their durability and resistance to moisture.
5. To reduce the overall construction cost by eliminating the use of mortar through the interlocking arrangement of bricks.
6. To examine the effect of proper compaction and curing on the strength and performance of the interlocking bricks.
7. To study the environmental benefits of utilizing industrial waste materials such as fly ash in brick manufacturing.
8. To analyze the suitability of interlocking bricks for low-cost housing and sustainable construction applications.

2. LITERATURE REVIEW

In recent years, researchers have shown increasing interest in sustainable and cost-effective building materials due to growing environmental concerns and rapid depletion of natural resources. Conventional burnt clay bricks are widely used in construction, but their production consumes large amounts of energy and fertile topsoil. Because of these issues, researchers have explored alternative construction materials, among which interlocking bricks have gained significant attention because of their lower environmental impact and ease of construction.

Several studies have focused on the structural performance of interlocking brick systems. Research has shown that interlocking masonry units can achieve satisfactory load-bearing capacity and structural stability when proper bonding and reinforcement techniques are used (Baneshi et al., 2023; Arunachalam and Henderson, 2023; Dorji et al., 2023; Waqas et al., 2023). Further investigations reported improvements in crack resistance and overall structural behavior with the use of reinforcement (Sangthongtong, 2023; Ejaz, 2023). However, most of these studies mainly concentrated on structural behavior and gave limited attention to material optimization and cost efficiency.

Material selection plays an important role in determining the performance and sustainability of interlocking bricks. Fly ash, which is a widely available industrial by-product, has been extensively studied because of its pozzolanic properties. It reacts with lime in the presence of water and forms cementitious compounds that improve compressive strength and durability (Ali, 2021; Rahman, 2021). Previous studies reported compressive strength values ranging from 5 to 10 N/mm² depending on mix proportions and curing conditions. Research also supports the use of recycled and industrial waste materials in brick production, as they help improve sustainability while maintaining acceptable mechanical properties (Singh, 2022; Kumar, 2021).

The mechanical and durability characteristics of interlocking bricks have also been studied widely. Research indicates that these bricks can achieve sufficient compressive strength for low-rise construction applications (Joyklad et al., 2020; Joyklad et al., 2023). Water absorption values are generally reported to be below 12%, which is considered acceptable for masonry units (Khan, 2022; Ali, 2021). Compared to conventional clay bricks, interlocking bricks show lower water absorption and better resistance to moisture. Studies have also highlighted their improved thermal insulation properties, making them suitable for energy-efficient building applications (John, 2020; Sharma, 2021).

From a construction perspective, interlocking brick systems offer many practical advantages. Mortarless construction significantly reduces labor requirements and construction time (Saingam, 2023; Ali, 2022). Researchers also observed faster project completion due to ease of assembly and reduced dependence on skilled labor (Hafeez, 2023; Joshi, 2022). Economic analyses indicated that overall construction costs can be reduced through savings in materials and labor (Reddy, 2021; Mehta, 2021). However, some limitations still exist, including the need for proper alignment during construction and the higher initial cost of moulds.

Environmental sustainability is another major advantage of interlocking brick systems. Studies have shown that these systems have a lower carbon footprint compared to conventional masonry construction (Bolong, 2020; Mirasa, 2020). The use of fly ash not only improves material performance but also helps in reducing industrial waste disposal issues. Comparative studies confirmed that interlocking bricks are more resource-efficient and environmentally sustainable than traditional clay bricks (Patel, 2022; Gupta, 2023).

Although extensive research has been conducted on interlocking brick systems, certain research gaps still remain. Most studies focus either on structural performance or material properties, with limited integration of both aspects together. In addition, there is limited research on optimizing the combined use of locally available materials such as fly ash, soil, cement, and limestone. Detailed cost analysis and practical implementation studies under real field conditions are also limited. Therefore, the present study aims to develop lightweight interlocking bricks using locally available materials and evaluate their compressive strength, water absorption, and cost efficiency to provide a sustainable and economical alternative for modern construction.

