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Sustainable Biobrick: Experimental Study and Numerical Analysis with ANSYS

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Abstract

Sustainable bio brick is an innovative and eco-friendly building material developed to replace conventional clay bricks that require high energy and natural resources for production. The bio brick is composed of cow dung ash powder (5%-15%), laterite soil (75%-100%), lime powder (5%), and coconut coir fiber (5%), each serving a specific purpose: cow dung ash functions as a natural binder and enhances insulation; laterite soil imparts strength and durability; lime improves water resistance; and coir fibers contribute to tensile strength while minimizing cracks.

In this study, we aim to prepare bio bricks with varying mix proportions and analyse their mechanical and physical properties, including compressive strength, tensile strength, water absorption, and efflorescence test. The bricks are fabricated using mechanical compaction and subjected to natural curing. Experimental test result (Compressive strength) are then validated through numerical simulation using ANSYS software to establish correlation and reliability.

This study seeks to determine the optimal mix design that ensures maximum strength, durability, and sustainability. By effectively utilizing agricultural and organic waste materials, the bio brick presents a green, low-cost, and energy-efficient alternative for future construction practices, promoting environmental conservation and sustainable development.Experimental result of compressive strength of brick from CTM machine is validated through using ANSYS software. Also another common test on brick such as tensile strength, water absorption test, efflorescence test has been conducted to provide a deeper understanding of the bio brick's overall performance. All tests and evaluations will be carried out in accordance with the standards specified in IS 1077:1992 & IS 3495 (Part 1,2 & 3) for common burnt clay building bricks.

Keywords: Bio-brick, ANSYS Simulation, Finite element analaysis, Coconut coir fibre.

1. Introduction

In recent years, the construction industry has been exploring sustainable and eco-friendly alternatives to conventional building materials to reduce environmental impact and promote resource efficiency. Among these innovations, bio bricks have emerged as a promising solution for sustainable construction. Bio bricks are environmentally friendly masonry units produced using natural, locally available, and biodegradable materials, thereby minimizing carbon emissions and the exploitation of non-renewable resources.

The present study focuses on the development of sustainable bio bricks using laterite soil, lime powder, coconut coir fibres, and cow dung ash powder. Laterite soil, being rich in iron and aluminium oxides, provides good binding properties and is abundantly available in tropical regions. Lime powder acts as a stabilizing agent, enhancing the strength and durability of the brick through pozzolanic reactions. Coconut coir fibres, a renewable agricultural by-product, improve the tensile strength and crack resistance of the bricks, while cow dung ash powder contributes to better thermal insulation and reduced density.

This combination of materials not only utilizes agricultural and organic waste but also reduces the dependency on fired clay bricks, which consume significant energy and cause environmental degradation. The proposed bio brick aims to achieve adequate strength, durability, and thermal performance suitable for low-cost and sustainable housing applications. Through this project, an attempt is made to assess the engineering properties and environmental benefits of these eco-friendly bricks and to promote greener construction practices for a sustainable future.

Methodology

The methodology adopted for the project "Sustainable Bio Brick: Experimental Study and Numerical Analysis with ANSYS" involves several systematic stages, starting from literature review to simulation and optimization. Each step ensures accurate evaluation of the brick's performance both experimentally and numerically.

1. **Project Topic Selection & Literature Review**
   - The first step involved reviewing numerous research papers, journals, and technical articles related to sustainable construction materials and bio bricks.
   - The aim was to identify eco-friendly alternatives to conventional clay bricks that reduce environmental impact while maintaining strength and durability.

- Based on the reviews, a suitable topic — Sustainable Bio Brick using agricultural and organic waste materials — was finalized.
- A base journal was selected to compare and validate results through ANSYS simulations.

2. Material collection

The essential raw materials were collected from locally available sources to ensure sustainability and cost-effectiveness.

- Laterite Soil – provides iron oxide and base strength.
- Cow Dung Ash Powder– acts as a natural binder and improves thermal insulation.
- Lime Powder – enhances water resistance and workability.
- Coconut Coir Fibre – adds tensile strength and reduces cracking.

3. Validation of Base Journal through ANSYS

- The base journal used in this project provided benchmark data for mechanical properties.
- Using ANSYS software, the journal's results were replicated by modeling bricks with similar proportions.
- The simulated results (stress, strain, deformation, and factor of safety) were compared with the published data to confirm the accuracy of the chosen analysis method.

4. Material Preparation:

- The collected materials were cleaned, sieved, and dried to remove impurities such as organic matter, roots, or oversized particles.
- Cow dung ash was obtained by controlled burning and sieved to obtain fine powder suitable for mixing.
- Laterite soil was crushed and passed through standard sieves to ensure uniform particle size.

4.1 Preparation of cow dung ash powder:

- Collected dried cowdung cakes from near by locality.
- Set up burning chamber using bricks of size 1m × 1m × 1m.
- Then place rice husk as the first layer in the chamber.
- Now add cow dung cakes on the top of rice husk layer.
- Again place the rice husk on the top of cow dung cakes.
- Ignite the chamber, allowing controlled burning (typically at 200-800ºc) until cow dung fully converted to ash.

- Add charcoal pieces for better burning of cow dung cakes.
- Now allow the ash to cool.
- Sieve the cooled ash through a fine mesh to obtain fine cow dung ash powder.

4.2 Preparation of coconut coir fibres :

- Collection of coconut coir fibres from the nearby locality.
- Clean the collected fibres using fresh water for removig dust, sand& other impurities.
- After washing of fibres, allow the fibres to dry in the presence of sunlight. Which helps to remove moisture from the cleaned fibres.
- The dried coir fibres are cut into small pieces of about 1-3cm length.
- The chopped fibres are stored in a dry and clean container or bag.

4.2 Preparation of lime powder:

- Collected quick lime from near by shop.
- Add hot water to the collected quick lime and wait for the chemical reaction.
- Slowly the quicklime (Cao) turns into lime powder ($Ca(OH)_2$).
- The mixture is allowed to cool down after the reaction.
- $Cao + H_2O \longrightarrow Ca(OH)_2 + Heat$

5. Determination of Material Properties :

Laboratory tests were conducted to understand the physical characteristics of the base materials:

- Specific Gravity Test – determines the ratio of soil particle density to water.
- Sieve Analysis– identifies the particle size distribution of the soil.
- Standard Proctor Test – determines Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) for proper compaction of the bricks.
- Chemical test - soil, cow dung ash and coconut coir fibre for finding different chemical compounds.

6. Material Mixing and Proportioning :

- Based on literature and experimental trials, different mix ratios of the raw materials were prepared.
- The goal was to identify the optimum composition balancing strength, workability, and water absorption.
- Mixing was done thoroughly in dry and wet stages to ensure even distribution of all components, particularly coir fibers and lime.

Table 1: Mix proportion

COMPONENTS	BB M1 (%)	BB M2 (%)	BB M3 (%)	BB M4 (%)
Laterite soil	100	85	80	75
Cow dung ash powder	0	5	10	15
Lime powder	0	5	5	5
Coconut coir fibre	0	5	5	5

7. **Brick Moulding :**
    - A mould of size 30 cm × 20 cm × 15 cm was used for casting the bricks.
    - The mixture was mechanically compacted in the mould to reduce voids and achieve uniform density.
    - After moulding, the bricks were carefully removed and kept under shade for initial setting.
8. **Curing Process :**

   The curing was carried out naturally (air drying) to maintain the eco-friendly nature of the project.

    - First 7 days: Air-cooled under shade to allow slow moisture loss.
    - Next 7–28 days: Cured at room/daylight temperature to gain sufficient strength.
    - No artificial heating or burning was used, reducing carbon emissions compared to traditional bricks.
9. **Testing and Evaluation :**

After curing, the bricks were tested for various physical and mechanical properties to assess performance:

- Compressive Strength Test– to determine load-bearing capacity.
- Tensile Strength Test – evaluates resistance to cracking and tension.
- Water absoption test -to determine the quality, porosity and durability of brick.

- Efflorescence test- determines the presence of soluble salts in brick which cause white powdery deposits upon drying.

10. Modelling and Simulation using ANSYS :

- A 3D model of the brick was created using SolidWorks and imported into ANSYS Workbench.
- Material properties derived from laboratory tests were input into the software.
- The model underwent Static Structural Analysis to study:
  - Total deformation
  - Equivalent stress
  - Elastic strain
  - Factor of safety (FOS)
  - Simulations were conducted for two mix designs (Mix 7 & Mix 12) under compression and bending loads, similar to the base journal for validation.
  - Similarly the 7 days and 28 days compressive strength of all bio bricks are validated.

11. Data Analysis and Optimization :

Experimental and simulated data were compared to identify correlations between Practical and theoretical results.

The optimum mix proportion was selected based on:

- Maximum compressive strength.
- Maximum tensile strength.
- Minimum water absorption.
- Acceptable Efflorescence limits.

