Development and Performance Evaluation of Mycelium-Based Bricks for Sustainable Rural Housing

Vikas Kumar
Central University of Haryana
Akash Priyadarshee
i.akashpriyadarshee1@gmail.com

Muzaffarpur Institute of Technology
Amardeep Singh
Changzhou Institute of Technology

Research Article

Keywords: Brick, Mycelium, straw, lime, Oyster spawn, sawdust, compressive strength

Posted Date: November 25th, 2025

DOI: https://doi.org/10.21203/rs.3.rs-7894429/v1

Additional Declarations: No competing interests reported.

Abstract

In rural India, housing predominantly comprises non-engineered kutcha structures constructed with locally sourced materials such as husk, clay, and bamboo, making them sustainable and environmentally friendly. However, enhancing the quality of these materials through innovation is crucial. This study examines Mycelium bricks, an eco-friendly building material produced using Oyster mushroom spawn, rice straw, plywood sawdust, and other sustainable materials, as a cost-effective alternative to traditional cement and bricks for rural construction. Various Mycelium brick compositions, combining clay, rice straw, lime, and Oyster spawn, were evaluated. Compressive strength tests revealed that bricks consisting of 70% clay, 10% lime, and Mycelium straw (or substrate) achieve a compressive strength of 3.5 to 3.8 N/mm². These findings suggest that Mycelium bricks with this composition are not only suitable for rural house construction but also contribute to a more sustainable and eco-friendly building material option.

1. Introduction

The rapidly increasing global population has placed significant pressure on the construction industry to meet the growing demand for infrastructure and materials. Traditionally, the construction sector has relied heavily on materials like steel and concrete, both of which have considerable economic and environmental costs. These materials dominate the industry due to their structural strength and durability. Even in rural regions of countries such as India, traditional materials like bamboo, straw, and clay are increasingly being replaced by more modern materials like concrete and steel, despite the environmental consequences [1].

One of the most pressing environmental issues related to modern construction is the high carbon footprint associated with cement production. Cement, a primary component of concrete, contributes to 5–8% of global carbon dioxide emissions during its production [1]. Additionally, concrete production leads to substantial air and water pollution, exacerbated by the release of harmful particulates and the acidification of nearby ecosystems [2].

Beyond concrete, other widely used construction materials such as bricks also contribute significantly to environmental degradation. The brick industry is a well-known emitter of greenhouse gases and other pollutants [3, 4]. In rural India, houses are traditionally classified based on the materials used, with pucca houses being built from durable materials like steel and concrete, and kutcha houses from less durable materials such as mud, bamboo, and straw [5]. While durable, pucca houses come with significant environmental costs, making it essential to explore alternative materials that are both sustainable and resilient.

A promising alternative that has gained traction in recent years is the use of mycelium-bound composite (MBC) materials. Mycelium, the vegetative structure of fungi, forms a network of thread-like hyphae that bind substrate materials like wood chips, straw, and coir, creating lightweight and sustainable construction materials [6]. These materials offer multiple advantages, such as low density, natural fire resistance, and excellent thermal insulation properties [7].

One of the most notable benefits of mycelium-based composites is their ability to absorb sound, with some studies showing an acoustic absorbance of up to 75% [8]. These composites are also naturally resistant to termites and emit significantly less smoke during combustion than traditional materials, making them safer for use in residential construction [9, 10].

In addition to these benefits, research on mycelium composites for structural applications has yielded encouraging results. For example, Velasco et al. [11] demonstrated that bricks made from mushroom compost waste showed a 26% reduction in thermal conductivity compared to traditional bricks. Meanwhile, Ghosh [12] reported that mycelium-glass composite bricks exhibited improved compressive strength, making them viable for load-bearing applications. Mycelium-based construction materials are typically used for lightweight bricks or dense boards, providing both strength and environmental benefits without the carbon footprint of traditional materials [1].

However, while mycelium bricks have demonstrated potential, further research is necessary to fully optimize their mechanical properties. Current studies are exploring various admixtures, such as the inclusion of clay and lime, to improve their load-bearing capacity and durability, thereby expanding their applications in mainstream construction. This study specifically focuses on the effects of incorporating soil, clay, and lime in different proportions to evaluate the structural integrity of mycelium bricks for use in sustainable construction projects.

2. Experimental Investigation

2.1 Materials and Methods

The materials used in this study are depicted in Fig. 1, providing a comprehensive overview of the key components involved in the brick preparation process. The clay, locally sourced and shown in Fig. 1 (a), was selected for its good plasticity, crucial for effective brick formation. The physical properties and the grain size distribution is presented in Fig. 2 and Table 2. Lime, another important material (Fig. 1 (b)), was procured from a nearby commercial source, with its primary component being CaO, having a specific gravity of 3.1 and a pH level of 12.2. To maintain its effectiveness, the lime was stored in an airtight container to prevent air exposure.

Mycelium spawn, a binding agent in this study, was developed in the lab by cultivating edible mushrooms on substrates [1]. Agricultural by-products such as grain straws and sawdust, chosen for their lignocellulosic content and compatibility with fungal growth, were used as substrates.

Table 1 Physical properties of clay.

