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EXPERIMENTAL EVALUATION AND DATA-DRIVEN OPTIMIZATION FRAMEWORK FOR STABILIZED SOIL MUD BRICKS REINFORCED WITH COCONUT FIBRE, JUTE FIBRE AND COCONUT LEAF STICKS

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ABSTRACT

Soil-based masonry is attracting renewed interest because it is cheap, locally available and far less carbon-intensive than fired brick. Its weak points are well known: low durability, sensitivity to water and a tendency to crack on drying. Natural fibres are a promising remedy, and agricultural residues such as coconut coir, jute and coconut leaf midribs are available in large quantities. This study sets out an experimental programme for cement-stabilized soil mud bricks reinforced with three natural materials: coconut fibre, jute fibre and coconut leaf sticks. Existing research has examined coir and jute individually, and coconut leaflets mainly in sandy soil, but very few studies compare all three under one soil, one stabilizer and one set of laboratory conditions. That comparison is the gap this work addresses. The paper consolidates the reported behaviour of the three fibres, defines the soil characterization, mixing, casting, curing and testing procedure, and records the preliminary laboratory work completed so far. It then proposes a data-driven extension based on quadratic response-surface modelling, support vector regression (SVR), random forest (RF), extremely randomized trees (Extra Trees) and gradient boosting (GB), followed by explainable AI (SHAP/permutation importance) and multi-objective optimization. At this stage the project has no completed compressive-strength or water-absorption dataset. No numerical strength values or machine-learning accuracy figures are therefore reported, and none have been invented. Instead, the paper provides a verified experimental plan and a reproducible pathway for turning fibre-reinforced earth-brick development into a data-driven materials-design problem.

Keywords: Stabilized mud brick, Compressed stabilized earth brick, Coconut fibre, Coir, Jute fibre, Coconut leaf sticks, Natural fibre reinforcement, Compressive strength, Water absorption, Machine learning, Sustainable construction

I. INTRODUCTION

Sustainable building materials are in high demand. Locally available soil, compacted with a suitable stabilizer, can be turned into stabilized earth bricks that are easy and economical to make and, in the literature, reach strengths comparable to conventional fired bricks. Earth has

been used for building for thousands of years. Traditional systems such as cob, wattle and daub and sun-dried adobe are durable only to a limited degree, which is why improved techniques are needed. Compressed Stabilized Earth Brick (CSEB) is one of them. Soil is mixed with a stabilizer such as cement or lime at optimum moisture content and compressed by simple mechanical means. Densification and stabilization make the brick resistant to softening in water. No firing is needed, so the process is environmentally friendly, and production can employ unskilled labour.

Fibres add a second layer of improvement. Fibres in soil behave much like plant roots: they interlock with soil particles, resist tension and bridge cracks. Laboratory and field studies have supported this idea, and fibre reinforcement is now one of the most active themes in earth-block research [1]–[5]. Agricultural waste is a natural source of such fibres. The coir industry, for example, generates large volumes of fibrous waste that biodegrades slowly because of its high lignin content, and its accumulation causes environmental problems [4]. Using that waste inside soil bricks turns a disposal problem into a building material.

This project focuses on three reinforcements: coconut fibre (coir), jute fibre and coconut leaf sticks (the hard midribs of coconut leaves). The purpose is not simply to add fibre to soil. It is to compare the three reinforcements fairly, find the optimum content of each, and identify which gives the best combination of strength, water resistance and crack control.

The contribution of this manuscript is twofold: (i) a structured experimental comparison plan for three natural reinforcements in cement-stabilized soil bricks; and (ii) a modern, experimentally anchored prediction-and-optimization workflow for the dataset that the experiments will generate. The second contribution is deliberately presented as a framework rather than as a set of machine-learning results, because no completed strength dataset exists yet.

II. RESEARCH GAP AND NOVELTY

2.1 Research gap

The literature supports each fibre separately. Coir improves frictional interlocking, tensile restraint, crack bridging and residual strength, and reviews report that effective coir content commonly falls around 0.5–1.5%, depending on soil and fibre characteristics [4], [6], [19]. Jute has been studied as randomly distributed reinforcement and is recognized as an important natural fibre for geotechnical use [9], [11]–[13]. Coconut leaflets of 2.5 cm length were examined in sandy soil at 1%, 2% and 3% using triaxial shear tests, with an improvement factor of 3.3 reported at 3% reinforcement [34]. What is missing is a side-by-side study. Table 1 summarizes the position.