Abbreviations:

1. BB M1 – Bio Brick Mix 1
2. BB M2 – Bio Brick Mix 2
3. BB M3 – Bio Brick Mix 3
4. BB M4 – Bio Brick Mix 4

EXPERIMENTAL STUDY

GENERAL :

The materials used for the preparation of sustainable bio bricks are laterite soil, cow dung ash powder, lime powder, and coconut coir fibre. Laterite soil forms the main base material, providing good strength and durability due to its high iron oxide content. Cow dung ash powder acts as a natural binder and enhances the thermal insulation property of the brick. Lime powder improves the setting property and water resistance, helping the brick achieve better stability. Coconut coir fibre is added in small proportions to increase tensile strength and reduce cracking during drying and loading. Together, these locally available and eco-friendly materials make the bio brick a sustainable and cost-effective alternative to conventional clay bricks.

MATERIALS

1. LATERITE SOIL

Laterite soil is a reddish-brown, iron- and aluminum-rich soil formed in tropical and subtropical regions through intensive weathering of underlying rocks. It is characterized by high porosity and a significant clay fraction, which contributes to its plasticity and binding ability when wet.

Properties of laterite soil:

- Chemical Composition: Laterite soil is rich in iron oxides (Fe_2O_3) and aluminum oxides (Al_2O_3), with varying amounts of silica (SiO_2), lime (CaO), and organic matter. These oxides help in stabilizing bricks and improving durability.
- Plasticity: Its clay content makes it moldable when mixed with water, enabling shaping into bricks.
- Porosity: The natural porosity allows for incorporation of organic additives (like coir fibers and cow dung ash) without significant cracking.
- Strength Potential: When properly stabilized with lime, cement, or other pozzolanic materials, laterite soil can achieve adequate compressive strength for construction applications.
- Thermal Insulation: Its porous structure contributes to moderate thermal insulation, making bricks suitable for energy-efficient building.

Advantages for Sustainable Bio Bricks:

- Locally Available: Laterite is abundant in many tropical regions, reducing transportation costs and carbon footprint.

- Eco-Friendly:Using laterite reduces the demand for conventional fired clay bricks, which consume high energy and emit CO_2.
- Compatibility with Organic Additives: Laterite can be mixed with lime, cow dung ash, and coconut coir fibers to produce bio bricks with improved strength, thermal performance, and crack resistance.
- Cost-Effective: As a natural material, laterite reduces overall production costs for eco-friendly bricks.

Figure 1: Laterite soil

2.COW DUNG ASH POWDER

Cow dung ash powder is a fine, grayish to black powder obtained by burning dried cow dung at controlled temperatures. It is considered an agro-waste material and has been traditionally used in agriculture, but in recent years it has gained attention as a sustainable additive in construction materials.

Properties of cow dung ash powder:

- Chemical Composition: Rich in silica (SiO_2), alumina (Al_2O_3), calcium oxide (CaO), and magnesium oxide (MgO), which can act as pozzolanic material in binding applications.
- Texture: Fine, powdery, and lightweight, making it easy to mix with soil or other construction materials.
- Porosity: The ash has micro-pores that can improve thermal insulation when incorporated into bricks.
- Eco-Friendly: Being a natural waste product, it reduces environmental pollution and promotes sustainable waste utilization.

Role of cow dung ash powder in Bio Bricks:

- Partial Replacement:It can replace a portion of clay or soil in brick manufacturing.
- Improved Thermal Performance: Increases porosity, reducing density and improving insulation.
- Binding Effect: Reacts with lime or cement in pozzolanic reactions to enhance compressive strength.
- Sustainability: Reduces dependence on conventional fired clay bricks and utilizes agricultural waste efficiently.

Figure 2: Cow dung ash powder

3. LIME POWDER

Lime Powder (Calcium Oxide or Calcium Hydroxide) is a key binding material used in the production of bio bricks. It is derived from limestone through calcination and hydration processes. In bio brick making, lime acts as a stabilizer and binder, improving the strength, durability, and workability of the bricks.

When mixed with soil and organic additives, lime undergoes a pozzolanic reaction, forming strong calcium silicate and aluminate compounds that bind particles together. It also helps in reducing shrinkage cracks, enhancing water resistance, and increasing compressive strength.

Properties of lime powder:

- Color: White or off-white fine powder.
- Chemical Composition: Mainly composed of calcium oxide (CaO) or calcium hydroxide ($Ca(OH)_2$).
- Texture: Smooth and fine in nature.

- Solubility:Slightly soluble in water; forms a milky suspension known as lime water.
- Nature:Strongly alkaline and reactive with water and carbon dioxide.
- Binding Property: Acts as a good binder by forming calcium silicate and aluminate compounds.
- Setting Property: Hardens slowly by absorbing CO_2 from the atmosphere (carbonation).
- Plasticity: Provides good workability when mixed with soil or other materials.
- Durability: Enhances the strength and weather resistance of materials.
- Thermal Property: Offers good thermal insulation and resists heat transfer.
- Eco-friendliness: Reduces carbon footprint compared to cement and supports partial CO_2 absorption during curing.

Role of lime powder in bio brick:

- Acts as a binder, holding soil and organic materials together.
- Enhances the compressive strength of the bricks through pozzolanic reactions.
- Improves durability and water resistance.
- Helps in reducing shrinkage and cracking during drying and curing.
- Increases workability and ease of molding.
- Contributes to thermal insulation and energy efficiency of the bricks.
- Acts as a stabilizing agent, especially for clayey or silty soils.
- Provides alkaline conditions that help prevent microbial decay of organic components.

Fig.No. 4.3 Lime powder

4. COCONUT COIR FIBRE

Coconut coir fibre, also known as coir, is a natural fibre extracted from the outer husk of coconuts. It is valued for its strength, durability, and eco-friendly characteristics, making it useful in textiles, agriculture, and construction materials such as biobricks.

Properties of Coconut coir fibres:

- High lignin content (45–46%): Provides rigidity and resistance to rotting.
- Cellulose content (~43%): Adds strength and structure.
- Density: 1.3–1.5 g/cm³.
- Tensile strength: Around 10 g/tex.
- Elongation at break: About 30%.
- Moisture regain: 10.5% at 65% relative humidity.
- Saltwater resistance: Naturally resistant to seawater and microbial attack.
- Thermal and sound insulation: Coir provides good insulation properties.
- Elastic and durable: Retains shape and strength over long periods.
- Biodegradable and renewable: An eco-friendly alternative to synthetic fibres.

Role of coir fibres in bio brick:

- Reinforcement: In bio-bricks, coir fibres act as natural reinforcement, improving compressive and flexural strength by bridging cracks and distributing load evenly.
- Lightweight structure: Reduces the overall density of the brick while maintaining adequate strength, enhancing ease of handling.
- Water regulation: The hollow, absorbent fibres regulate moisture within the bio-brick, reducing shrinkage and enhancing durability.
- Eco-friendliness: Coir-based bio-bricks are biodegradable and use agricultural waste, promoting sustainability in construction.
- Thermal and acoustic insulation: Coir's natural insulation enhances the bio-brick's energy efficiency and comfort performance.
- Binding compatibility: Coir interacts effectively with cement, lime, or clay binders, improving bonding and surface cohesion

Figure 4: Coconut coir fibres

5 WATER

Water plays a crucial role in the preparation and curing of bio bricks. It acts as a medium for chemical reactions, bonding, and workability of the mixture.

Properties of water:

- Appearance: Clear, colorless, and odorless liquid.
- State: Liquid at room temperature (25°C).
- Boiling point: 100°C (at 1 atm pressure).
- Freezing point: 0°C.
- Density: 1 g/cm^3 (at 4°C).
- Specific gravity: 1.0 (reference for most liquids).
- pH value: Around 7 (neutral).
- Surface tension: High — helps in binding particles in mixtures.
- Viscosity: Low, enabling easy mixing of materials.
- Chemical formula: H_2O.
- Molecular weight: 18.015 g/mol.
- Reactivity:Reacts with lime (CaO) to form calcium hydroxide ($Ca(OH)_2$).
- Stability:Chemically stable under normal conditions.
- Solvent nature:Excellent universal solvent — dissolves many minerals, salts, and gases.

Role of water in bio brick:

- Acts as a mixing medium for uniform blending of laterite soil, lime, cow dung ash, and coconut coir fibres.
- Activates lime hydrationand pozzolanic reactions that enhance strength.
- Provides workability and plasticity to the mixture for easy molding.
- Helps in bond formation between particles and fibres.
- Maintains moisture during curing, aiding in strength development.
- Prevents cracking and shrinkage when used in optimal quantity.
- Ensures uniform distribution of materials in the brick mix.

TESTING OF MATERIALS:

1. TEST ON SOIL

Soil testing plays a vital role in determining the suitability of soil for construction purposes. It helps engineers understand the physical and engineering properties of soil such as strength, density, compressibility, and permeability. The following are the most commonly performed tests on soil in geotechnical laboratories:

1.1 SPECIFIC GRAVITY TEST:

PURPOSE:

To determine the ratio of the weight of soil solids to the weight of an equal volume of water at a standard temperature.