Physical Properties	Value
Specific gravity	2.57
Liquid limit	43.3
Plastic limit	19.5
Plasticity index	23.8
Optimum moisture content	18.3
Dry unit weight	18 kN/m^3
Maximum dry density	1.86 kN/m^3
Undrained cohesion	0.15 kN/m^2
Classification based on plasticity characteristics (AS PER IS)	CI

2.2 Methods

In this study, mycelium bricks were prepared using four different methods to evaluate mycelium's performance as a brick constituent. Their strength and water absorption capacity were assessed to determine their effectiveness. The different mix types used for brick preparation are detailed in Table 2. The first type of brick was prepared with mycelium substrate and sawdust. The second type was prepared with mycelium and rice straw. The third type of mycelium brick was created by mixing mycelium with clay, with clay content varying by volume: 30%, 50%, and 70%. The fourth type of brick was prepared by mixing mycelium with clay and lime, with clay content varying from 30%, 50%, and 70%, and lime content varying from 5%, 10%, and 15%. The codes used to indicate the brick types are shown in Table 2 and will be referenced in further discussions.

Table 2
Details of the mix used for preparing brick

Mix Description	Mix ID	Sub-Mix Details
Mycelium Spores + Sawdust	MSDB	Sawdust 100%
Mycelium Spores + Rice Straw	MRSB	Rice Straw
Mycelium Spores + Rice Straw + Clay (30%)	MRSCB + C30%	MRSB + Clay
	C30%+L5%	Clay 30% + Lime 5%
	C30%+L10%	Clay 30% + Lime 10%
	C30%+L15%	Clay 30% + Lime 15%
Mycelium Spores + Rice Straw + Clay (50%)	MRSCB + C50%	MRSB + Clay
	C50%+L5%	Clay 50% + Lime 5%
	C50%+L10%	Clay 50% + Lime 10%
	C50%+L15%	Clay 50% + Lime 15%
Mycelium Spores + Rice Straw + Clay (70%)	MRSCB + C70%	MRSB + Clay
	C70%+L5%	Clay 70% + Lime 5%
	C70%+L10%	Clay 70% + Lime 10%
	C70%+L15%	Clay 70% + Lime 15%

2.3 Preparation of Brick

First, mycelium was grown on a substrate to prepare the mycelium bricks. Sawdust was used as the substrate for the MSDB brick, and rice straw for the MRSB brick. The mycelium spawn of oyster mushrooms was mixed with the substrate, as shown in Fig. 3(a). Sufficient moisture was added to facilitate mycelium growth. The mix was then placed in an airtight plastic bag and kept in a dark place at 20°C for 14 days, with added sugar to improve the growth rate. After 14 days, mycelium fibers appeared as white growth (Fig. 3 (b)). The material was then placed in a mold to form bricks (Fig. 3 (c) and (d)). These were removed from the mold and dried in an oven at 100–110°C for 10–12 hours (Fig. 3 (e) and (f)), resulting in the preparation of MSDB and MRSB bricks (Fig. 3 (g)).

For MRSCB and MRSCLB bricks, the mycelium was first grown for 14 days as described. Then, for MRSCB bricks, clay was added to the mycelium-substrate mix, with clay content varied at 30%, 50%, and 70% by brick volume. For MRSCLB bricks, both clay and lime were added, with lime content varying from 5% to 15%. The clay, lime, and mycelium-substrate mix was placed in a brick mold and dried in an oven at 100–110°C for 10–12 hours (Fig. 3 (h)).

2.4 Test procedure

Compressive Strength Test: After the preparation of the bricks, the compressive strength test was conducted as per IS 3495: Part I standards [13]. The bricks were placed in a compression testing machine, and a load was applied gradually at a uniform rate until failure occurred. The maximum load at failure was recorded, and the compressive strength was calculated by dividing this load by the cross-sectional area of the brick. This test is crucial for evaluating the load-bearing capacity of the bricks and determining their suitability for structural applications.

Water Absorption Test: The water absorption test was performed in accordance with IS 3495: Part II standards [13]. Bricks were first dried in an oven at 105°C until a constant weight was achieved, then cooled to room temperature. The dried bricks were weighed (W1) and subsequently immersed in water for 24 hours. After soaking, the bricks were removed, wiped to remove surface water, and weighed again (W2). The water absorption percentage was calculated using the formula:

$$\text{Water Absorption (\%)} = ((W2 - W1) / W1) * 100$$

This test helps in assessing the durability of the bricks, particularly their ability to resist water penetration in humid or wet conditions.

Density Determination

The density of the bricks was determined by measuring their mass and volume. Each brick was weighed using a digital weighing scale to determine its mass. The volume was calculated by measuring the dimensions (length, width, and height) of the brick. The density was then calculated by dividing the mass by the volume. This test is important for evaluating the lightweight properties of the bricks and their potential for use in construction where low weight is advantageous.

SEM Analysis

Scanning Electron Microscopy (SEM) was used to study the microstructure of the mycelium bricks. The SEM analysis provided detailed images of the internal structure, revealing the distribution and bonding of mycelium fibers with clay and lime particles. This analysis helped in understanding the material's internal morphology, the presence of pores, and the effectiveness of the binding network, which are all critical for assessing the mechanical properties and potential improvements in the brick formulation.

3. RESULTS AND DISCUSSION

3.1 Performance of MSDB and MRSB

Figure 4a shows the compressive strength of MSDB and MRSB bricks. The compressive strength of MSDB bricks was found to be 0.6 MPa, and MRSB was found to be 0.4 MPa. The growth of the Mycelium depends upon the substrate [14]. Mycelium acts as a binding medium. So, the better growth of the mycelium helps in better binding capability. Due to this, a brick's compressive strength depends upon the substrate type. Ongpeng [6] has also shown that the brick prepared with mycelium grown on sawdust is stronger than that prepared with rice ban.