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Table 1. Summary of existing research and the remaining gap.

Material	Existing research	Research gap
Coconut fibre (coir)	Improves interlocking, tensile restraint, crack bridging and residual strength; effective content commonly about 0.5–1.5%	Optimum content for the soil used here must be found experimentally and compared with other natural reinforcements under identical conditions
Jute fibre	Studied as randomly distributed reinforcement; reviews identify it as an important geotechnical natural fibre	Performance in the selected soil and stabilizer system is not available for direct comparison
Coconut leaf sticks / leaflets	2.5 cm leaflets in sandy soil at 1–3% improved engineering properties in triaxial tests	Needs comparison with coir and jute for the selected soil using common engineering tests
Coir + jute + leaf sticks	Each investigated individually	Three-material comparison under one soil and one test regime is not reported: the main gap addressed here

2.2 Proposed novelty

- Direct comparison of coconut fibre, jute fibre and coconut leaf sticks in the same soil, with the same stabilizer, moulding and curing procedure.
- Determination of the optimum percentage of each reinforcement rather than reliance on values from other soils.
- Integration of standardized brick tests with a multivariable database of composition, fibre length, compaction state and curing age.
- Benchmarking of quadratic response-surface modelling against nonlinear ML models (SVR, RF, Extra Trees and GB).
- Use of explainable ML to identify which variables dominate strength and water absorption.
- Multi-objective optimization balancing strength, water absorption, cost and cement use, with independent experimental validation of the optimized brick.

III. LITERATURE EVIDENCE

Table 2 collects the main findings that guide the present design. Only findings reported by the cited authors are listed. Values apply to the specific soils and mixes of those studies and should not be transferred directly to this work.

Table 2. Summary of reported literature on stabilized and fibre-reinforced earth blocks.

Ref.	Material system	Main reported finding
[1]	Stabilized mud block masonry, cement and soil-cement mortars	Wet compressive strength of blocks and prisms is lower than dry strength; strength falls with weaker mortar
[2]	Soil with cement, lime, straw, coir and plastic fibre (11 mixes)	10% cement, 10% cement + 3% coir and 10% cement + 3% plastic fibre exceeded minimum compressive strength and water absorption limits (IS 1725)
[3]	Soil-cement-fly ash with coir	Optimum moisture content rises and maximum dry density falls as coir increases; CBR benefit declines beyond 1% coir
[4]	Lateritic blocks with coir waste; coconut and sisal fibres at 4%	Fewer visible cracks and highly ductile blocks; barley straw and other fibres gave 17–21% compressive strength improvement
[6]	Clayey subgrade soil with coir at 0.25–1%	Soaked and unsoaked CBR increased with fibre content
[7]	Mud bricks with cement (5–18%), 3% lime, 5% fly ash, 1% coconut fibre	Strength increased with curing age; Brick B reached 4.7 N/mm² and 9.6% water absorption at 28 days
[8]	Earth blocks with coir/bamboo fibre and cement	Maximum compressive strength 3.24 MPa; 15% cement with 0.75% bamboo fibre gave best overall performance
[9]	Glass, polypropylene, banana and jute fibres in soil blocks	All fibres improved strength, durability and crack resistance; jute performed best and was economical
[10]	Natural agricultural-waste fibres at 0.25–1%	Fibre type and content change block properties; two soils and three fibres studied
[11]	Jute fibre with lime-stabilized mud blocks	8–10% lime gave best compressive and flexural strength with low water absorption
[12], [13]	Jute in compressed earth bricks and composites	Jute improved compressive performance; fibre aspect ratio and test conditions matter
[14]	Coconut fibre (about 15 mm) in cement-stabilized rammed earth	Improved toughness and ductility and helped control cracking
[15]	Sisal fibre with cement	Best result at 10% cement and 1% sisal fibre after 28 days
[16]	Areca, coir and flax fibres, with and without cement	Coir improved mechanical performance; small cement content improved erosion resistance, shrinkage and absorption
[18]	Date-palm fibres, treated and untreated, in lime-stabilized blocks	Effect of fibre treatment on strength, density and thermal behaviour compared
[19]	Review of natural-fibre-reinforced compressed earth blocks	Strength, water sensitivity, durability, fibre treatment and standardization identified as key research areas

Several consistent messages emerge. Moderate fibre contents, typically around 0.5–1.5% by weight, tend to help; beyond that, workability, density and sometimes strength decline [3], [6]. Cement or lime remains important for water resistance [2], [11], [16]. And curing age matters, with strength gain reported between 7 and 28 days [7], [8].