EQUIPMENT USED:

Pycnometer, weighing balance, oven, distilled water.

PROCEDURE:

1. Clean and weigh the pycnometer (W_1): Ensure the pycnometer is dry and record its empty weight with the cap.
2. Add oven-dried soil (W_2): Place 200–300 g of oven-dried soil sample passing through a 4.75 mm sieve into the pycnometer and record the combined weight.

3. Add water and remove air: Add de-aired distilled water to half the pycnometer, stir thoroughly with a glass rod, and fill to about three-quarters. Apply gentle vacuum or shake well to remove trapped air bubbles.
4. Fill completely (W_3): After removing air, fill the pycnometer up to the calibration mark and determine its total weight with soil and water.
5. Weigh pycnometer with water only (W_4):Empty, clean, and fill the pycnometer completely with water only. Record the weight.
6. Record temperature: Note the test temperature, ideally around 27 °C (standard for comparison).

$$G = \frac{(W2-W1)}{(W2-W1)-(W3-W4)}$$

Where:

- W1= Weight of empty pycnometer
- W2= Weight of pycnometer + dry soil
- W3= Weight of pycnometer + soil + Water
- W4= Weight of pycnometer + water

1.2 STANDARD PROCTOR TEST

PURPOSE:

To determine the relationship between moisture content and dry density of soil and to find the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD).

EQUIPMENT USED:

Proctor mould (1000 cc), standard rammer (2.6 kg), balance, oven.

PROCEDURE:

1. Weigh the empty mould with base, but without the collar accurately.
2. Take about 3kg (1000cc mould) or 5kg (2250cc mould) of thoroughly mixed air dried soil.
3. Knowing the natural moisture content, add as much as water as required to make the water content 12% mix it thoroughly.
4. Place the collar, fill the mould with this mix for about half (more than $1/3^{rd}$) height and smoothen the surface by gently pressing.

5. Compact the moist soil in the three equal layers by the rammer of weight 2.6kg and freefall 310mm with 25 numbers of evenly distributed blows to each layer for 1000cc mould or 56 blows for 250cc mould.
6. Scratch the soil surface with spatula before placing succeeding layer.
7. Remove the collar and trim off the excess soil.
8. Remove all the loose soil on the outside of the mould and take weight of the mould with base plate and soil.
9. Take representative sample for determining water content.
10. Repeat the above procedure for 4-5 times with increasing water content until the total weight decreases or remains the same.

$$\gamma_{dry} = \frac{\gamma}{1+w}$$

Where:

γdry = Dry density in g/cc

γ = unit weight of soil (g/cc)

w = Water content (%)

1.3 SIEVE ANALYSIS

PURPOSE:

To determine the particle size distribution of a given soil sample and classify it as gravel, sand, silt, or clay.

EQUIPMENT USED:

Set of IS sieves (4.75mm, 2.36mm, 1.18mm, 600 micron, 300 micron, 150 micron, 75 micron) mechanical sieve shaker, balance.

PROCEDURE:

1. Take suitable quantity of oven dried soil for analysis and weigh it.

2. Sieve the soil through the standard set of sieves by the sieve shaker, starting from the sieve no. 4.75 to sieve No.75 micron in the decreasing order of sizes.
3. Weigh the residue retained in each of these sieves.
4. Plot graph for percentage finer on Y axis and size of particle (mm) in X axis .and obtain the Cc and Cu value

2.1 CHEMICAL PROPERTY TESTING ON COW DUNG ASH POWDER

PURPOSE:

To determine the various necessary cementious compunds (iron oxide, calcium oxide, aluminium oxide etc.) ad also to check the Ph and specific gravity of the cow dung ash powder.

Table 2: Chemical test on cow dung ash powder (Source: Envirodesigns Eco Labs Pvt.Ltd)

SI. No.	Parameters	Unit	Method	Result
1.	Silicon Dioxide(SiO_2)	%	SOP No. EEL/WP/E/029	55.61
2	Calcium Oxide (Cao)	%	SOP No. EEL/WP/E/029	16.21
3	Aluminium Oxide (Al_2O_2)	%	SOP No. EEL/WP/E/029	15.93
4	Iron oxide(Fe_2O_3)	%	SOP No. EEL/WP/E/029	1.82
5	Potassium Oxide (K_2O)	%	SOP No. EEL/WP/E/035	4.94
6	Sodium Oxide (Na_2O)	%	SOP No. EEL/WP/E/035	0.34
7	pH	-	IS 10158: 1982	9.9
8	Specific gravity	-	SOP No. EEL/WP/E/036	2.218

2.2 CHEMICAL PROPERTY TESTING ON LATERITE SOIL SAMPLE

PURPOSE:

To determine the various oxides (Silicon Dioxide,Aluminium Oxide, Iron Oxide) present in the soil sample.

Table 3: Chemical test on soil sample (Source: Envirodesigns Eco Labs Pvt.Ltd)

SI. No.	Parameters	Unit	Method	Result
1	Silicon Dioxide(SiO_2)	%	SOP No. EEL/WP/SO/030	45.74
2	Aluminium Oxide (Al_2O_2)	%	SOP No. EEL/WP/SO/030	29.29
3	Iron oxide(Fe_2O_3)	%	SOP No. EEL/WP/SO/030	15.71
4	pH	-	IS 10158: 1982	7.5
5	Acidity	mg/kg	SOP No. EEL/WP/SO/021	10.39
6	Alkalinity	mg/kg	SOP No. EEL/WP/SO/022	51.97

2.3 CHEMICAL PROPERTY TESTING ON COCONUT COIR FIBRE

PURPOSE:

To determine the amount of ash content of the coir fibre.

Table 4: Chemical test on coconut coir fibre (Source: Envirodesigns Eco Labs Pvt.Ltd)

SI. No.	Parameters	Unit	Method	Result
1	Ash content	%	SOP No. EEL/WP/E/014	1.14

3. COMPRESSIVE STRENGTH TEST

PURPOSE:

To determine the maximum load that a brick can withstand under compression without failure

EQUIPMENTS USED:

CTM machine, Steel plates, Weighing balance.

PROCEDURE:

1. Immerse the bricks in the water pool for 24 hrs.
2. Remove the samples from the water pool (after 24 hrs) and each sample shall be removed the surface water wipped off with a damp cloth and calculate the area of the face which load will apply on.

3. Place the sample horizontally on the the CTM machine and along with a steel plates on both top and bottom of the brick.
4. Now apply load on the brick and obtain the maximum load at which brick crushed on the CTM machine.

$$\text{Compressive strength } (N/mm^2) = \frac{\text{Maximum load at failure (P)}}{\text{Loaded cross sectional area (A)}}$$

Figure 5: Compressive strength testing on brick.

Figure 6: Obtaining maximum compressive strength from CTM machine

3.TENSILE STRENGTH TEST ON BRICK

PURPOSE:

To assess the ability of bricks to resist cracking or failure under tension.

EQUIPMENTS USED:

Flexural strength testing machine, weighing machine, scale.

PROCEDURE:

1. Clean the brick face and measure its size.
2. Soak in water for 24 hrs and wipe the surface.
3. Place the brick on two supports in the testing machine.
4. Apply load gradually at the center.
5. Continue loading until the brick breaks.
6. Note the breaking load.

$$\text{Tensile strength } (N/mm^2) = \frac{\mathbf{3PL}}{\mathbf{2\ bd^2}}$$

Where,

P = Maximum load at failure.

L= Length between supports.

b = width of specimen.

d = depth/thickness of specimen.

Figure 8: Flexural testing machine

4.WATER ABSORPTION TEST ON BRICK

PURPOSE:

To find out the amount of water absorbed by the brick and to check the porosity of the brick.

EQUIPMENTS USED:

Weighing machine, water curing tank, dry cloth etc.

PROCEDURE:

1. Take the dry weight (W1) of the brick sample.
2. Now immerse the brick in the water curing tank for 24 hrs .
3. After 24 hrs take out the brick from the curing tank and wipe off surface water and take the wet weight (W2) of the brick.
4. Calculate water absorption (%) = $\frac{(\mathbf{W2} - \mathbf{W1})}{\mathbf{W1}} \times \mathbf{100}$

Figure 9:Water absorption test on bricks.

5.EFFLORESCENCE TEST ON BRICK

PURPOSE:

To detect the presence of soluble salts in the bricks.