The water absorption behavior of MSDB and MRSB bricks is presented in Fig. 4b. For MSDB, it was around 30%, and for MRSB, it was around 35%. Both materials, sawdust and rice straw, can absorb water. Also, the structure of mycelium and substrate have space between them. Due to this, such bricks have greater water absorption behavior. Figure 4b Shows the Density of the MSDB and MRSB bricks. It can be observed that the MSDB density is 400 kg/m^3. At the same time, the MSRB density is 375 kg/m^3. Both bricks are light and can help construct a lightweight structure.

3.2 Performance of the MRSCB brick

The compressive strength of the MRSCB bricks with different clay content is presented in Fig. 5a. The result of MRSB is also presented for comparison. Clay content varied from 30% to 70%. It can be observed that the inclusion of 30% clay improves the compressive strength by around 3.5 times. More inclusion of clay, i.e., from 30% to 50%, has improved the strength of brick by more than 20%. This shows that including clay can significantly improve the load-carrying capacity of the brick. Clay content with mycelium prepares a dense matrix. Due to this reason, the strength of the brick improves.

The water absorption behavior and density of MRSCB bricks are presented in Fig. 5b. The water absorption without clay was 35%, while with 30% clay, it was 22%. Further, with the increase in the clay content, a decrease in water absorption takes place. The inclusion of clay covers the space in the matrix of the mycelium network. Also, a portion of the mycelium composite gets replaced by the clay. Due to both of these reasons, water absorption decreases. The impact of clay on the density of MRSCB brick can be observed in Fig. 5b. With the increase in the clay, the density of the brick increases. The specific gravity of clay particles is greater. The inclusion of heavy materials in a mix of mycelium and clay is the reason for improving the density of brick.

3.3 Performance of MRSCLB brick

The SEM image of the MRSCLB brick is shown in Fig. 6. The image reveals a rough and uneven surface; it indicates the presence of a heterogeneous mixture of materials. The irregular texture visible in the image indicates regions of high porosity, and soother areas reflect denser packing of particles. The presence of pores can act as a weak point and reduce both compressive and tensile strength. Mycelium fibers seem to be integrated within the brick matrix, possibly contributing to some reinforcement. The degree to which these fibers are interwoven with the particles is crucial for improving tensile strength and preventing crack propagation under stress. A denser mycelium network would enhance the overall structural integrity. The interface between the mycelium and brick particles shows a moderate degree of bonding. Stronger bonds at these interfaces would improve load transfer and increase the overall strength. The small crack on the surface is also visible. These cracks are susceptible to failure under load. This may cause the brittle behavior of brick. Enhancing the cohesion of the material through any technique may help in this regard.

The compressive strength of MRSCLB bricks with different clay content and lime content is presented from Fig. 7a to Fig. 9a. In Fig. 7a, the compressive strength of MRSCLB bricks with 30% clay content is presented. It shows that adding lime content about 5–15% improves the compressive strength of MRSB brick around 6–10 times. It can also be observed that the improvement in compressive strength due to the inclusion of lime is around 1.3 to 2.3 times that of mycelium brick mixed with clay alone. A similar type of trend can be observed for the MRSCLB brick with clay content of 50% and 70%. In all the cases of mycelium, bricks prepared with lime and clay have significant strength. So, these bricks can be used as structural members, especially for rural houses.

The water absorption behavior of the MRSCLB bricks with different lime and clay content is presented in Fig. 7b-Fig. 9b. Due to the increase in the lime content, water absorption of MRSCLB brick decreases for all clay content, i.e., 30% to 70% clay content. But the extent of the decrement is marginal. The density of mycelium brick mixed with different clay and lime content is depicted in Fig. 7b-Fig. 9b. It shows that the density increases with an increase in the lime content for all the clay content.

4. Conclusions

The performance of mycelium brick mixed with lime and clay was investigated through the evaluation of the compressive strength, water absorption capacity, and density of the brick. Based on the result, the following important conclusions were drawn.

- The incorporation of 70% clay and 10% lime in mycelium-bound bricks resulted in compressive strengths ranging from 3.5 to 3.8 N/mm². This strength is comparable to conventional non-load-bearing construction materials, indicating their potential suitability for rural housing where high load-bearing capacity is not required. The combination of clay and lime provided a dense matrix, which enhanced the binding capabilities of mycelium.
- Mycelium-based bricks present a sustainable alternative to conventional construction materials, significantly reducing the carbon footprint associated with traditional bricks. The use of locally sourced and renewable agricultural by-products such as rice straw and sawdust contributes to a circular economy, minimizing waste and reducing reliance on non-renewable resources. The production process also consumes less energy compared to fired bricks, making it an environmentally friendly option.
- The mycelium bricks exhibited a low density, approximately 400 kg/m³, which makes them suitable for lightweight construction. This property is particularly advantageous in rural areas where transportation infrastructure may be limited, as it allows for easier handling and assembly. The lightweight nature of these bricks also offers potential thermal insulation benefits, contributing to improved energy efficiency in constructed buildings.
- The inclusion of clay in the mycelium brick mix significantly reduced water absorption from 35% (in bricks without clay) to approximately 22%. This improvement in water resistance enhances the durability of the bricks, making them more suitable for use in regions with varying climatic

conditions, including areas prone to high humidity or rainfall. The reduced water absorption also helps maintain the structural integrity of the bricks over time, reducing the risk of deterioration.

