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Development and Performance Evaluation of Cold-Pressed Cement-Free Bricks using Detarium Senegalense Bio-Binder

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Abstract

The increased environmental footprint of Portland cement production has spurred efforts to find sustainable, bio-based alternatives for masonry. The use of *Detarium senegalense* seed powder as the sole binding material in cement-free interlocking bricks has received little attention, despite the study of other plant-derived binders. This study aims to assess the viability of producing cold-pressed, cement-free bricks using a *Detarium senegalense* bio-binder. Bricks with 10, 20, and 30 wt. % bio-binder were prepared by cold pressing and a controlled curing process. They were assessed by measuring their density, water absorption, compressive strength, failure characteristics, and scanning electron microscopy (SEM) observations. Addition of more bio-binder increased the density of the bricks, from 1386.91 ± 56.68 to 1521.49 ± 50.97 kg/m³, with enhanced particle packing. After absorption, though, the number of water molecules absorbed rose from 10.29 ± 1.90% to 16.92 ± 7.47%, with all specimens showing shape distortion post-immersion, indicating low moisture resistance. The optimum wt.% bio-binder for maximum compressive strength was obtained at 20 wt.% and the best bio-binder formulation, exhibiting the best compressive strength of 5.53 ± 0.10 MPa, was achieved. The results show that *Detarium senegalense* has remarkable potential as an alternative bio-binder to manufacture sustainable and eco-friendly cement-free interlocking bricks for non-load-bearing construction, particularly for outdoor use, where water resistance must be improved.

1. Introduction

The building and construction industry is one of the biggest sectors of the global economy that causes environmental problems, as it consumes about 35–36% of the global energy consumption and up to 38–39% of global CO_2 emissions [1], [2]. As a result of rapid urbanization and industrialization, environmental pollution has become a growing problem, where waste accumulation is a major problem that needs to be overcome by developing more environmentally friendly and sustainable construction materials [3]. Conventional concrete and cement-based materials influence climate change; concrete making is responsible for a massive amount of sand, gravel and water usage, and almost 8% of global CO_2 emissions are caused by the production of concrete [4]. The construction industry needs to move toward low-carbon materials and resource use, and materials that are environmentally friendly, in order to meet global climate targets, such as the IPCC's 1.5°C target, which calls for an 80–90% reduction in the emissions of all building-related materials by 2050 [5].

Renewable materials, such as bio-based materials and agricultural by-products, have become more prominent as an alternative sustainable material because they can reduce waste disposal problems and have lower embodied energy. The use of bio-binders, which are sourced from biomass, is a potential alternative to the traditional cementitious binders, as they require less energy, emit less CO2, and are able to reduce the amount of agro-waste sent to landfills [6], [7]. Likewise, fine sand (mainly silica dioxide SiO_2) is extensively utilized as filler in composite materials for the purposes of strengthening, stiffening, and improving thermal stability; sand, which passes through the sieve with a diameter of 250 μm, is most effective for the manufacture of construction elements with large compressive strength [6]. This has encouraged extensive, ongoing research on the use of agricultural and industrial residues in the manufacture of construction materials like sandcrete and concrete blocks to help in reducing environmental degradation, carbon emissions, and sustainable circular resource utilization [8].

This has led to innovative solutions to the use of cement-based bricks, with the use of waste materials, bio-binders, and recycled aggregates to minimize environmental impact and maximize resource use. Research has shown that plastic-infused concrete bricks with a partial replacement of fine aggregate with PET had a moderate compressive strength within ASTM limits with reduced density with increased water absorption due to an increase in porosity [4], and other study optimized the ratio of PET to LDPE for producing concrete bricks using plastic waste and sand, which also helped with waste management and sustainable construction practices [9]. Usually, conventional bricks are either stabilized using cement or lime and compacted through hydraulic pressing [10]. However, recent studies have expanded to include the use of agricultural residues and natural polymers as additives for brick modification [11], or biomass and seashell powder for creating compacted soil bricks [12], for improving the mechanical strength and microstructural properties of brick units [13]. Other research has used industrial and agricultural wastes to enhance the mechanical strength and thermal characteristics of concrete blocks [8] and geopolymer binders made from fly ash to produce environmentally friendly bricks [14]. Thermally melted plastic-sand bricks have also been found to be promising as cement-less bricks [15]. Although development has taken place, there is a lack of research that has investigated the use of bio-binders derived from plants as the only stabilizer. Based on this, the feasibility of using *Detarium senegalense* seed powder as a natural bio-binder in cement-free bricks manufactured using fine sand as raw material is assessed, and the effect of different proportions of the binder on the compressive strength and water absorption capacity is examined to determine the optimum mixing ratio for non-load-bearing masonry bricks.