2.1. METHODOLOGY

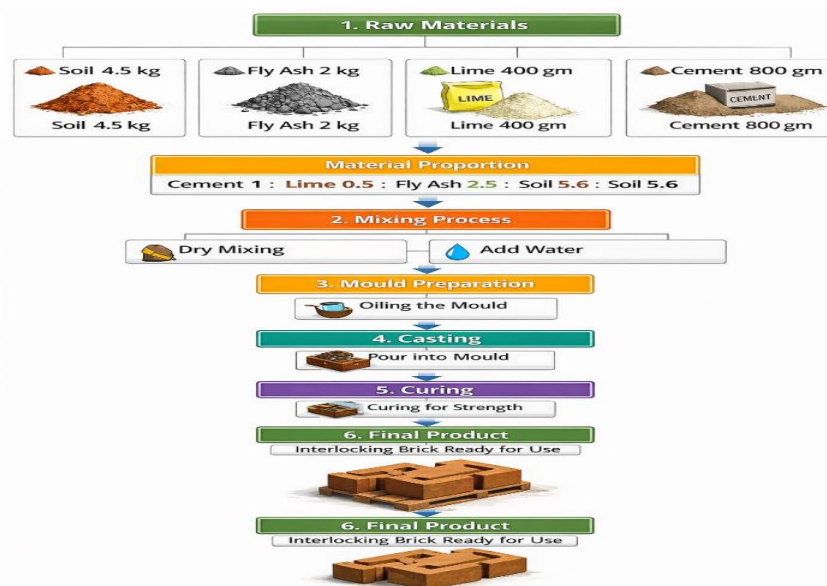


Fig.2: Manufacturing Process of Interlocking Brick

The methodology adopted for the development of interlocking bricks consists of material selection, mix preparation, moulding, curing, and testing, As shown in Fig.2

2.2. MATERIALS USED

The materials used in this study are selected based on their properties and how they help in improving the performance of interlocking bricks.

1. **Fly Ash:** Fly ash is used as the main material because it has good binding properties. When it reacts with lime and water, it helps in increasing the strength and durability of the bricks over time.
2. **Cement:** Cement is added to provide initial strength and to hold all the materials together properly. It helps in forming a strong bond between the particles.
3. **Limestone (Lime):** Lime improves the workability of the mix, making it easier to handle during moulding. It also reacts with fly ash and helps in improving the overall bonding.
4. **Soil:** Soil is used as the base material, which gives volume to the brick and supports its structure. It also helps in maintaining the shape and stability of the brick.

2.3. MIX PROPORTION

The mix proportion for preparing the interlocking bricks was decided based on the strength requirement and ease of handling of the materials. In this study, fly ash, soil, cement, and limestone were used and mixed in proper proportions to get a suitable combination.

For making ten bricks, the materials were taken as follows: fly ash – 20 kg, soil – 30 kg, cement – 7 kg, and limestone – 3 kg. These quantities were selected in such a way that the bricks can achieve good strength while also keeping the cost reasonable.

Water was then added to the dry mix to make it workable and to ensure proper mixing of all materials. Maintaining the right consistency is important so that the mix can be easily moulded and compacted, which finally affects the strength and quality of the bricks.

3. PROCEDURE

The interlocking bricks were prepared step by step as described below:

1. First, the materials such as fly ash, soil, cement, and limestone were sieved to remove unwanted particles and make the size uniform. After that, all the materials were mixed properly in the required proportion to get a uniform mix.
2. The prepared mix was then filled into interlocking brick moulds of size 10" × 6" × 4", making sure that the mould was filled evenly.
3. Compaction was done either manually or with the help of equipment to remove air gaps and to make the bricks dense and strong.
4. After allowing initial setting, the bricks were removed from the moulds after about 24 hours carefully so that their shape is not disturbed. The bricks were then kept for water curing for a period of 7 to 14 days. This helps in proper hydration and improves the bonding and strength of the bricks.
5. Water curing was continued for 7–14 days to ensure that the bricks gain sufficient strength.

3.1. TESTING PROCEDURE

After the completion of the curing period, the interlocking bricks were tested to evaluate their mechanical and durability properties. The following tests were conducted:

Compressive Strength Test: The compressive strength of the bricks was determined in accordance with IS 3495 (Part 1): 1992, using a Universal Testing Machine (UTM). The brick specimens were placed centrally in the machine, and load was applied gradually until failure occurred. The maximum load at failure was recorded, and the compressive strength was calculated by dividing the load by the loaded area of the brick. This test provides a reliable indication of the load-bearing capacity of the bricks.

Water Absorption Test: The water absorption test was carried out as per IS 3495 (Part 2): 1992, to determine the amount of water absorbed by the bricks, which indicates their porosity and durability. The dry weight of the brick was first recorded, after which the brick was immersed in water for 24 hours. The specimen was then removed, surface dried, and weighed again. The percentage of water absorption was calculated based on the increase in weight.

These tests are essential for evaluating the strength and durability performance of the developed interlocking bricks.