Declarations

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Author contributions

Vikas Kumar- Contributed to planning and experimentation, Akash Priyadarshee- Experiment and writing of manuscript text writing, Amardeep singh- preparation of figures and manuscript text writing. All authors have reviewed the manuscript

Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Clinical Trial Regisration

Not applicable

Ethical Approval

Not applicable

Not Applicable

This article does not contain any studies involving animals human participants performed by any of the authors

Consent to Participate

Not applicable. No human participants were involved in this study.

Consent to Publish

All authors have read and approved the final version of the manuscript and consent to its publication.

Data Availability Statement

All data generated or analysed during this study are included in this published article and its supplementary information files.

References

1. A. Javadian, H. Le Ferrand, D. E. Hebel, N. Saeidi, Application of Mycelium-Bound Composite Materials in Construction Industry: A Short Review, SOJ Materials Science & Engineering 7(2) (2020) 1-9.
2. T.H. Kim, C.U. Chae, Environmental impact analysis of acidification and eutrophication due to emissions from the production of concrete, Sustainability 8(6) (2016) 578.
3. D. Freestone, The World Bank and Climate Change, The World Bank and Sustainable Development, Brill Nijhoff2013, pp. 163-185.
4. S.A. Alam, Use of biomass fuels in the brick-making industries of Sudan: Implications for deforestation and greenhouse gas emission, Helsingin yliopisto, 2006.
5. B. Das, A. Mistri, Household quality of living in Indian states: analysis of 2011 census, Environment and Urbanization Asia 4(1) (2013) 151-171.
6. J. Maximino C. Ongpeng, E. Inciong, V. Sendo, C. Soliman, A. Siggaoat, Using waste in producing bio-composite mycelium bricks, Applied Sciences 10(15) (2020) 5303.
7. F. Collet, S. Pretot, Thermal conductivity of hemp concretes: Variation with formulation, density and water content, Construction and building materials 65 (2014) 612-619.
8. M. Pelletier, G. Holt, J. Wanjura, E. Bayer, G. McIntyre, An evaluation study of mycelium based acoustic absorbers grown on agricultural by-product substrates, Industrial Crops and Products 51 (2013) 480-485.
9. M. Jones, T. Bhat, T. Huynh, E. Kandare, R. Yuen, C.H. Wang, S. John, Waste-derived low-cost mycelium composite construction materials with improved fire safety, Fire and Materials 42(7) (2018) 816-825.
10. M. Jones, A. Mautner, S. Luenco, A. Bismarck, S. John, Engineered mycelium composite construction materials from fungal biorefineries: A critical review, Materials & Design 187 (2020) 108397.
11. P.M. Velasco, M.P.M. Ortiz, M.A.M. Giro, M.C.J. Castelló, L.M. Velasco, Development of better insulation bricks by adding mushroom compost wastes, Energy and Buildings 80 (2014) 17-22.
12. T. Ghosh, Developing a composite mycelium-glass brick unit, (2019).
13. C. Bureau of Indian Standards, IS 3495,, 1992.
14. R. Sharma, R. Sumbria, Mycelium bricks and composites for sustainable construction industry: A state-of-the-art review, Innovative Infrastructure Solutions 7(5) (2022) 298.