The three species of *Detarium* from west tropical Africa, of which the *Detarium Senegalense* is the most commonly known. Tree reaches a height of approximately 36 m, has a highly buttressed bole and is from tropical Africa. It is highly socio-economic in West Africa and has the potential to be a part of food security. It is one of the very well-known species in the region as a nutritious and medicinal non-timber forest product. These nutritional and medicinal value from the fruit pulp and seed oil are exceptional [16].

So far, although research in the field of sustainable alternatives to cement-based construction materials has increased, most of the studies have been concentrated on the incorporation of plastic waste, industrial by-products, geopolymer binders, and modified natural additives in interlocking bricks, either as a partial replacement for the use of conventional cementitious stabilizers [4], [8], [9], [10], [14] or in combination with them. Very little research has been done on a cement-free system where the plant-derived bio-binder is the only stabiliser used, and little, if any, research has been conducted on the adhesive properties of underutilised tropical seed gums in the production of bricks. The seeds of *Detarium senegalense* are reported to be rich in polysaccharides and proteins [16], which form gel-like binding networks, but their use to bind construction materials has not been reported. This gap points toward the need for a systematic study of *Detarium senegalense* seed powder as an alternative binder that is capable of replacing the cement completely in matrices that can be made with fine sand. The novelty of this study is due to the fact that it involves the development and performance evaluation of completely cement-free bricks obtained with bio-binder *Detarium senegalense*, without any thermal or chemical treatment; and the production of bricks by cold-compaction is a very

innovative technique. This study allows for the first empirical evaluation of *Detarium senegalense* as a natural binder of clay bricks by examining the effects of different proportions of bio-binder on the compressive strength and water absorption of bricks.

2. Materials and Methods

2.1. Materials

The main granular material used was fine sand and *Detarium senealense* fruit which was purchased at Gamboru market in Maiduguri, Nigeria. The sand used was air-dried and filtered (250 μm) to eliminate oversized particles and impurities. The defatted meal of *Detarium senegalense* seeds were ground into fine powder, which passed through a 150 μm sieve. All mixing processes were done with distilled water. The testing machine (Universal testing machine) from Sharda School of Engineering and Sciences was used. The molds of 150×100×50 (mm) and 50×50×50 (mm) were designed and produced in the mechanical engineering workshop.

2.2. Chemical composition of *Detarium Senegalense* seed powder determination

The functional groups of *Detarium senegalense were* identified by FT-IR analysis, indicating the feasibility of *Detarium Senegalense* as a bio-binder. The microstructural characteristics of bricks were analysed by scanning electron microscopy (SEM)

2.3. Preparation of *Detarium senegalense* bio-binder

The bio-binder was prepared by adding *Detarium senegalense* seed powder to distilled water that was pre-heated to 80°C in a ratio of 1:1.2 (w/v) (Table 1) and stirred manually to create a paste of the seed powder with water, which is viscous. This mixture was kept for 10 min at this temperature to activate the binder, then it was cooled down for use [12].