IV. MATERIALS AND FIBRE CHARACTERISTICS

The materials are locally available soil, Portland Pozzolana Cement (PPC, 43 grade) as stabilizer, potable water, and three reinforcements: coconut fibre, jute fibre (obtained from

gunny bag material) and coconut leaf sticks. The soil will be characterized before mixing so that its classification and compaction behaviour are known.

Table 3. Reported properties of the reinforcement materials.

Property	Coconut fibre (coir)	Jute fibre	Coconut leaf sticks
Tensile strength	About 10–20 MPa	About 200–800 MPa	Not quantified in the source; to be measured or taken from literature
Density	1.15–1.46 g/cm³	About 1.3–1.5 g/cm³	Light relative to mineral reinforcement
Elongation at break	15–40%	About 1–3%	Not quantified
Water absorption	About 131–180% of dry weight	Hydrophilic; swells when wet	Hydrophilic; some swelling expected
Young's modulus	Not quantified	About 10–30 GPa	Not quantified
Behaviour in soil	Crack bridging, shrinkage control, ductility	High tensile resistance, friction with soil	Crack bridging when processed to small pieces

The contrast in Table 3 is worth noting. Jute is much stronger and stiffer in tension but breaks at small strain, whereas coir is weaker but far more extensible. This suggests the two will act differently once a brick cracks, and it is one reason the comparison is worth running.

4.1 Durability considerations

Durability of a stabilized soil brick means its ability to withstand moisture, rain and temperature changes without losing strength. The main factors are the stabilizer, water absorption (which should be low), erosion resistance and resistance to wet–dry cycles. All three fibres are plant-based and hydrophilic. They swell when wet and shrink when dry, which can disturb the fibre–soil bond over repeated cycles. They are also biodegradable, which is environmentally attractive but a potential long-term concern in continuously wet conditions. Fibres can reduce surface cracking, distribute stress and bridge micro-cracks, so net durability depends on how these effects balance. Wet–dry cycle testing is therefore recommended for the best-performing mixes.

V. EXPERIMENTAL METHODOLOGY

The process runs from material selection and collection, through laboratory testing and data analysis, to brick preparation, brick testing and analysis of results. Collected materials are tested against standard requirements. Each mix will be cast in at least three trials and tested after curing.

5.1 Workflow

1. Collect soil, PPC, coconut fibre, jute fibre and coconut leaf sticks.
2. Clean and dry the fibres, then cut them to selected lengths.

3. Characterize the soil: sieve analysis, moisture content, liquid limit and compaction (water content–dry density relation as per IS 2720 Part 7 [27]).
4. Mix soil, cement and fibre uniformly at the chosen percentages and at optimum moisture content.
5. Mould and compact the bricks, using a manual rammer or block press.
6. Cure under controlled conditions with proper water supply.
7. Test cured bricks and compare with a conventional burnt brick and with IS 1725 requirements [28].

5.2 Recommended experimental matrix

The fibre contents below are proposed starting levels informed by the 0.25–1.5% range commonly reported [3], [6], [10], [19]. They are to be confirmed by the project team and guide before casting.

Table 4. Proposed experimental variables.

Variable	Proposed levels / representation	Role
Fibre type	Coconut fibre, jute fibre, coconut leaf sticks, plus control with no fibre	Reinforcement type
Fibre content	At least 4 levels by dry weight of soil (for example 0.5, 1.0, 1.5, 2.0%)	Reinforcement dosage
Fibre length	At least 2 levels, held constant within a series	Aspect ratio
Cement (PPC 43)	One fixed dosage after trial mixes (literature range about 8–15%)	Stabilization
Moisture content	Optimum from compaction test	Densification
Curing age	7, 14 and 28 days	Strength development
Replicates	At least 3 bricks per mix and age	Repeatability and uncertainty

5.3 Tests on bricks

Table 5. Test programme.

Property	Test	Purpose
Compressive strength	Compression Testing Machine on cured bricks, dry and wet	Primary performance measure; wet strength is typically lower [1]
Water absorption	Weight gain after immersion	Indicator of durability [2]
Density	Mass and volume of dry bricks	Effect of fibre on unit weight
Shrinkage / cracking	Visual and dimensional observation after drying	Crack-control benefit of fibre
Wet–dry cycles	Repeated wetting and drying of selected mixes	Long-term durability
Comparison	Conventional burnt brick under the same tests	Benchmark

Facilities required are an Atterberg liquid limit apparatus with grooving tool, a sieve set, moisture content apparatus, mixing area, brick moulds, compaction equipment (manual

rammer or block press), a curing area with water supply, a weighing balance, a Compression Testing Machine, a drying oven or space, and storage for raw materials. These are available in the institute laboratory.