Figures

Figure 1

Different materials used in this study

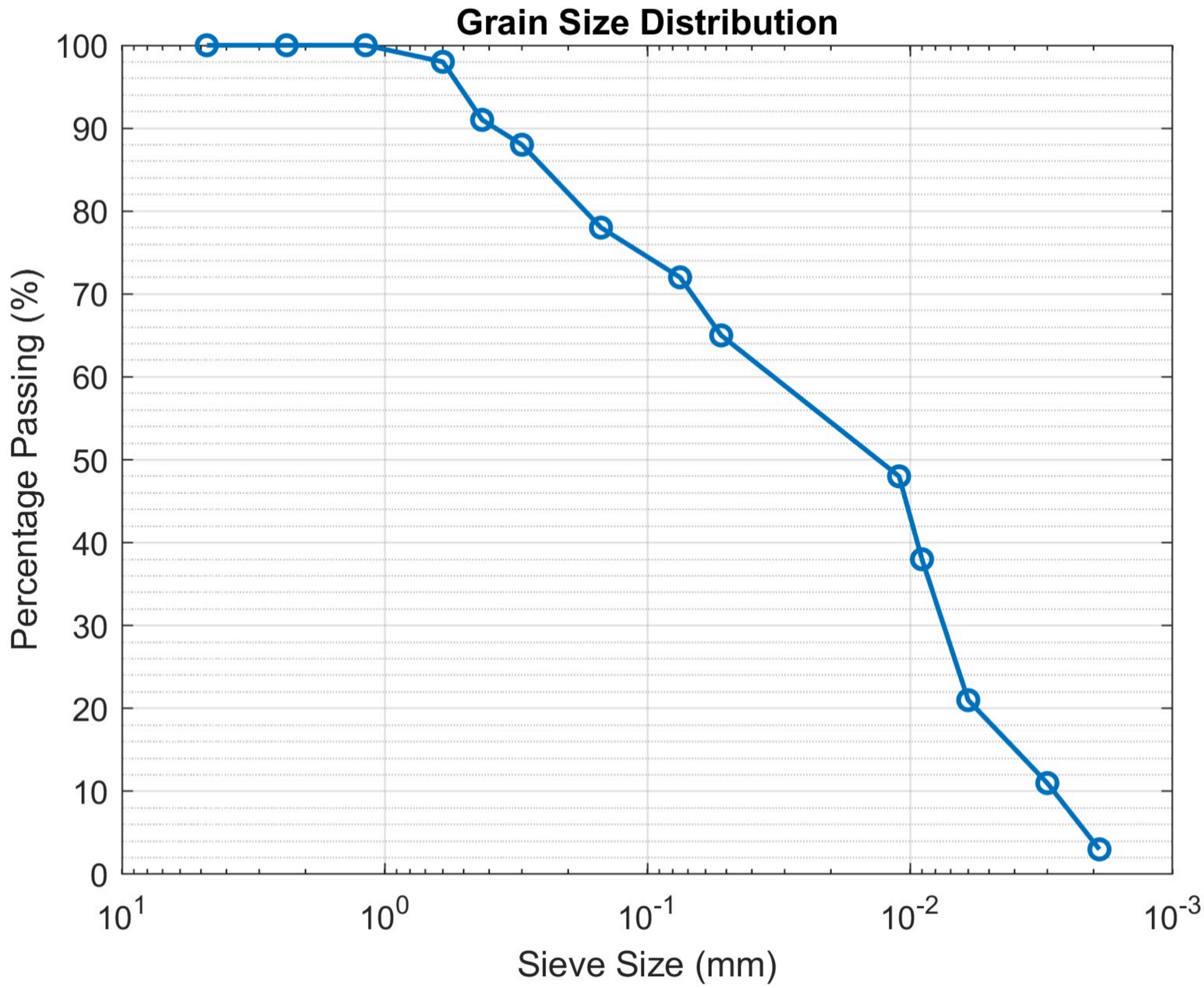
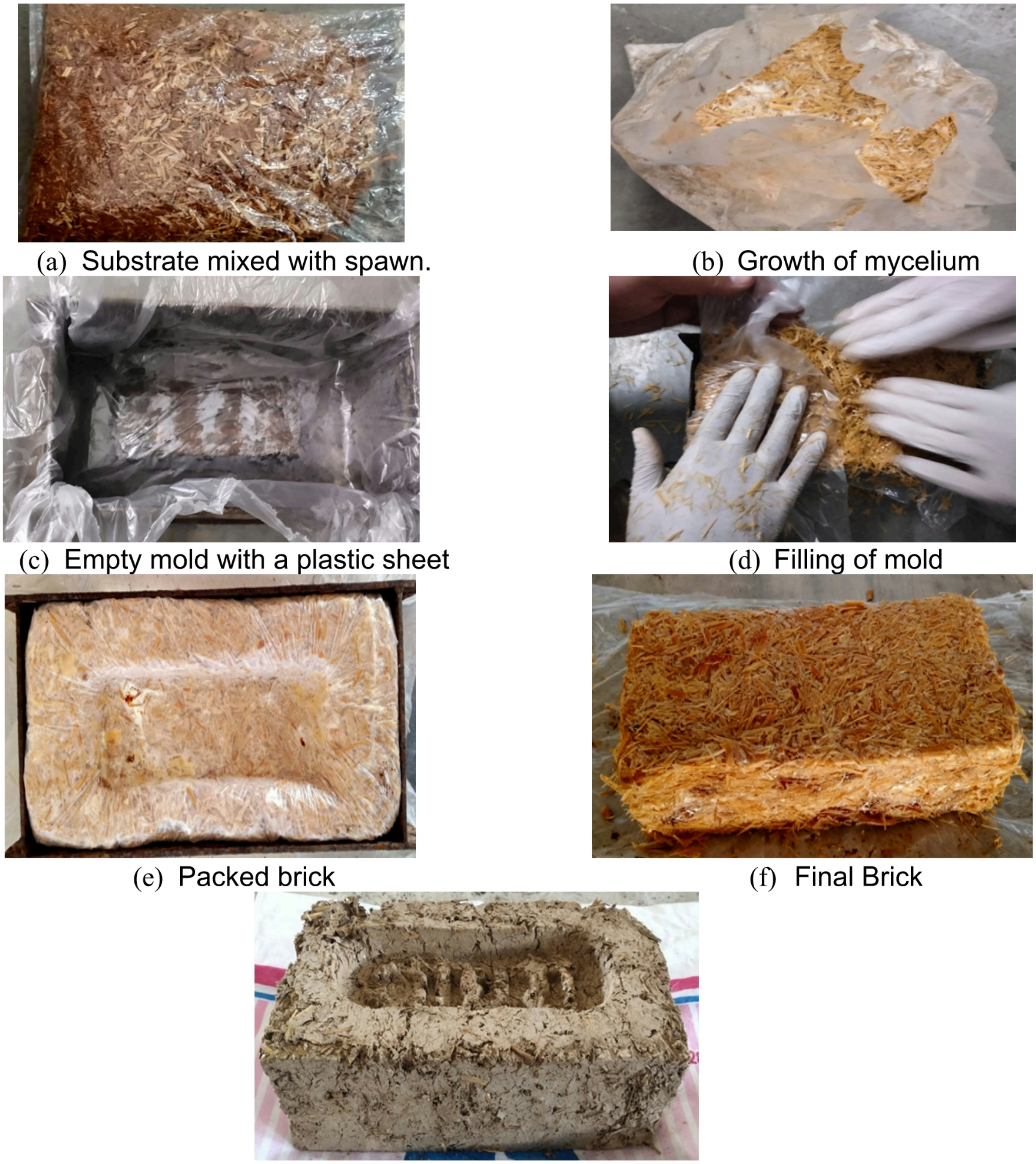