Table 1
Bio-binder Paste Preparation

Material	Sample A	Sample B	Sample C
Detarium seed powder (g)	120	240	360
Distilled water (mL)	144	288	432

2.4. Mix Proportions

To produce brick mixtures, fine sand and *Detarium senegalense* seed powder were used as bio-binder contents of 10, 20, and 30 (wt)% of total dry mass were added. Water content was adjusted to obtain the proper stiff, moldable, and compactable properties. Three sample ratios of 90:10, 80:20, and 70:30 (%) (w/w) of fine sand to bio-binder were selected. Bricks were made with a cold-pressing method with a targeted density of 1600 kg/m3. The amount of material needed per board was calculated with the aid of Eq. 1. The weight of materials was derived from the panel target density and mold volume [17], [18], and the results are given in Table 2 below.

$$Density\ (\rho) = \frac{Mass\ (kg)}{Volume\ (m^3)} \quad (1)$$

Table 2
Sand and *Detarium senegalense* seed powder mix proportions

Material	Sample A		Sample B		Sample C	
	%	Mass (g)	%	Mass (g)	%	Mass (g)
Fine sand	90	1080	80	960	70	840
Bio-binder powder	10	120	20	240	30	360
Total dry solids	100	1200	100	1200	100	1200

2.5. Brick Production

This was done using a steel mold with internal dimensions of 150x100x50 (mm). The product release oil was evenly applied on the inner surface of the mold for easy product removal. This mold was then securely connected. Weighed fine sand was added to a mixing bowl, and prepared binder paste was then added slowly and mixed by hand to ensure a uniform distribution (Fig. 1a). All of the mixture was poured into the mold and smoothed out by hand. Hand compressed to eliminate air voids and to level the surface. The loaded mold was mounted on the hydraulic press and pressed for 30 minutes before removing the brick. The demolded bricks were laid on a nonabsorbent surface for uniform moisture loss to prevent warping [18]. The first 7 days of curing were done in humid conditions and oven-dried at 100 ℃ to facilitate the process of hydration of the binder and bonding. The specimens were then air-dried for 7 days in shaded areas (Fig. 1b).

2.6. Property testing

The standard for sampling and testing concrete masonry units called for the test of properties such as compression strength, dry density, and water absorption testing [19]. To effectively understand the influence of the organic admixture in combination with the sandcrete, the mechanical test of the solid blocks and physicochemical test of the leachate from the blocks were conducted on the samples [20]. Bricks were physically and mechanically tested

according to ASTM D1037, ASTM C109, and ASTM C140. The 150×100×50 (mm) brick and 50×50×50 (mm) cube were used to make specimens for physical and mechanical testing for compressive strength, respectively. 3 specimens were made for each test and ratio (Fig. 1b).

2.6.1. Physical property testing

2.6.1.1. Density determination

The density, water absorption, and thickness of the bricks were tested following ASTM C642 and ASTM C140 procedures [4], [10]. Using the electronic weighing balance, each brick mass was measured, and the volume was calculated using the geometry technique [20]. The standard procedure was followed to check the density by Eq. 1 [10].

$$Density\ (\rho) = \frac{Mass\ (kg)}{Volume\ (m^3)} \quad (1)$$

2.6.1.2. Water Absorption (WA) and Thickness Swelling (TS)

Evaluation of the WA and TS of the brick was done in accordance with procedures approved by ASTM C642. The different samples of bricks produced were weighed prior to immersion in distilled water for 24 h (Fig. 3a). After the agreed time, the bricks were again removed, dried on a towel, and reweighted. The mass (M_o) and thickness (T_o) of the specimens were measured, and they were placed in water at room temperature for 24 hours. The surface water was removed after the specimens were taken out of the water, and the final mass (M_1) and thickness (T_1) were measured. The outcome is expressed as percentages using equations 2 and 3 [9], [10], [13], [15], [18], [20], [21], [22], [23], [24], [25]. The bricks should not have more than 10% water absorption [26], [27].

$$WA\ (\%) = \frac{M_1 - M_0}{M_0} \times 100 \quad (2)$$

$$TS\ (\%) = \frac{T_1 - T_0}{T_0} \times 100 \quad (3)$$

2.6.2. Mechanical testing

The compressive strengths and the failure modes under compression were assessed in accordance with ASTM C39, C78, and C496, respectively.