VI. PRESENT STATUS OF THE PROJECT

Preliminary laboratory work has begun. The project record documents soil samples prepared for testing, sieve analysis, a liquid limit test, weighing of samples, and trial mixing and casting of bricks with fibre, including cement-marked bricks. These are preparatory activities. They are not yet a dataset: no compressive strength, water absorption or optimum fibre content has been established. Results from these tests will be added to this manuscript as they are completed.

The objectives of the proposed work are:

- To characterize the selected soil and determine its basic engineering properties.
- To stabilize the soil using coconut fibre, jute fibre and coconut leaf sticks.
- To study the effect of different fibre percentages on soil strength and compaction properties.
- To determine the optimum percentage of each natural reinforcement.
- To compare the performance of the three reinforcement materials.
- To identify a sustainable and effective natural-fibre reinforcement for civil engineering applications.

VII. MODERN PREDICTION METHODOLOGY

Once brick tests are complete, performance can be treated as a nonlinear function of composition and processing. The candidate input vector is X = [fibre type, fibre content, fibre length, cement content, moisture content, dry density, curing age]. The target y may be compressive strength (dry or wet), water absorption or a combined durability index.

7.1 Quadratic response-surface model. $y = \beta_0 + \Sigma\beta_i x_i + \Sigma\beta_{ii} x_i^2 + \Sigma\beta_{ij} x_i x_j + \varepsilon$. It captures curvature and interactions, gives an interpretable baseline and can locate the optimum fibre content directly.

7.2 Support Vector Regression (SVR). Suited to small-to-medium nonlinear datasets. An RBF kernel is recommended. Hyperparameters C, γ and ε should be tuned inside training folds only, to avoid information leakage.

7.3 Random Forest (RF). An ensemble of randomized decision trees whose predictions are averaged. It handles nonlinearity and interaction without a predefined functional form and supplies permutation-based variable importance.

7.4 Extra Trees. Adds further randomization in tree construction and should be benchmarked against RF on identical cross-validation splits.

7.5 Gradient Boosting (GB). Adds weak learners sequentially to reduce residual error. Strong on structured engineering data, but it must be carefully regularized because small experimental datasets overfit easily.

7.6 Explainable AI. SHAP values or permutation importance should show which variables drive strength and absorption. Partial-dependence plots can then show how fibre content, length and curing age shape the predicted response. For design purposes this is more useful than reporting R^2 alone.

7.7 Optimization. After validation, Bayesian optimization or an evolutionary algorithm such as NSGA-II can search for mixes that maximize compressive strength while minimizing water absorption, cement content and cost. Candidate optima must be cast and tested before being claimed.

VIII. MODEL VALIDATION PROTOCOL

The main methodological risk is overfitting. A meaningful train/test split is only possible after the experimental matrix has produced enough observations. Recommended practice:

- Reserve an independent test set before model tuning; do not use it for feature selection or hyperparameter optimization.
- Use repeated k-fold cross-validation on training data, with k chosen according to final sample size.
- Scale predictors for SVR inside each training fold only; tree models need no scaling.
- Use nested cross-validation for tuning when the dataset remains small.
- Report prediction intervals or bootstrap uncertainty, not only point predictions.
- Compare every ML model with the quadratic response-surface baseline.
- Use parity plots, residual plots and error-versus-fibre-content plots.
- Validate the final optimum with new bricks not used in model fitting.

Table 6. Evaluation metrics.

Metric	Expression / interpretation
R^2	$1 - SSE/SST$; goodness of fit, but not sufficient alone
RMSE	Square root of mean squared error; penalizes larger errors
MAE	Mean absolute error; directly interpretable average error
MAPE	Mean absolute percentage error; use cautiously near zero responses
Residual analysis	Checks systematic bias, heteroscedasticity and model inadequacy

IX. PROPOSED DATABASE ARCHITECTURE

Each row should correspond to one tested brick, keeping raw observations rather than only averages.

Table 7. Proposed database fields.