Figure 2

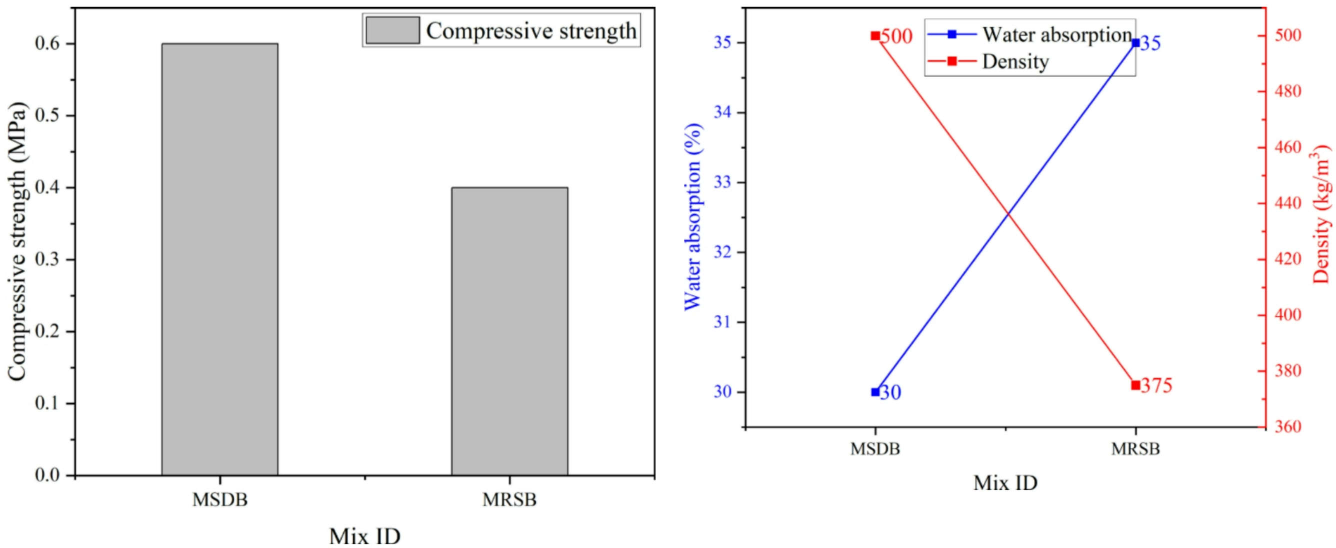
Grain size distribution of Clay



(a) Substrate mixed with spawn.
(b) Growth of mycelium
(c) Empty mold with a plastic sheet
(d) Filling of mold
(e) Packed brick
(f) Final Brick
(g) Final brick (MRSCLB)