2.6.2.1. Compressive strength ($\varvec{\delta}_{\varvec{c}}$)

The compressive strength test is the most commonly used test to check the quality of the bricks. It is often carried out to determine the load-bearing capacity when the bricks are compressed. The soil type, type of binding agent, and percentage of binding agent all have an impact on compressive strength [27]. The compressive strength determination of the sandcrete brick was done after curing in harmony with the ASTM C39/C39M standard. Compressive strength tests were carried out using the universal testing machine (Fig. 2) based on ASTM C140 [10]. At least three samples were used for each mix, and the mean value was given with the standard deviation. The compressive strength of the block was calculated after each test, using Eq. 4 [15], [20].

$$\delta_c = \frac{Force\ (N)}{Surface\ area\ (mm^2)} \quad (4)$$

2.6.3. Morphological analysis

The surface morphology and microstructural characteristics of the specimens were investigated using a Scanning Electron Microscope (SEM). The samples were prepared by coating with a thin layer of gold before imaging to improve conductivity [1], [13], [15].

2.7. Experimental design and statistical analysis

All experiments were carried out in triplicate. The results were presented as mean data ± standard deviation. The statistical analysis was carried out using the software Microsoft Excel [17], [18], [24], [28].

3. Results and Discussion

3.1. Physical properties

Table 3
Physical properties of the bricks produced with 10%, 20%, and 30% *Detarium senegalense* bio-binder.

Binder content (%)	Density (kg/m³)	WA (%)	TS (%)
10	1386.907±56.68	10.285±1.9	Shape distorted
20	1466.667 ±32.47	14.294±3.3	Shape distorted
30	1521.493±50.97	16.916±7.47	Shape distorted

Table 3 gives the density, water absorption (WA) and dimensional stability of the cement-free bricks manufactured using 10, 20 and 30 wt.% *Detarium senegalense* bio-binder. The density values of the composite materials were found to be 1386.91 ± 56.68 kg/m³ and 1521.49 ± 50.97 kg/m³ for 10 wt. % and 30 wt. % bio-binder content, respectively, showing that the higher content of bio-binder led to the formation of a denser composite. This effect is attributed to the better packing of inter-particle voids and/or better encapsulation of particles by the bio-binder, which makes the fine sand particles more densely packed. Water absorption, on the other hand, increased with increasing binder content from 10.29 ± 1.90% to 16.92 ± 7.47%. The enhanced moisture absorbency is attributed to the presence of hydroxyl rich molecular structure of polysaccharides and proteins in *Detarium senegalense* that easily attract water. Accordingly, the bricks with higher bio-binder contents absorbed more moisture after being immersed. All specimens showed visible shape distortion after 24 hours of immersion, making reliable thickness-swelling measurements impossible, but the formulation with the lowest water absorption (10 wt.%)) still showed the greatest water absorption. Based on the observations, it is understood that the bio-binder has a positive effect in promoting particle consolidation but the moisture in the binder has presented a challenge for its use in wet conditions for long-term storage. Thus, further research is needed to enhance the water resistance by surface treatment or combined bio-mineral stabilisation systems.

3.2. Mechanical properties

The mechanical response of bricks was found to be significantly affected by the concentration of bio-binder as shown by the compressive load-displacement curves (Fig. 4). All three formulations showed a linear elastic portion and subsequent plastic deformations and failure; however, the differences among the three formulations in the plastic deformations were quite large. The 10 wt. % formulation had a low resistance to compressive deformation and slow load development. The quantity of bio-binder supplied was not enough to form a uniform bond between the sand particles, causing a lack of stress transfer and early onset of cracks. The result is that the specimen experienced a relatively high maximum load, but the stress distribution in the matrix was less efficient, thereby yielding a lower compressive strength. The mechanical behaviour was significantly enhanced if the binder concentration was increased to 20 wt.%. The specimen which showed the most stable load-displacement response, able to sustain the highest load for the widest displacement range and highest compressive strength (5.53 ± 0.10 MPa). This is an improvement and shows that the bio-binder was able to create a continuous and uniform matrix that was able to distribute compressive stresses between the neighbouring sand particles efficiently. The smaller the standard deviation, the greater the uniformity and reproducibility of the specimens. A further increase in the bio-binder content to 30 wt.% further decreased the compressive strength to 4.75 ± 0.70 MPa, although the density of the bio-binder increased. Too much bio-binder may have caused localised agglomeration and shrinkage during drying, causing microstructural discontinuities that decreased the efficiency of stress transfer and increased brittle failure. These results show that there is an optimum concentration of binder beyond which further addition will be detrimental to the compressive performance.