Fig.3: Compressive Strength Testing of Interlocking Brick Using Universal Testing Machine (UTM)

3.2. RESULTS AND DISCUSSION

Table1. Compressive Strength of Interlocking Bricks

Curing Days	Sample 1	Sample 2	Sample 3	Average (N/mm ²)
7	5.8	6.1	5.9	5.93
14	6.9	7.2	7.0	7.03
28	7.8	8.2	8.0	8.00

Table2. Water Absorption of Interlocking Bricks

Sample	Dry Weight (kg)	Wet Weight (kg)	Water Absorption (%)
1	2.5	2.8	12.0
2	2.6	2.9	11.5
3	2.55	2.85	11.8

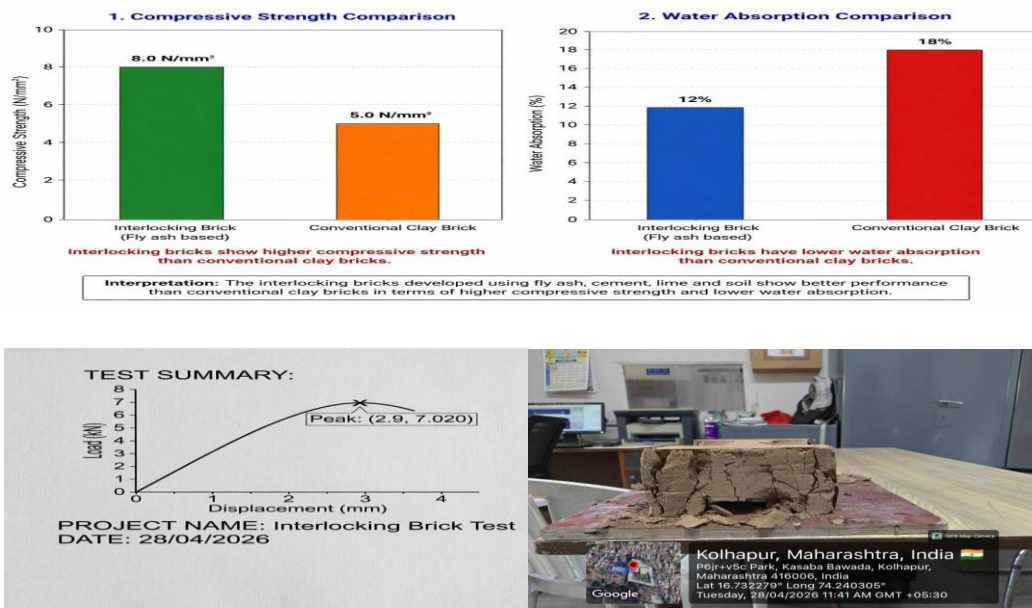


Fig.4: Graphical Comparison of Compressive Strength and Water Absorption of Interlocking and Conventional Clay Bricks

4. DISCUSSION

The compressive strength of the developed interlocking bricks is primarily influenced by the proportion of constituent materials, including fly ash, cement, soil, and limestone. The experimental results indicated that the compressive strength reached approximately 8 N/mm² at 28 days of curing, which is higher than that of conventional clay bricks. The increase in strength can be attributed to several factors. The pozzolanic reaction between fly ash, lime, and water leads to the formation of additional cementitious compounds, which enhance bonding between particles. The presence of cement and limestone further contributes to strength development by acting as effective binding agents. In addition, proper compaction during brick formation reduces internal voids and increases density, resulting in improved mechanical performance. Adequate curing plays a crucial role, as continuous hydration over time enhances the strength and durability of the bricks. However, a decrease in compressive strength may occur under certain conditions. Excessive use of fly ash or soil can reduce the binding capacity of the mix, leading to weaker bricks. Similarly, insufficient quantities of cement or lime result in poor particle bonding. Improper compaction can introduce air voids, reducing density and strength. Inadequate curing also affects the hydration process, preventing full strength development. Overall, the results highlight the importance of maintaining an optimal mix proportion, proper compaction, and sufficient curing duration to achieve desirable strength and durability in interlocking bricks.