Figure 3

Preparation brick for study

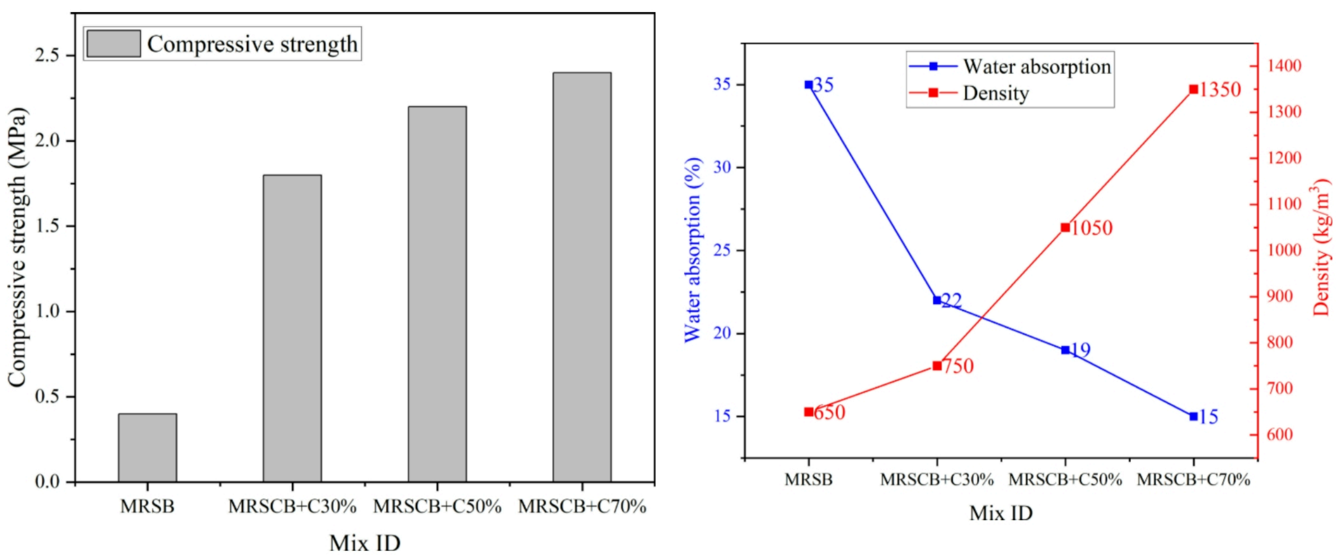


(a) Compressive strength

(b) Water absorption and density

Figure 4

MSDB and MRSB

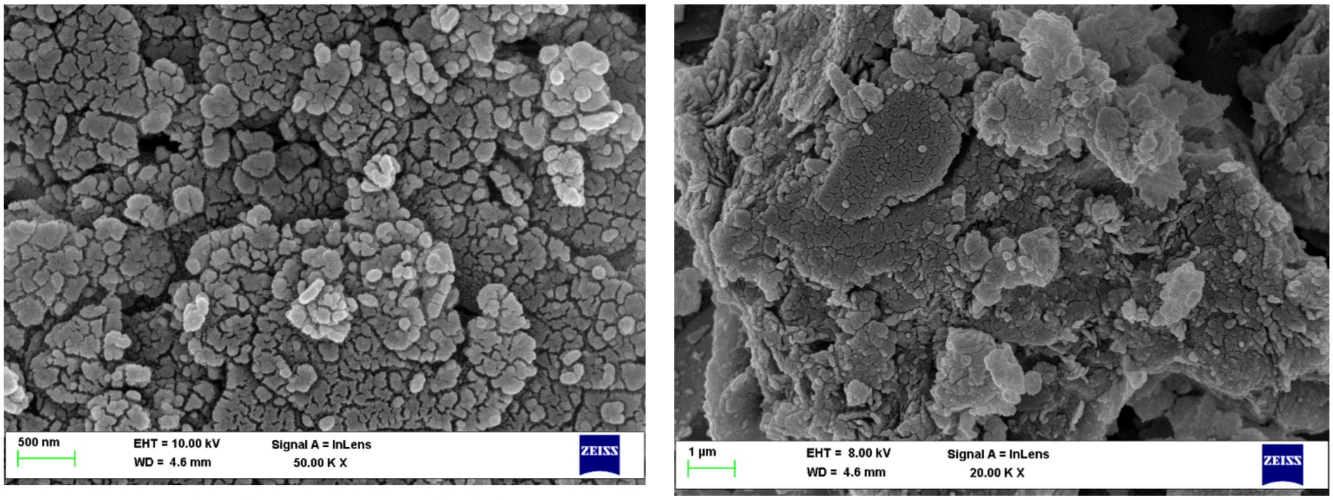


(a) Compressive strength

(b) Water absorption and Density

Figure 5

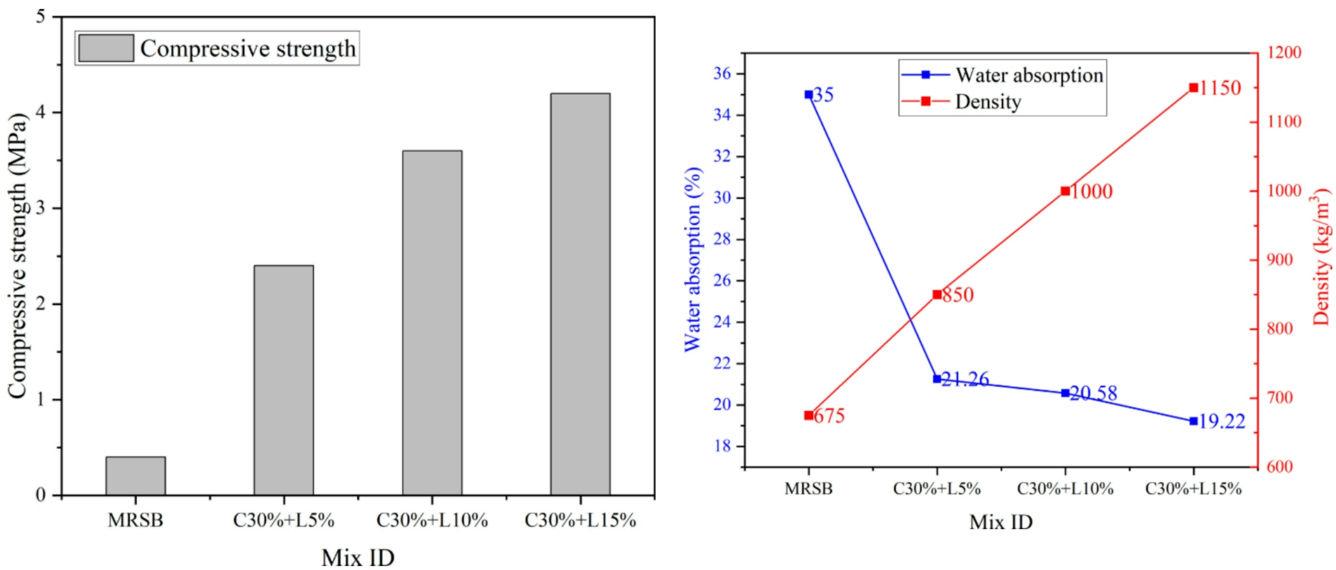
MRSCB brick with different clay content



(a) SEM image at 50 kX (b) Sem image at 20 kX

Figure 6