Table 4
Compressive strength at maximum load of the brick samples

20Binder content (%)	Maximum load (kg)	Compressive strength (MPa)
10	2891.33 ± 1.9	5.106667 ± 1.2
20	2793 ± 6.1	5.533333 ± 0.1
30	2559 ± 0.9	4.746667 ± 0.7

The compressive properties of the bricks made with sand and *Detarium senegalense* as bio-binder have shown that the mechanical properties are mainly influenced by the bio-binder content of the bricks (Table 4). The 10 wt.% formulation had the highest maximum load of 2891.33 ± 1.90 kg, but resulted in a slightly lower compressive strength of 5.11 ± 1.20 MPa compared to the 20 wt.% formulation with the highest compressive strength of 5.53 ± 0.10 MPa and marginally lower maximum load of 2793.00 ± 6.10 kg. This is a signal that 20 wt.% of bio-binder gave the best interparticle bonding and stress distribution in the sand matrix, which led to better mechanical efficiency and a more uniform performance. However, the addition of more (30 wt.%) bio-binder resulted in lower values of the maximum load (2559.00 ± 0.90 kg) and the compressive strength (4.75 ± 0.70 MPa), indicating that the higher amount of the bio-binder was detrimental to the rigid sand skeleton and caused premature failure under compression. Overall, these results suggest that 20 wt.% *Detarium senegalense* bio-binder is the best option, achieving the highest load-bearing capacity and the highest compressive strength, while the strength range (4.75–5.53 MPa) obtained shows that the bricks developed are suitable for non-load-bearing and lightweight masonry applications.

The visual assessment and failure characteristics are presented in Table 5, as seen in Fig. 2.

Table 5
Visual assessment and failure characteristics

Binder content (%)	Edge integrity	Surface cracks	Failure mode under compression
10	Fair	Visible minor cracks	Progressive crushing with gradual crack propagation
20	Excellent	No visible cracks	Controlled compressive failure with the highest load-bearing capacity and ductile post-peak response
30	Good	Slight surface cracks	Brittle crushing with rapid post-peak load reduction and localized failure

Failure modes after compression testing confirm the effect of bio-binder concentration on structural integrity (Table 5). The 10 wt.% specimens failed with the appearance of surface cracks, while the crushing process was progressive, suggesting the failure resulted from the progressive propagation of surface cracks due to inadequate bonding between the particles. The 20 wt % formulation, on the other hand, retained good edge integrity with no pre-failure cracks observed and showed controlled compressive failure, attributed to controlled stress redistribution in the composite. The 30 wt. % specimens exhibited brittle crushing patterns with a fast post-peak load drop, indicating that too much organic binder led to an increase in the ease of unstable crack propagation and a loss in the rigidity of the sand skeleton. Such observations are in accordance with the mechanical results and validate that 20wt.% bio-binder gives the optimum balance of strength, ductility, and structural stability.

Table 6
Overall performance assessment

Binder content (%)	Density	Water resistance	Strength	Suitability
10	Low	Good (lowest water absorption)	Moderate	Marginal
20	Moderate	Moderate	Highest	Optimal
30	High	Poor (highest water absorption and shape distortion)	Lower than 20% (brittle failure)	Acceptable

Overall performance of cold-pressed sand bricks using different proportions of *Detarium senegalense* bio-binder contents is summarized in Table 6. The results show that the density, water resistance, and mechanical performance are significantly affected by binder concentration. The 10 wt. % formulation had the least dense and most water-resistant formulation, as it had the lowest water absorption, yet it was not sufficiently strong in compression to be used in practical applications, being suitable only slightly. The higher the bio-binder content, the higher the density and the higher the compressive strength, suggesting that the interparticle adhesion was higher and stress transfer was more efficient in the sand matrix, contributing to the improvement of water resistance. Hence, this formulation gives the best compromise between physical stability and mechanical performance and hence the optimum composition for developed bio-bricks. On the other hand, the addition of increasing amounts of binder content increased the density, but increased the water absorption, causing serious shape distortion after immersion, and reduced the compressive strength with brittle failure. The above observations indicate that when the amount of bio-binder exceeded the optimum, a hydrophilic composite structure was formed and the rigid sand skeleton was weakened, which lowered the structural efficiency. In general, the results show that 20 wt% *Detarium senegalense* bio-binder has the best compromise of moisture resistance, compression, and durability, while the increase of the binder content has an adverse effect on the durability even though it improves the densification.