EQUIPMENTS USED:

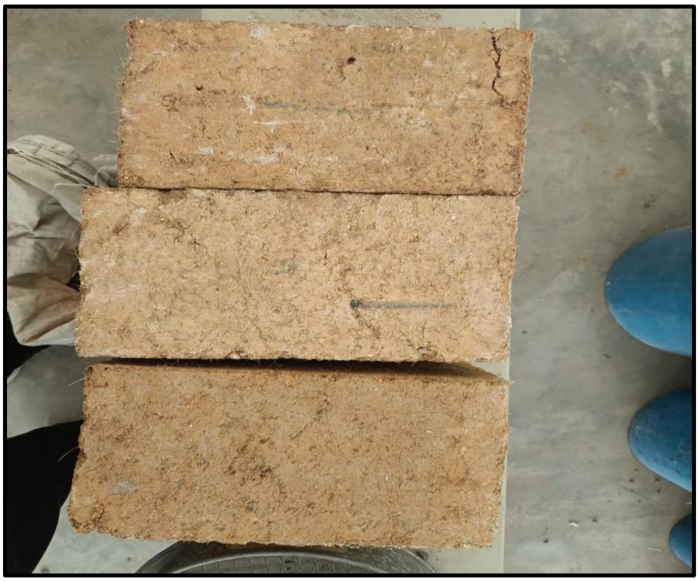
Shallow dish, distilled water, measuring cylinder.

PROCEDURE:

1. Place the brick vertically into the dish and keep water level at 25mm in the dish.
2. Place the whole arrangement in a warm well ventilated room until all the water absorbed by specimen & surplus water evaporates.
3. Cover the dish container with glass cylinder so that excessive evaporation doesn't take place.
4. When water gets absorbed by the specimen, add same amount of water in the dish & allow to get absorbed and get evaporated.
5. Examine the bricks efflorescence after 2nd evaporation.

Figure 10: Efflorescence test on BB M1

Figure 11: Efflorescence test on BBM2, BBM3, BBM4



Ansys software

The validation of both 7 days and 28 days compressive strength obtained from compressive strength testing machine(CTM) is validated by using ANSYS software. And for modelling the brick ,it is done by using Solids work software. For validation purpose the first step is to create a microstructure in the ANSYS software . And certain engineering data is required for creating microstructure. The datas include: young's modulus of elasticity, poisson's ratio, bulk density, compressive yield strength & tensile yield strength etc.

After creating the microstructure, then static structure is applied where the datas added in the material designer are copied to the static structure and add geometry of the brick modelled in the soildswork software. And load is applied on the brick and corresponding compressive strength value is obtained .

Along with compressive strength, the total deformation, equivalent strain, safety factor etc can also obtained from solving the model.