Field	Example / requirement
Specimen ID	Unique identifier
Fibre type	Coir / jute / leaf stick / none
Fibre content	Measured % by dry weight of soil
Fibre length	Measured mm
Cement content	Measured %
Moisture content	Measured % at casting
Dry density	Measured kg/m³
Curing age	7 / 14 / 28 days
Dry compressive strength	Measured MPa
Wet compressive strength	Measured MPa
Water absorption	Measured %
Replicate number	At least 1–3
Observations	Cracking, shrinkage, failure mode

X. DISCUSSION AND ENGINEERING SIGNIFICANCE

The approach links three needs at once: low-cost housing material, use of agricultural waste, and lower environmental load. Stabilized soil bricks avoid firing, so carbon emissions are lower than for burnt brick, and cement use can be moderated if fibres share the work of controlling cracks. Local availability of soil and fibre also reduces transport and supports rural and affordable housing, toilets and government buildings where CSEB is already used.

Two cautions apply. First, benefits reported elsewhere depend strongly on soil type, cement content and fibre dimensions, so the present soil must be tested in its own right; the numbers in Table 2 are guides, not predictions. Second, plant fibres are biodegradable and hydrophilic. A brick that is strong at 28 days may behave differently after many wet–dry cycles, which is why durability testing is part of the plan and not an optional extra.

A techno-economic comparison should follow once strengths are known, covering cement, fibre preparation, labour, curing and transport.

XI. CONCLUSIONS

This manuscript defines a comparative programme for cement-stabilized soil mud bricks reinforced with coconut fibre, jute fibre and coconut leaf sticks. The literature supports each fibre individually, but a three-way comparison in one soil is missing, and that is what the project

will provide. Preliminary laboratory work is under way. No strength, absorption or optimum-content results are claimed at this stage.

The next stage is to complete soil characterization, cast the matrix in Table 4, test at 7, 14 and 28 days, and determine the optimum content of each fibre. The resulting dataset can then be used to benchmark SVR, RF, Extra Trees and gradient boosting against quadratic response-surface modelling, with SHAP-based interpretation and multi-objective optimization. Only results supported by measured data should enter the final manuscript.

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XIII. REFERENCES

1. S. Vimala and K. Kumarasamy, "Studies on the strength of stabilized mud block masonry using different mortar proportions," Int. J. Emerging Technology and Advanced Engineering, vol. 4, no. 4, Apr. 2014.
2. V. Prakash and A. Raj, "Studies on stabilized mud block as a construction material," Int. J. Innovative Research in Advanced Engineering (IJIRAE), vol. 3, no. 1, Jan. 2016.
3. E. M. Gooding, "Soil testing for soil cement block preparation," DTU Working Paper No. 38, 1993.
4. M. G. Sreekumar and D. G. Nair, "Stabilized lateritic blocks reinforced with fibrous coir wastes."
5. E. A. Adam and A. R. A. Agib, evaluation of natural cellulose coir fibres for soil reinforcement.
6. R. R. Singh and S. Mittal, "Improvement of local subgrade soil for road construction by the use of coconut coir fiber," Int. J. Research in Engineering and Technology (IJRET).
7. A. Adsul, A. Bhagat and S. Borude, "Experimental study on behaviour of stabilized mud brick," Int. J. Research Publication and Reviews, vol. 6, no. 6, pp. 3871–3875, Jun. 2025.
8. Narayan, R. Rahul, Maharaj and Sumesh, study on eco-friendly earth blocks with coir and bamboo fibres and cement.
9. E. R. Sujatha and S. S. Devi, study on soil blocks reinforced with glass, polypropylene, banana and jute fibres, SASTRA University, Thanjavur.
10. H. Danso, D. B. Martinson, M. Ali and J. B. Williams, study on natural agricultural-waste fibres in soil building blocks.