3.3. Scanning Electron Microscopy (SEM) Analysis

The SEM micrographs give direct evidence of the relationship between the microstructure and mechanical performance. Inadequate matrix was observed in the 10 wt.% sample, as it had loosely packed sand particles, discontinuous binder bridges, and many voids between the particles (Fig. 5a). The relatively poor compressive performance can be attributed to such discontinuities, which reduce the adhesion at the interfaces and lead to stress concentration. The 20 wt. % (Fig. 5b) specimen had the highest and most uniform microstructure with continuous binder bridges, lower porosity, and better particle encapsulation. This small shape allowed the uniform stress distribution with loading and is in agreement with the strongest compression value from the experimental results. The 30 wt. % (Fig. 5c) sample was found to have areas of binder agglomeration, microcracks and structural discontinuities. The defects are probably related to differential shrinkage of the organic phase during the cure. The added binder raised density, but the resulting heterogeneity caused a decrease in the rigid sand skeleton and a decrease in its compressive efficiency. The good correlation between the SEM observations and the mechanical results shows that the performance of the bricks is mainly controlled by matrix continuity and also by the bonding between matrix and interfaces, and not only by the amount of binder used.

4. Engineering Implications

The results show that *Detarium senegalense* bio-binder can be used as an alternative to Portland cement for the production of non-load-bearing bricks using the cold-pressed method in a renewable and environmentally friendly manner. The desired formulation with 20 wt.% bio-binder showed the highest compressive strength, density, and structural integrity, while also reducing the carbon emissions of cement. These bricks are a potential solution for providing low-cost housing, partition walls, rural infrastructure, and temporary buildings, especially in areas where *Detarium senegalense* is locally abundant. Additionally, the cold-press manufacturing process decreases energy consumption, which decreases production cost and environmental impacts, as there is no need for firing. Based on the moisture sensitivity and dimensional instability observed, however, other stabilization methods such as hydrophobic treatments or bio-mineral hybrid binders are required before the bricks can be recommended for extended outdoor use or as structural materials.

5. Conclusions

In this study, the use of *Detarium senegalense* seed powder as a new bio-binder for bricks was successfully demonstrated, showing the feasibility of manufacturing sustainable bricks using the use of the new bio-binder. The results of the experiment indicated that the concentration of bio-binder had a significant effect on the physical, mechanical, and microstructural characteristics of the fabricated composites. As the content of bio-binder increases, the particles formed a better bond and developed a matrix up to 20 wt. % of bio-binder (maximum compressive strength and homogeneous microstructure). The balance was: The greater the amount of binder, the greater the shrinkage and agglomeration rate in the area of high binder content, causing discontinuities; the smaller the amount of binder, the less the particles would be encapsulated, and the bonding between particles and binder would be inadequate, resulting in poor compressive performance. SEM observations revealed there was a clear correlation between matrix continuity and structural performance, which was complemented by mechanical results. The results of the binder content also showed an increase in flexural deformation and energy absorption, but also a higher water affinity, so that the water resistance of the material would have to be improved in order to be used for outdoor structures. Overall, the results share the potential of *Detarium senegalense* as a natural binder in manufacturing low-carbon masonry products and scientifically support the formulation of natural and environmentally friendly masonry products without cement. Further improvement of the engineering performance might be achieved by introducing a natural water-resistant process, long-term weathering tests, and optimization of curing conditions, which would be worthy of future research.

Declarations

Data Availability Statement

The datasets generated and analysed during the current study are available from the corresponding author upon reasonable request. These datasets comprise the raw and processed experimental data, including physical, mechanical, and microstructural characterization results, necessary to support the conclusions presented in this article.

Declaration of Interests

The authors declare that there are no competing financial interests or personal relationships that could have appeared to influence this work.