Figure 12: Meshed image of micro structure 1

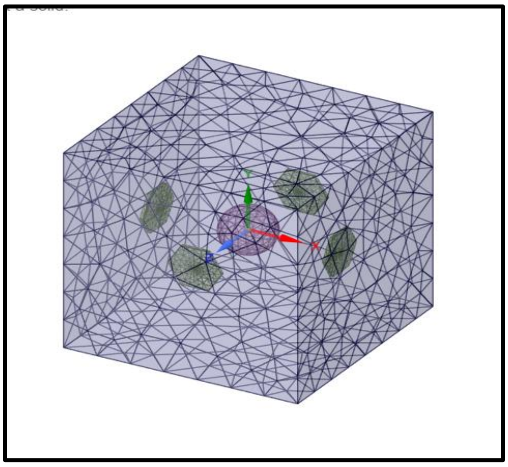


Figure 13: Meshed image of microstructure 2

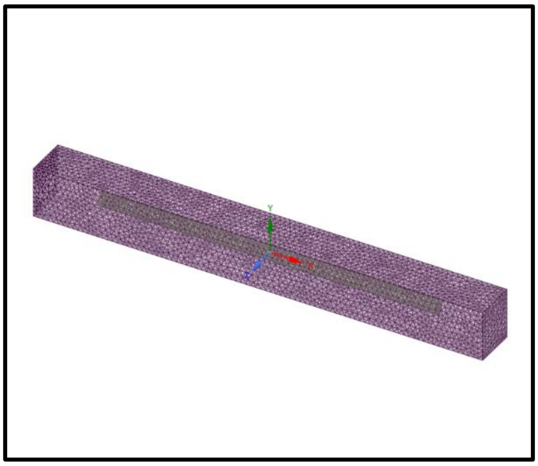


Figure 14: days compressive strength of BBM1

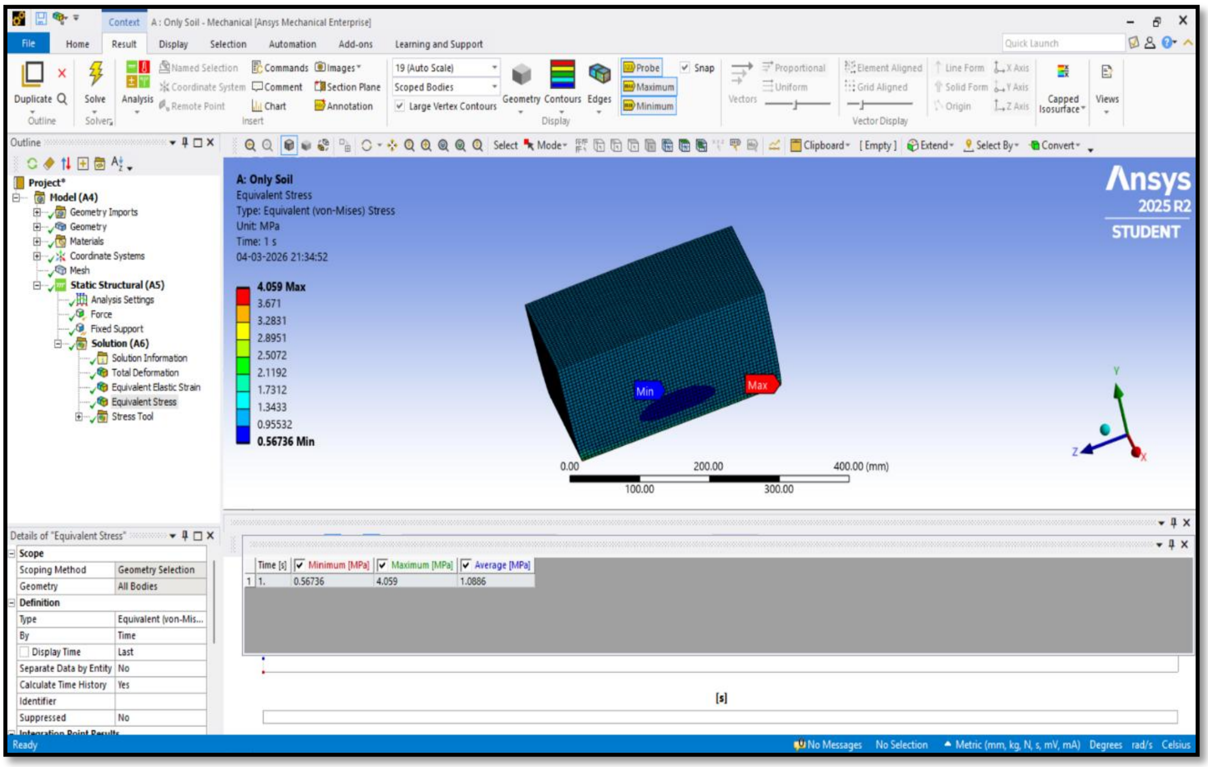


Figure 15: 28 days compressive strength of BBM1

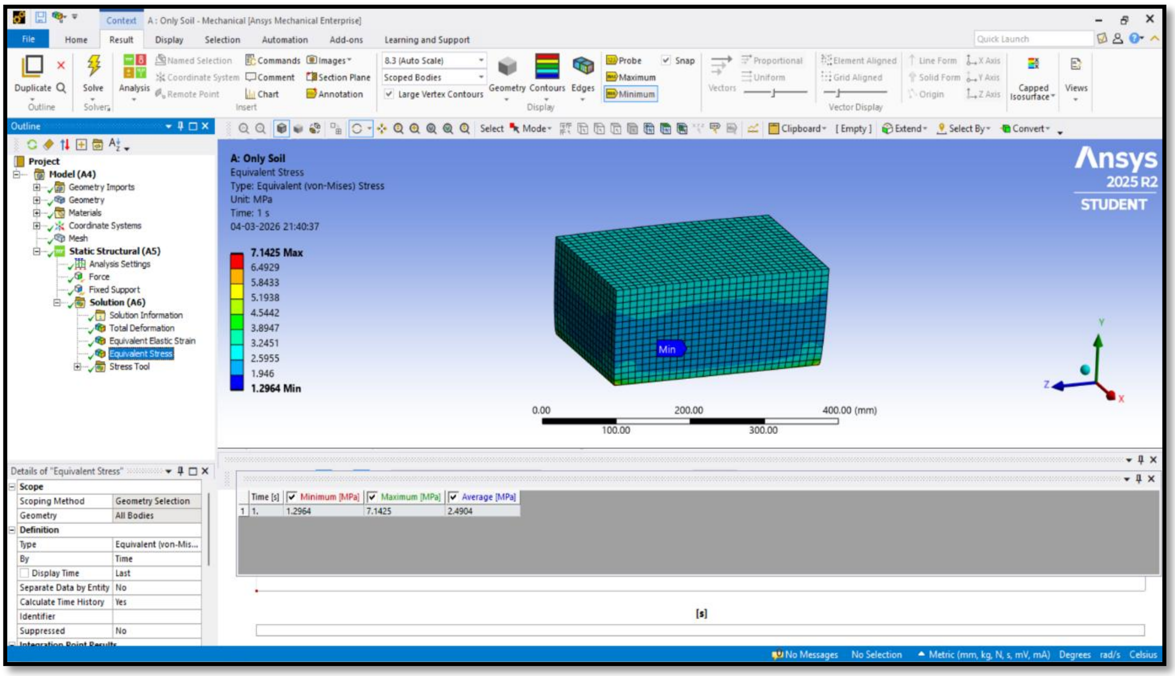


Figure 16: 7 days compressive strength of BBM2

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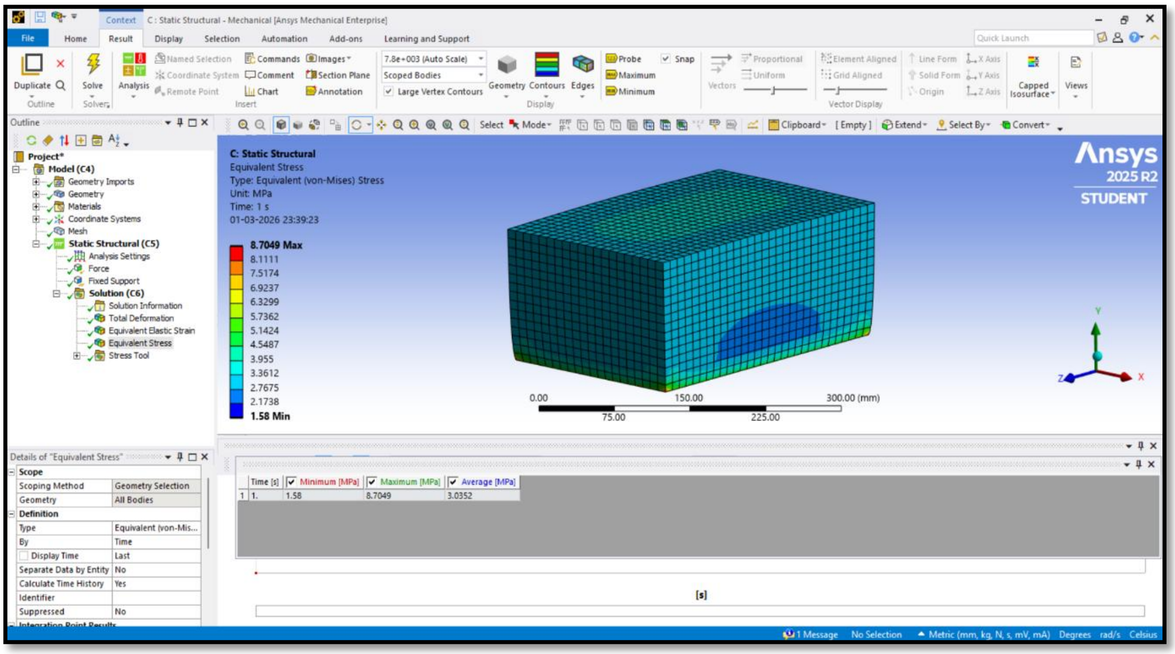