11. Y. Nidhish, N. Muralidhar, K. Nandan Patel, D. C. Harish and S. Supreeth, study on jute-fibre-reinforced, lime-stabilized mud blocks.
12. Saleem, Abbas and Haider, "Jute fibre as reinforcement in compressed earth bricks," 2016.
13. M. Ali, J. A. Cottrell, B. Martinson and D. Lavorato, study on compressed earth composites reinforced with jute fibres.
14. Raj et al., "Coconut fibre reinforced cement-stabilized rammed earth blocks," 2017.
15. T. E. Alene, T. A. Mohammed and A. G. Gualu, study on sisal fibre and cement in traditional mud blocks.
16. E. R. Sujatha, S. Mahalakshmi and G. Kannan, "Potential of fibre reinforced and cement stabilized fibre reinforced soil blocks as sustainable building units," J. Building Engineering, vol. 78, Art. 107733, 2023, doi: 10.1016/j.jobe.2023.107733.
17. A. T. Latha, B. Murugesan and B. S. Thomas, "Compressed earth block reinforced with sisal fiber and stabilized with cement: Manual compaction procedure and influence of addition on mechanical properties," Materials Today: Proceedings, 2023, doi: 10.1016/j.matpr.2023.04.373.
18. B. Taallah and A. Guettala, "The mechanical and physical properties of compressed earth block stabilized with lime and filled with untreated and alkali-treated date palm fibers," Construction and Building Materials, vol. 104, pp. 52–62, 2016, doi: 10.1016/j.conbuildmat.2015.12.007.
19. S. Riffi, E. Ghorbel, F. Schmidt and F. Cuccagna, "Review of natural fiber-reinforced compressed earth blocks: Toward enhanced performance and environmental sustainability," Journal of Natural Fibers, vol. 23, no. 1, Art. 2619017, 2026, doi: 10.1080/15440478.2026.2619017.
20. B. Hanifi, A. Orhan, N. B. Mehmet, A. Erhan and K. Selim, "Thermal isolation and mechanical properties of fiber reinforced mud blocks as wall material," Construction and Building Materials, vol. 21, pp. 901–906, 2007.
21. D. Savita and V. Preeti, "The effect of surface modification on the water absorption behavior of coir fibers," Advances in Applied Science Research, vol. 3, pp. 1463–1465, 2012.
22. P. J. Walker, "Strength, durability and shrinkage characteristics of cement stabilised soil blocks," Cement and Concrete Composites, vol. 17, pp. 301–310, 1995.
23. G. Khosrow, R. D. T. Filho and N. P. Barbosa, "Behaviour of composite soil reinforced with natural fibers," Cement and Concrete Composites, vol. 21, pp. 39–48, 1999.
24. M. Bouhicha, F. Aouissi and S. Kenai, "Performance of composite soil reinforced with barley straw," Cement and Concrete Composites, vol. 27, pp. 617–621, 2005.

25. B. Hanifi, A. Orhan and S. Tahir, "Investigation of fiber reinforced mud brick as a building material," Construction and Building Materials, vol. 19, pp. 313–318, 2008.
26. B. V. V. Reddy and G. Ajay, "Strength and elastic properties of stabilized mud block masonry using cement-soil mortars," J. Materials in Civil Engineering, ASCE, pp. 472–476, 2006.
27. IS 2720 (Part VII): 1980 (Reaffirmed 1997), Methods of test for soils: Determination of water content–dry density relation using light compaction, Bureau of Indian Standards, New Delhi.
28. IS 1725: 1982 (Reaffirmed 1997), Specification for soil based blocks used in general building construction (first revision), Bureau of Indian Standards, New Delhi.
29. M. Mostafa and N. Uddin, "Experimental analysis of compressed earth block (CEB) with banana fibers resisting flexural and compression forces," Case Studies in Construction Materials, vol. 5, pp. 53–63, 2016, doi: 10.1016/j.cscm.2016.07.001.
30. H. Danso, "Improving water resistance of compressed earth blocks enhanced with different natural fibres," The Open Construction and Building Technology Journal, vol. 11, pp. 433–440, 2017, doi: 10.2174/1874836801711010433.
31. A. B. Laibi, P. Poullain, N. Leklou and M. Gomina, "Influence of the kenaf fiber length on the mechanical and thermal properties of compressed earth blocks (CEB)," KSCE Journal of Civil Engineering, vol. 22, no. 2, pp. 785–793, 2018, doi: 10.1007/s12205-017-1968-9.
32. C. Turco, A. C. Paula Junior, E. R. Teixeira and R. Mateus, "Optimisation of compressed earth blocks (CEBs) using natural origin materials: A systematic literature review," Construction and Building Materials, vol. 309, Art. 125140, 2021, doi: 10.1016/j.conbuildmat.2021.125140.
33. A. A. Velasco-Aquino et al., "Compressed earth block reinforced with coconut fibers and stabilized with aloe vera and lime," J. Engineering, Design and Technology, vol. 19, no. 3, pp. 795–807, 2021, doi: 10.1108/JEDT-02-2020-0055.
34. Jishnu, Sankar and Chandrakaran, study on coconut leaflets as reinforcement in sandy soil.