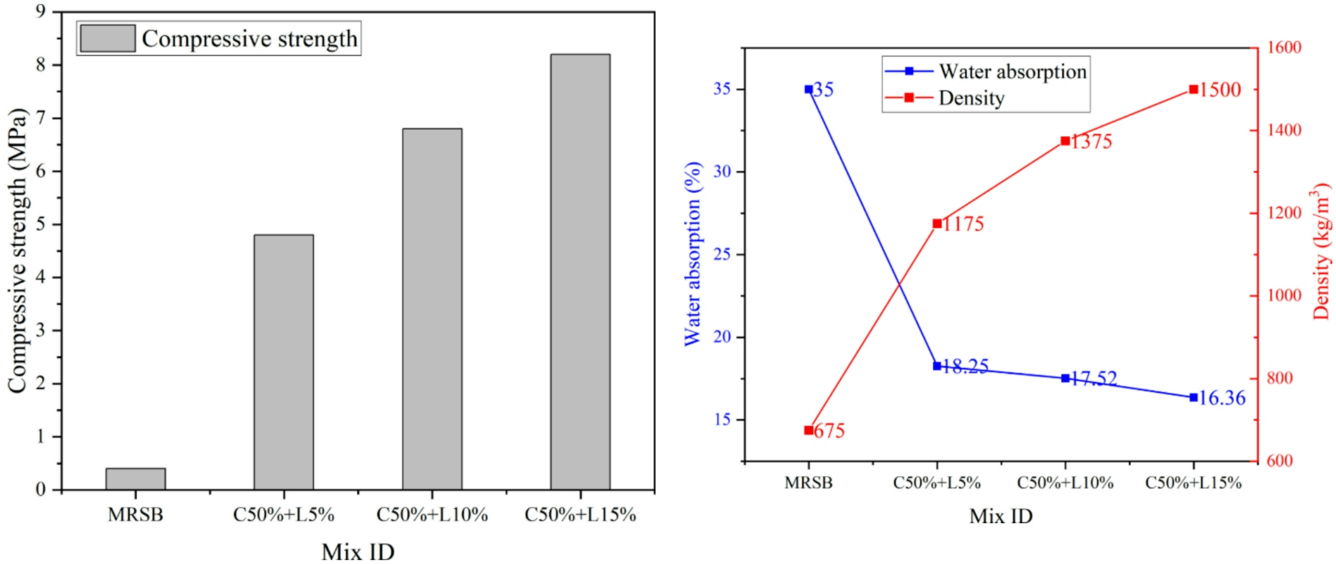
SEM image of MRSCLB brick



(a) Compressive strength (b) Water absorption and Density

Figure 7

MRSCLB brick with different 30% clay content

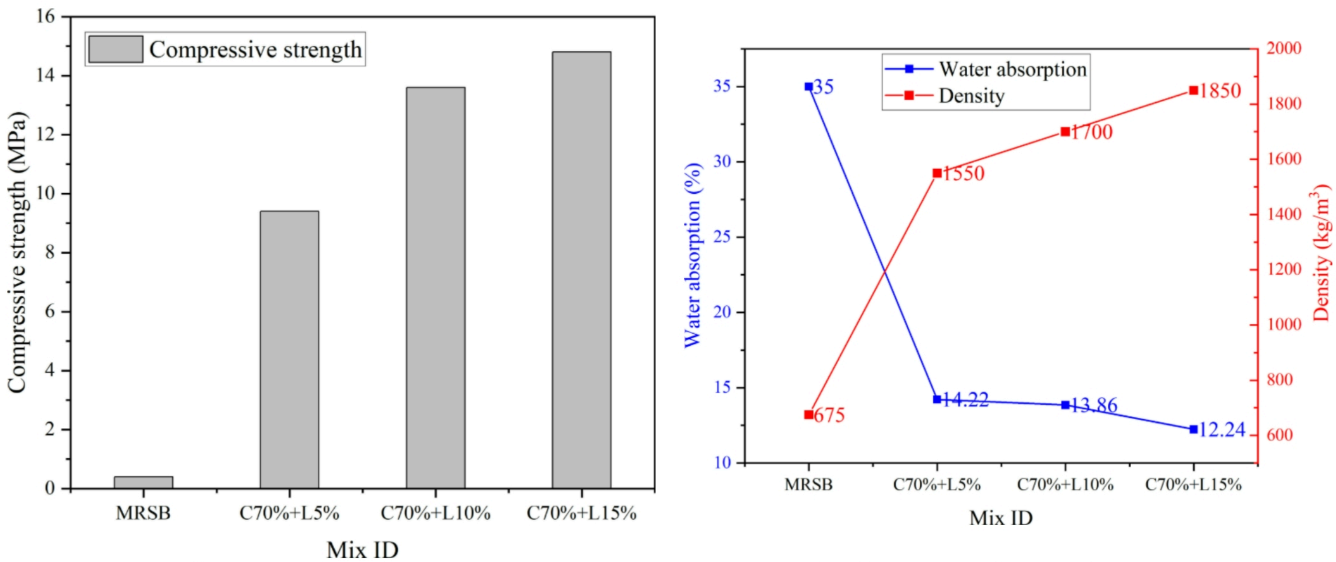


Compressive strength

Water absorption and Density

Figure 8

MRSCLB brick with different 50% clay content



Compressive strength

Water absorption and Density

Figure 9

MRSCLB brick with different 70% clay content