Figure 17: 28 days compressive strength of BBM2

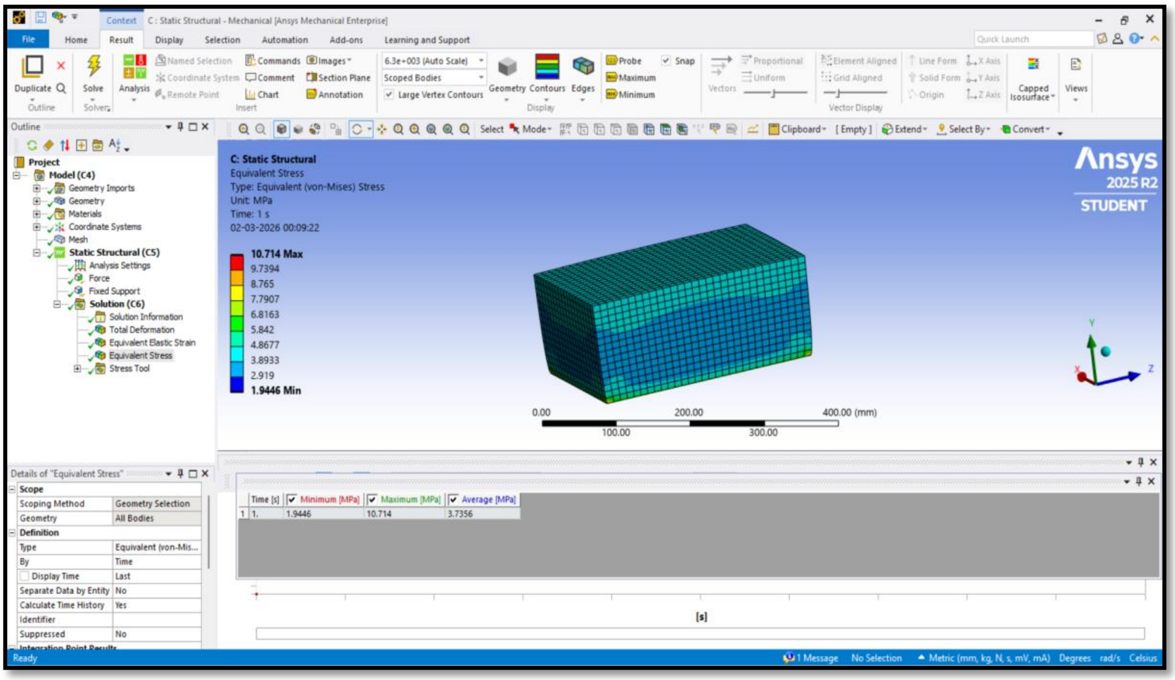

Figure 18: 7 days compressive strength of BB M3 brick

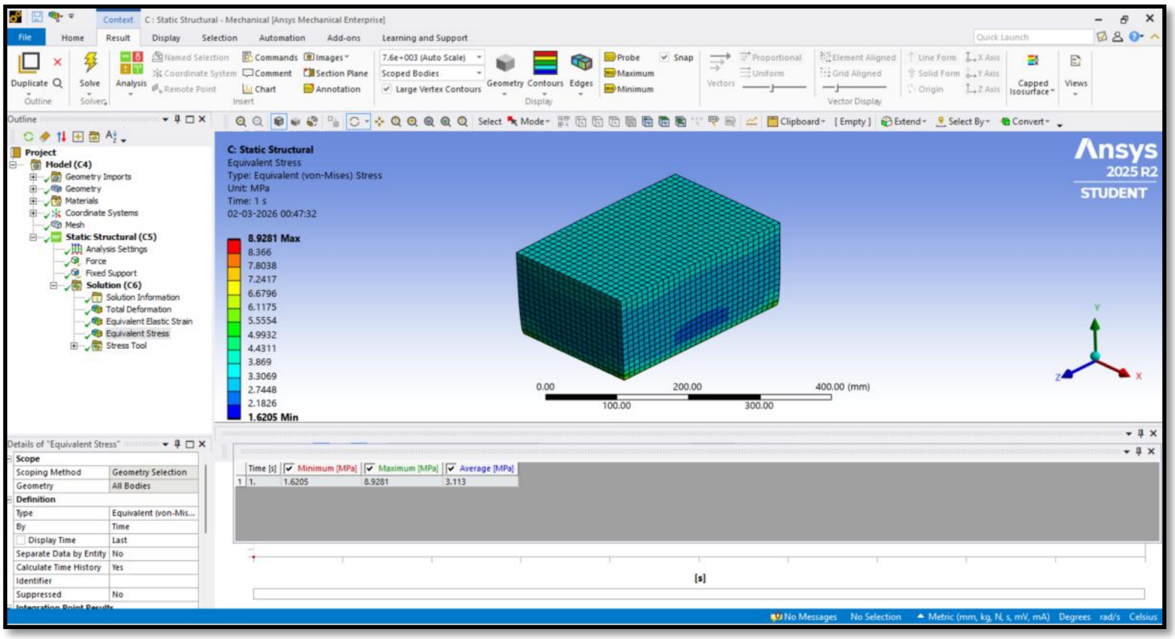

Figure 19: 28 days compressive strength of BBM3 brick

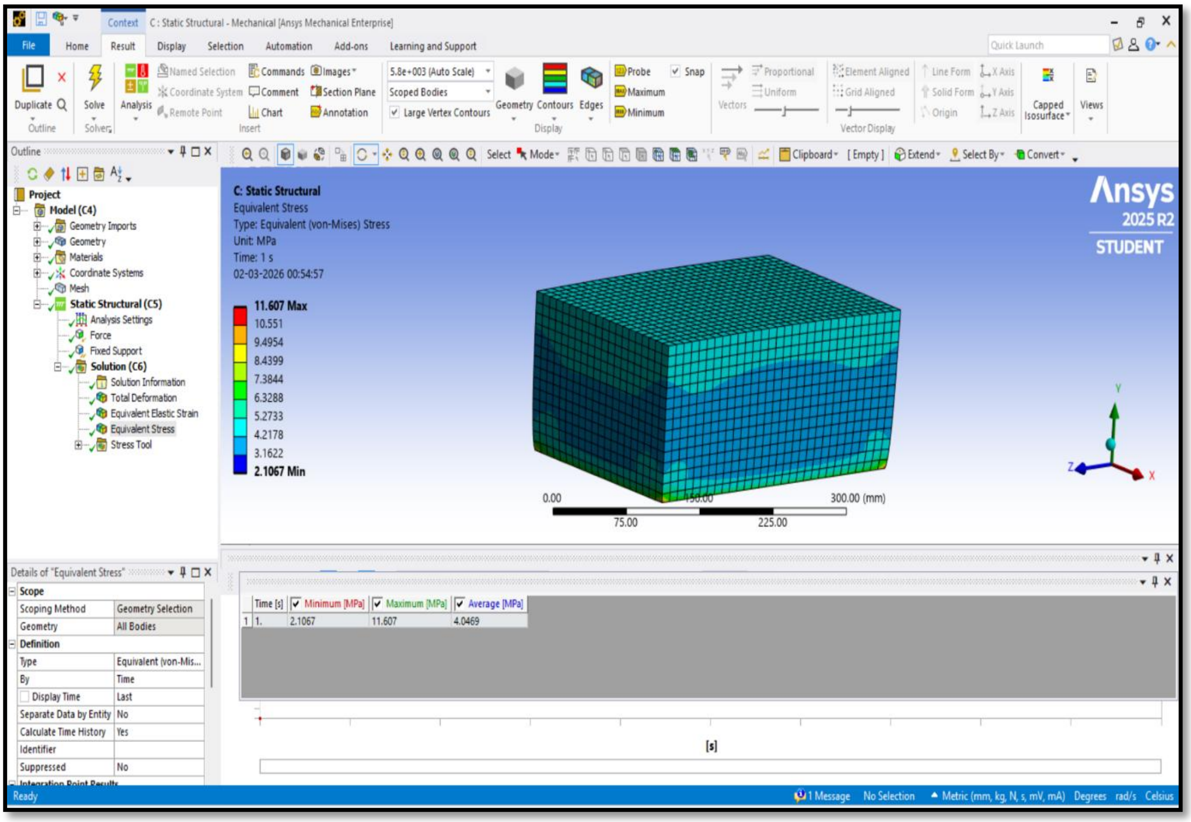

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Figure 20: 7 days compressive strength of BB M4 brick

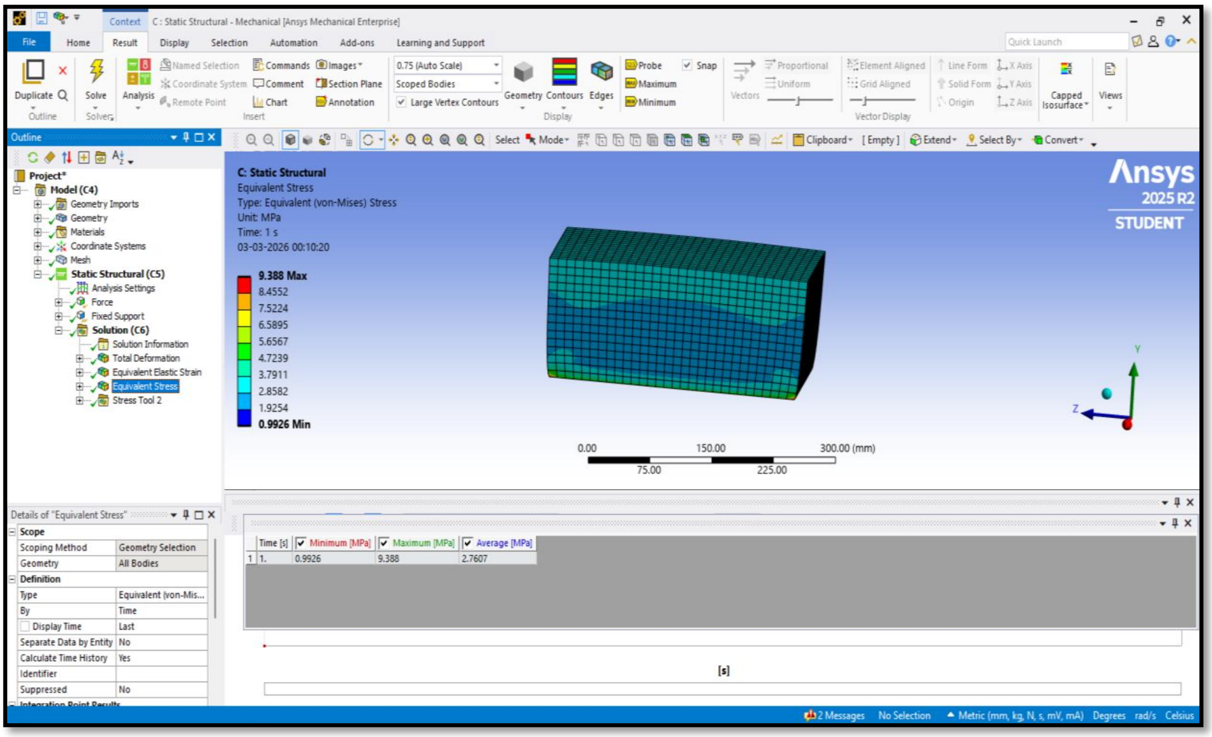


Figure 21: 28 days compressive strength of BB M4 brick

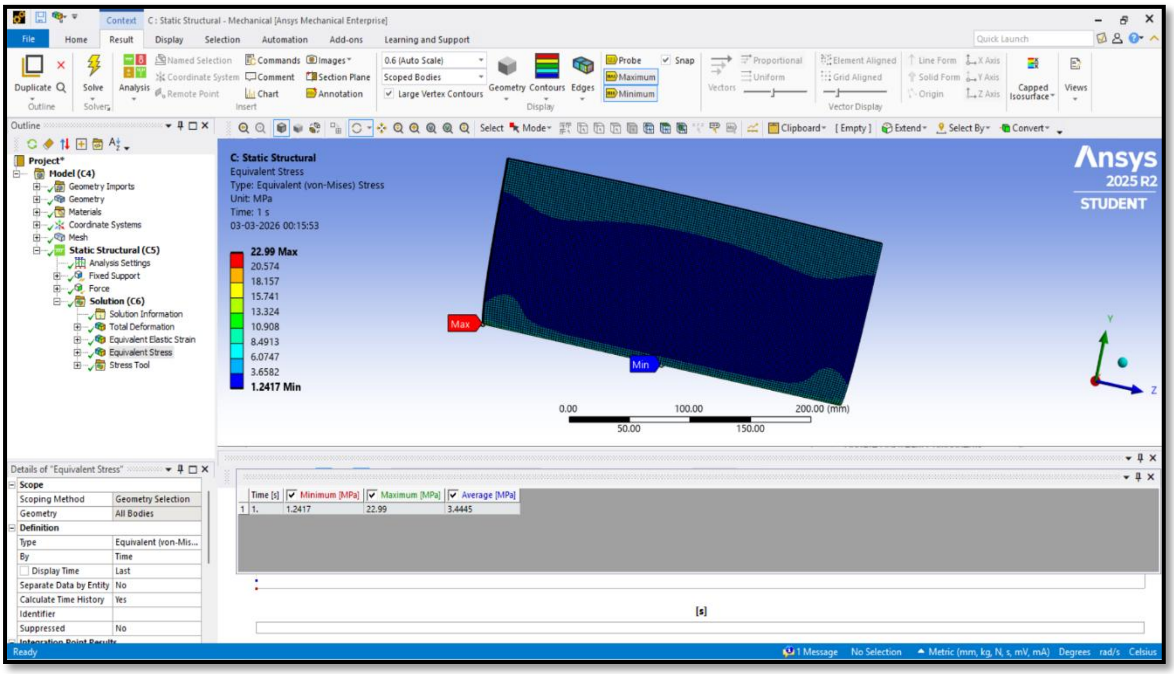


Table 5: validation results obtained from ANSYS

Brick designation	7 days compressive strength (N/mm^2)	28 days compressive strength (N/mm^2)
BB M1	1.0886	2.4904
BB M2	3.0352	3.7356
BB M3	3.113	4.0469
BB M4	2.7607	3.4445

Results and Discussion

1. specific gravity test:

Table 6: specific gravity result

SAMPLE No.	G VALUE	SPECIFIC GRAVITY RANGE
1.	2.4	2.65-2.85

Result:

The specific gravity for a soil is 2.65 to 2.85. Here we got the value as 2.4 this is due to the presence of organic matter present in the soil sample.