4.1. COST ANALYSIS

Table 3. Comparative Cost Analysis of Conventional and Interlocking Bricks

Sr. No.	Cost Component	Conventional Brick (₹)	Interlocking Brick (₹)	Remarks
1	Cost per Brick	6 - 12	12 - 16	Slightly higher for interlocking
2	Mortar Cost	High	0	100% saving in interlocking
3	Labor Cost	High	Reduced (20-30%)	Less skilled labor required
4	Construction Time	More	Less (30-50% faster)	Faster construction
5	Overall Construction Cost	Moderate	Lower (30-40% reduction)	Economical in long term

The cost analysis presented in Table 4 highlights the economic feasibility of interlocking brick construction in comparison with conventional clay brick masonry. Although the initial cost per interlocking brick (₹12–16) is slightly higher than that of traditional clay bricks (₹6–12), significant savings are achieved in other aspects of construction. The elimination of mortar results in a complete reduction in mortar cost, while the simplified interlocking mechanism reduces labor requirements by approximately 20–30%. In addition, construction using interlocking bricks is faster, leading to a reduction in project duration by about 30–50%. These combined factors contribute to an overall reduction in total construction cost by approximately 30–40%. Therefore, despite the higher unit cost, interlocking bricks prove to be more economical in the long term, particularly for large-scale and low-cost housing projects.

5. CONCLUSION

In this study, lightweight interlocking bricks were prepared using fly ash, soil, cement, and limestone as construction materials. From the test results, it was observed that these bricks have good compressive strength and lower water absorption when compared to conventional clay bricks. The use of fly ash helps in improving strength due to its reaction with lime, while cement and limestone support better bonding, making the bricks strong and stable.

The interlocking feature of the bricks removes the need for mortar, which helps in faster construction and reduces both labor and material costs. Also, since the materials used are easily available locally, the overall process becomes economical and suitable for large-scale use, especially in low-cost and rural housing. Even though the cost per brick is slightly higher, the total construction cost is reduced by about 30–40%.

Proper curing for a period of 7 to 14 days is important to achieve the required strength and durability. It is also necessary to maintain the correct mix proportion, as any imbalance in materials can affect the strength of the bricks.

Overall, interlocking bricks made with fly ash, soil, cement, and limestone can be considered a good alternative to traditional bricks. They are cost-effective, easy to use, and more environmentally friendly, making them suitable for sustainable construction practices.



Fig.5: Final Product

5.1. ENVIRONMENTAL IMPACT

The use of interlocking bricks made from fly ash, soil, cement, and limestone is better for the environment when compared to traditional brick construction. Fly ash, which is an industrial waste material, is used in these bricks. This helps in reducing disposal problems and also lowers environmental pollution. At the same time, it reduces the need for natural materials like clay, which helps in protecting fertile soil.

Unlike conventional bricks, these interlocking bricks do not require kiln burning. Because of this, there is less energy consumption and lower carbon emissions. Also, since mortar is not required, the use of cement is reduced, which further decreases the overall environmental impact.

Another advantage is that most of the materials used are locally available. This reduces transportation needs, which in turn saves fuel and reduces emissions. In addition, faster construction and less material wastage also support sustainability.

Overall, interlocking bricks can be considered an ecofriendly option for construction. They help in reducing environmental impact and support sustainable building practices for future needs.

5.2. ADVANTAGES AND LIMITATIONS

The interlocking bricks made using fly ash, soil, cement, and limestone show many advantages when compared to normal clay bricks in terms of performance, cost, and environmental impact.

One of the main advantages is the use of fly ash, which is an industrial waste material. Using it in brick making helps in reducing waste and also decreases the use of natural resources like topsoil. This makes the process more environmentally friendly and supports sustainable construction.

Another important benefit is that these bricks do not require mortar because of their interlocking design. This helps in saving the cost of cement and also reduces labor work. The construction process becomes faster, which is useful for large projects and time-limited work. The bricks also show good strength due to the presence of cement and lime along with proper compaction. These materials help in better bonding, which makes the bricks strong and durable. In addition, the bricks absorb less water, which improves their resistance to moisture and increases their life.

One more advantage is that construction becomes easier because the bricks are uniform in size and fit properly with each other. This reduces the need for highly skilled workers. Also, in some cases, the bricks can be reused, which makes them useful for temporary or modular construction.

5.3. FUTURE SCOPE

The present study shows that interlocking bricks made from fly ash, soil, cement, and limestone have good potential, but there is still scope for further improvement and study.

1. The work can be extended by using other waste materials like slag, silica fume, or construction waste to make the bricks more sustainable.
2. The mix proportion can be further adjusted to achieve better strength and durability for different types of construction.
3. Use of machines for manufacturing can be increased to improve production speed and maintain uniform quality on a large scale.
4. More studies can be carried out to understand how these bricks behave in multi-storey buildings and load-bearing structures.
5. Long-term tests can be done to check durability, resistance to weather conditions, and thermal performance of the bricks.
6. Proper design guidelines and standard codes can be developed to increase acceptance of interlocking bricks in the construction field.