Declarations of Ethics, Consent to Participate, and Consent to Publish

Ethics, consent to participate, and consent to publish declarations are not applicable.

Author Contribution

Conceptualization: All authors.Methodology: A, C and D.Formal analysis and investigation: A, C and D.Writing original draft preparation: AWriting review and editing: All authors.Visualization: ASupervision: B and D.

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Figures



Figure 1

Steps for brick production (a) Mold loading (b) Brick production

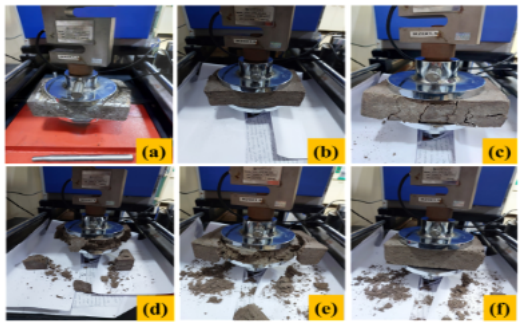


Figure 2

Brick under compressive strength testing

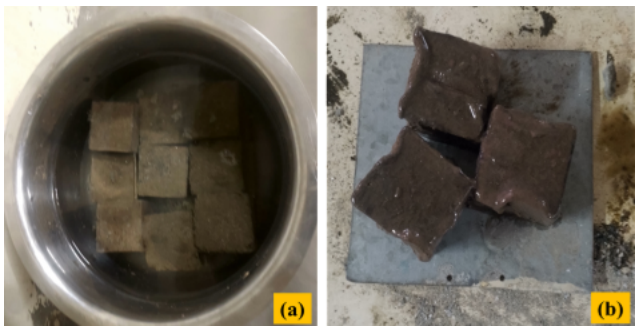


Figure 3

(a) Bricks immersed in water for 24 hours (b) Bricks removed after 24 hours

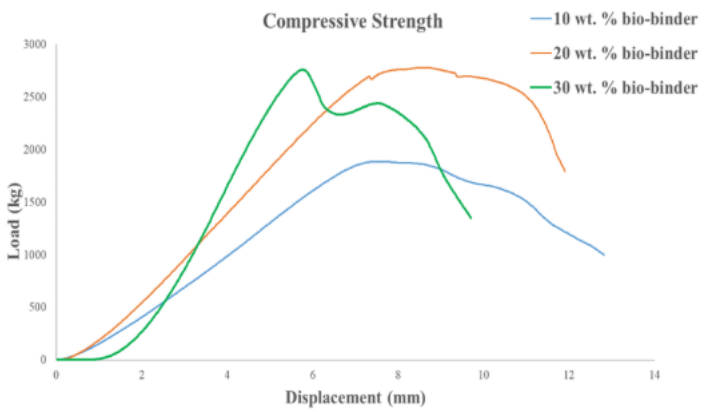


Figure 4

Load–displacement curves obtained from compressive testing

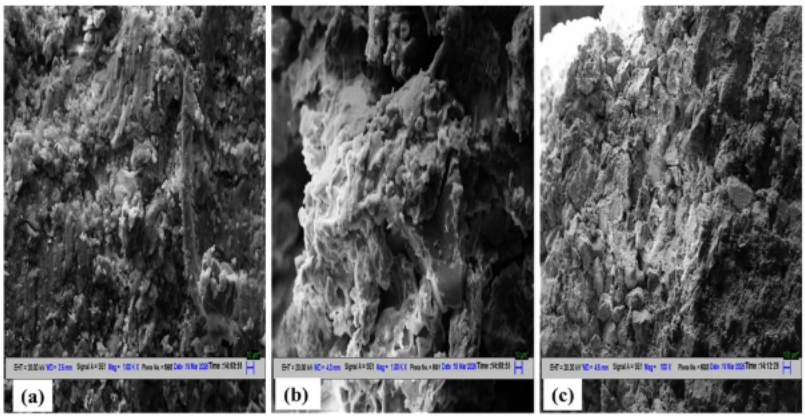


Figure 5

SEM micrographs of cement-free bricks containing (a) 10 wt.% bio-binder, (b) 20 wt.% bio-binder, and (c) 30 wt.% bio-binder.