Inference

The specific gravity value of soil typically ranges from 2.65 to 2.85 . But here we got a value of 2.4 , which indicates that the soil contains some organic matters.

2. Standard Proctor Test:

Table 7: Standard proctor results

S.No	DRY DENSITY (g/cc)	WATER CONTENT (%)
1.	1.128	25
2.	1.005	50
3.	0.84	66
4.	1.148	33

Result:

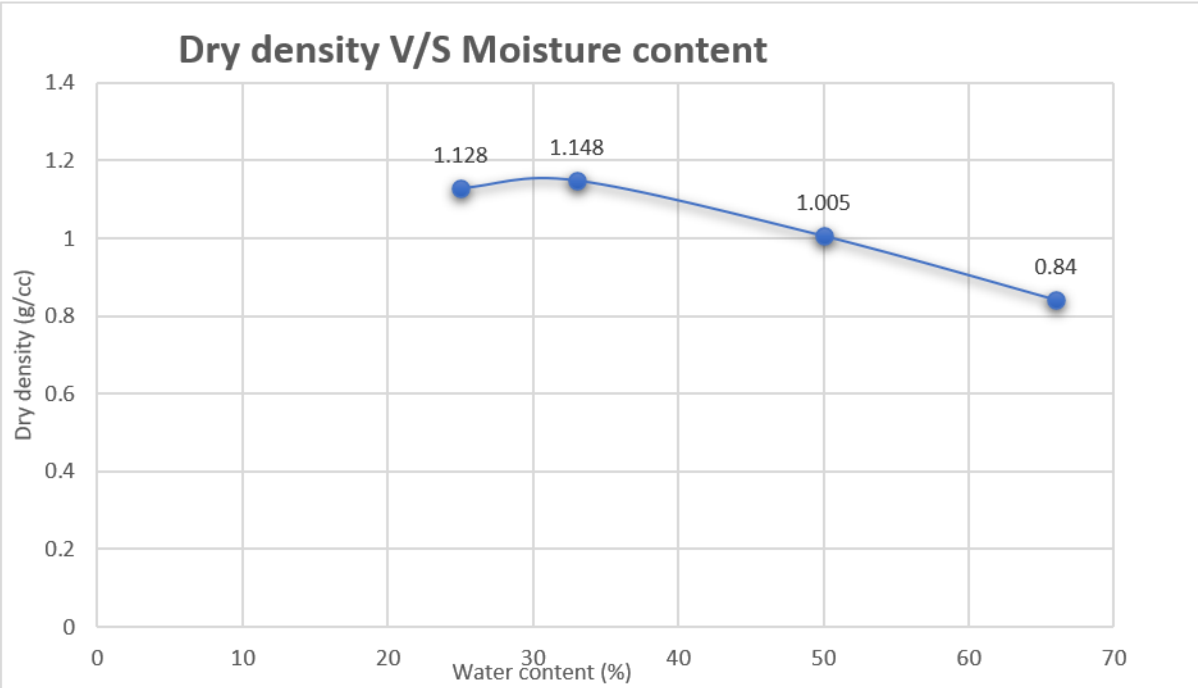
- Maximum dry density : 1.148 g/cc
- Optimum moisture content : 33%

Inference:

OMC = 33% and MDD = 1.148 g/cm³ indicate a highly fine-grained or clayey soil with low compactability.

Graph:

Figure 22: Standard proctor test graph



3. Sieve Analysis

Table 8: sieve analysis test

IS sieve no. (mm)	Particle size (D) mm	Wt. of soil retained (g)	%Wt. retained	Cummulative % retained	% finer (100-cu% retained)
4.75	4.75	48.5	4.85	4.85	95.15
2.36	2.36	106.5	10.65	15.5	84.5
1.18	1.18	211	21.1	36.6	63.4
600	0.60	340.5	34.05	70.65	29.35
300	0.30	191.5	19.15	89.8	10.2
150	0.15	99	9.9	99.7	0.3
75	0.075	3	0.3	100	0
Pan		0	0	100	0

Result

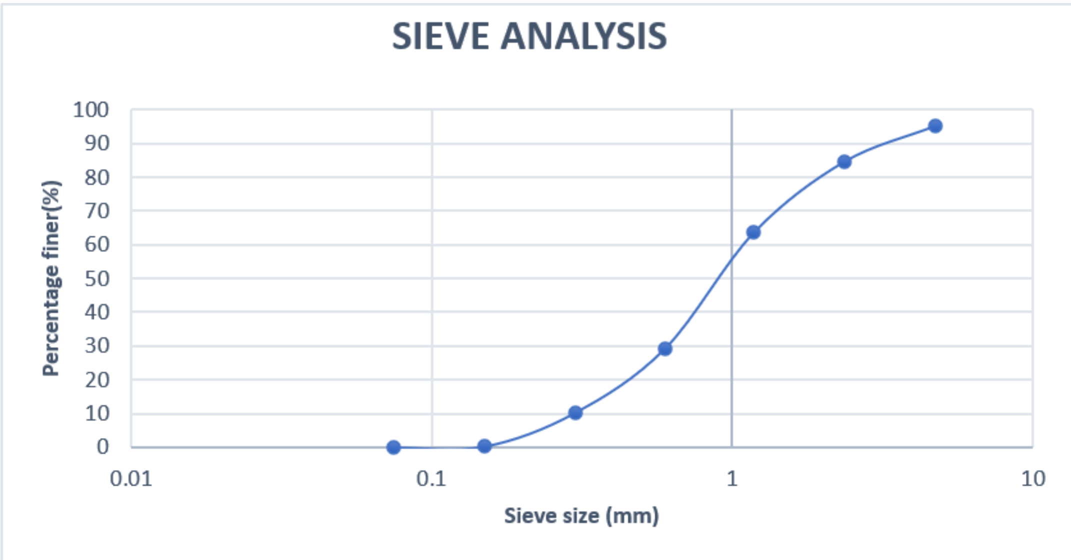
- $D_{10} = 0.3$
- $D_{30} = 0.64$
- $D_{60} = 1.1$
- $Cu = D_{60}/D_{10} = 3.98$
- $Cc = D_{30}^{2} / D_{60} \times D_{30} = 1.248$

Inference

Here we obtain the cc value as 1.248, and the Cc value should be in between 1& 3 which indicates a well graded soil. So this soil comes under well graded soil.

Graph:

Figure 23: Sieve analysis graph



Compressive Strength Test On Brick

1.Compressive Strength Test On BB M1, BBM2, BB M3, BB M4

Table 9: Compressive strength of BB mixes (7 days)

Brick designation	Compressive strength (N/mm^2)
BB M1 (Only soil)	1
BB M2 (85-5-5-5)	3.125
BB M3 (80-10-5-5)	3.415

BB M4 (75-15-5-5)	2.958

Table 10: Compressive strength of BB mixes (28 days)

Brick designation	Compressive strength (N/mm^2)
BB M1 (Only soil)	2.583
BB M2 (85-5-5-5)	4
BB M3 (80-10-5-5)	4.25
BB M4 (75-15-5-5)	3.625

Result:

- The compressive strength of normal laterite soil block has been improved by adding admixture to the soil mix.
- The bricks can be compared to third class bricks (having minimum compressive strength 3.5 N/mm^2) according to IS 1077:1992.
- The BBM2 and BBM3 can be considered as the good mix ratio.
- The BBM4 mix ratio contains 15% of cow dung ash powder but its overall compressive strength (28 days) is less as compared to BB M2& BB M3. It is due to the inadequate lime content to create the C-S-H bond in the mix.

Inference:

- For the BB M2 brick, the strength has been increased by 54.86% as compared to 28 days strength of normal soil block(BB M1)
- For BB M3 brick, the strength has been increased by 64.57% as compared to 28 days compressive strength of normal soil block(BB M1).
- For BB M4 brick, the strength has been increased by 40.34% as compared to the 28 days compressive strength of the normal soil block (BB M1).