Overall, with improvements in material selection, production methods, and structural use, interlocking bricks can become a widely used option for sustainable construction.

6. REFERENCES

- 1) Ali, E. (2022). Dry stack masonry systems: A review. *Structures*, 38, 120–130.
- 2) Ali, M. (2021). Development of fly ash-based interlocking bricks. *Construction and Building Materials*, 245, 118–126.
- 3) Arunachalam, K. P., and Henderson, J. H. (2023). Experimental study on mechanical strength of vibrocompacted interlocking concrete blocks using image processing and microstructural analysis. *Iranian Journal of Science and Technology, Transactions of Civil Engineering*, 47, 3571–3589.
- 4) Bolong, N. (2020). Low carbon construction materials: A review. *Journal of Cleaner Production*, 258, 120–130.
- Chauhan, A. (2022). Low-cost housing using interlocking bricks. *Materials Today: Proceedings*, 52, 1450–1456.
- 5) Baneshi, V., Dehghan, S. M., and Hassanli, R. (2023). An experimental study on the behavior of interlocking masonry blocks manufactured using 3D printed mold. *Advances in Structural Engineering*, 26(2), 360–380.
- 6) Deshmukh, R. (2022). Case studies of brick construction practices. *International Journal of Civil Engineering Research*, 13(2), 89–96.
- 7) Ejaz, A. (2023). Crack resistance in interlocking brick structures. *Construction and Building Materials*, 310, 125–133.
- 8) Gupta, A. (2023). Sustainability assessment of interlocking bricks. *Journal of Cleaner Production*, 330, 129–138.
- 9) Hafeez, A. (2023). Construction efficiency of interlocking brick systems. *Engineering, Construction and Architectural Management*, 30(4), 567–580.
- Dorji, S., Derakhshan, H., Thambiratnam, D. P., and Zahra, T. (2023). Behaviour and material properties of semi-interlocking mortarless masonry. *Materials and Structures*, 56, 17.
- 10) John, V. O. (2020). Thermal performance of sustainable brick materials. *Energy and Buildings*, 210, 109–118.
- Joshi, M. (2022). Time efficiency in brick masonry construction. *International Journal of Civil Engineering*, 20(3), 455–463.
- 11) Joyklad, P., et al. (2020). Compressive strength of interlocking bricks. *Materials Today: Proceedings*, 27, 1045–1050.
- 12) Joyklad, P., et al. (2023). Strength improvement of interlocking bricks using additives. *Case Studies in Construction Materials*, 19, e01892.
- 13) Khan, K. (2022). Durability and water absorption characteristics of bricks. *Construction and Building Materials*, 280, 122–130.
- 14) Kumar, S. (2021). Use of recycled materials in sustainable bricks. *Journal of Building Engineering*, 44, 103–110.
- 15) Kulkarni, P. (2021). Adoption of interlocking bricks in India. *Indian Concrete Journal*, 95(7), 23–30.
- 16) Mehta, P. (2021). Economic benefits of alternative masonry materials. *Construction Economics and Building*, 21(2), 75–85.
- 17) Mirasa, A. K. (2020). Environmental impact of interlocking bricks. *Sustainable Materials and Technologies*, 24, e00150.
- 18) Patel, D. (2022). Comparative study of brick types for sustainable construction. *Construction and Building Materials*, 295, 123–131.
- 19) Rahman, M. (2021). Pozzolanic properties of fly ash in brick production. *Journal of Cleaner Production*, 289, 125134.
- 20) Reddy, K. (2021). Cost analysis of interlocking brick construction. *Journal of Construction Engineering and Management*, 147(6), 04021045.
- 21) Saingam, P. (2023). Mortarless construction using interlocking bricks. *Construction Innovation*, 23(1), 45–58.
- Sangthongtong, A. (2023). Performance of reinforced interlocking brick systems. *Case Studies in Construction Materials*, 18, e01789.
- 22) Sharma, P. (2021). Thermal insulation properties of ecofriendly bricks. *Journal of Building Engineering*, 35, 102–110.
- 23) Singh, R. (2022). Utilization of industrial waste in brick manufacturing. *Resources, Conservation and Recycling*, 170, 105–112.
- 24) Singh, V. (2023). Application of interlocking bricks in rural housing. *Journal of Rural Studies*, 85, 210–218.
- Waqas, H. A., Ali, M., and Rehman, K. (2023). Seismic performance of interlocking brick structures. *Structures*, 47,