Graph:

Figure 24: 7 days compressive strength of bricks

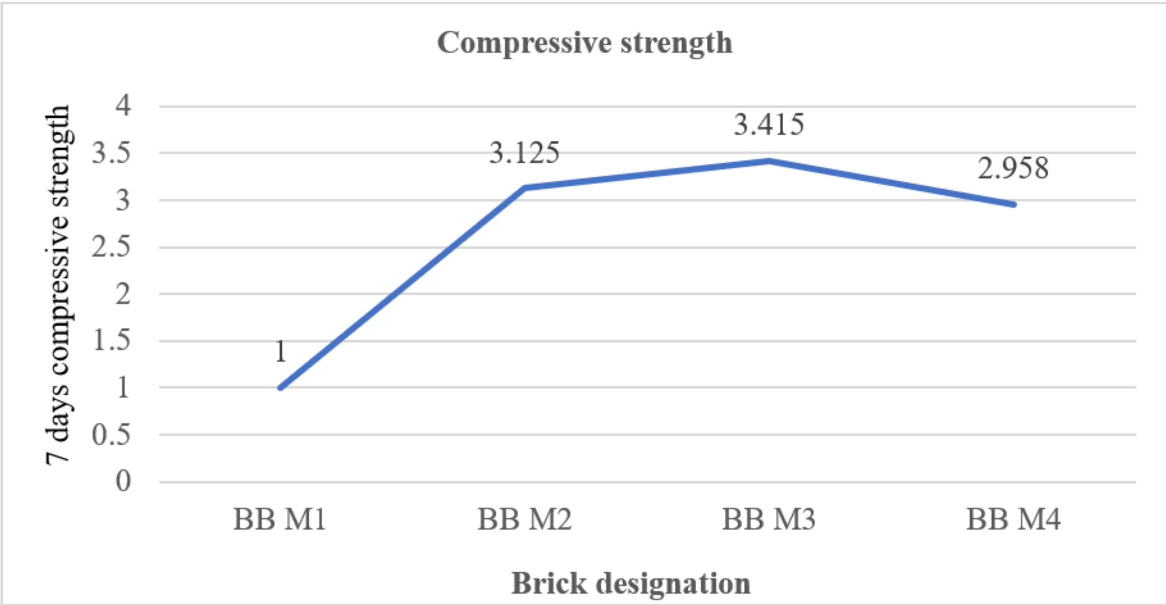
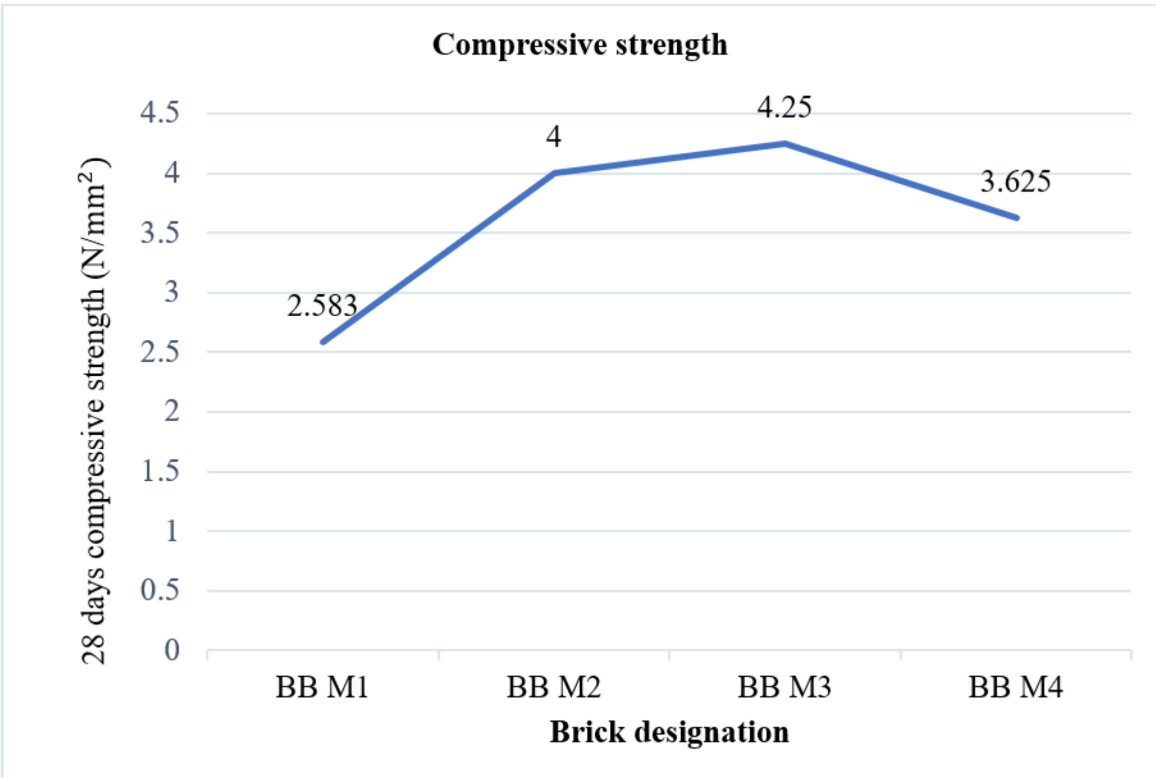


Figure 25: 28 days compressive strength of bricks



Tensile Strength On Bricks

Table 11: Tensile strength of bricks

Brick designation	Tensile strength (N/mm^2)
BB M1 (Only soil)	0.533
BB M2 (85-5-5-5)	0.833
BB M3 (80-10-5-5)	1
BB M4 (75-15-5-5)	1.166

Result:

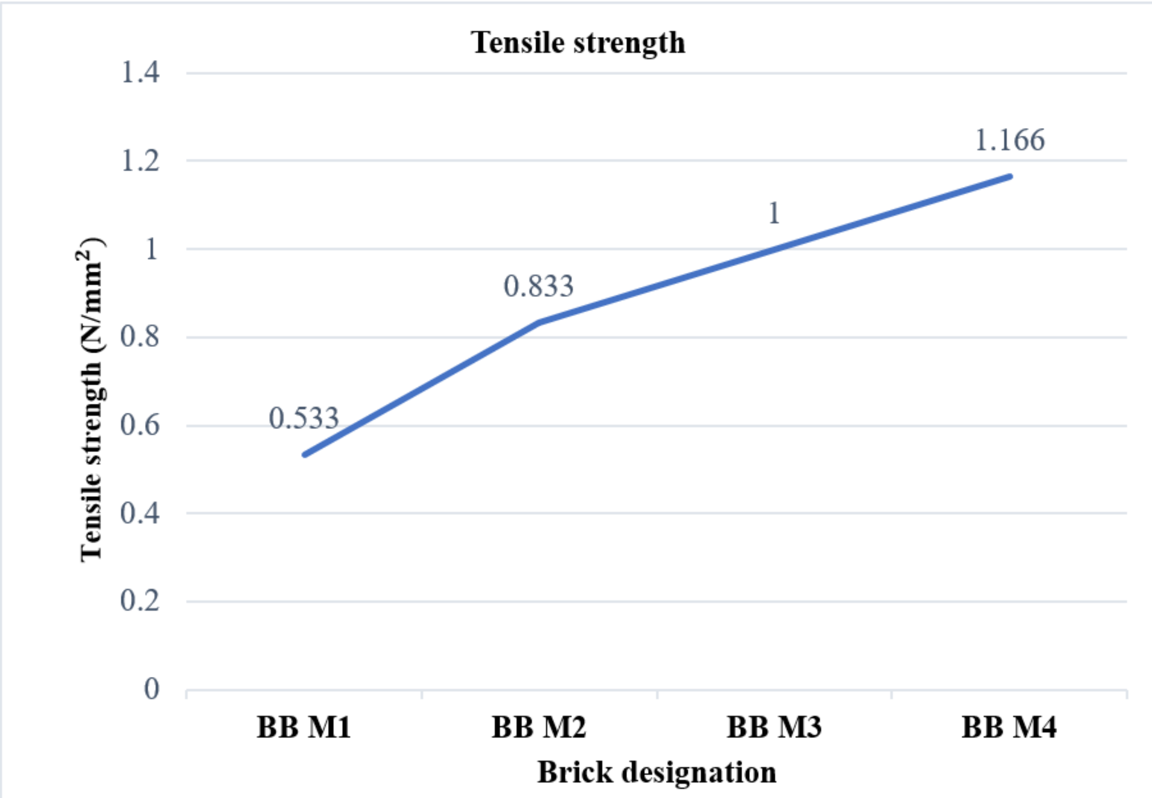
- Tensile strength of stabilized laterite soil bricks is generally low.
- The value of tensile strength of a brick is generally between 10-20% of its compressive strength.
- Here the BB M4 have the greater tensile strength value.
- The tensile strength have been improved by adding coconut coir fibres.

Inference:

- For BB M2 brick, the tensile strength have been increased by 56.29% as compared to BB M1 brick.
- For BB M3 brick, the tensile strength have been increased by 87.617% as compared to BB M1 brick.
- For BB M4 brick, the tensile strength have been increased by 118.76% as compared to BB M1 brick.

Graph:

Figure 26: Tensile strength of bricks



Water Absorption Test On Bricks

Table 12: Water aborption test of bricks

Brick designation	Water absorption (%)
BB M1 (Only soil)	16.2
BB M2 (85-5-5-5)	10.71
BB M3 (80-10-5-5)	9.20
BB M4 (75-15-5-5)	8.16

Result:

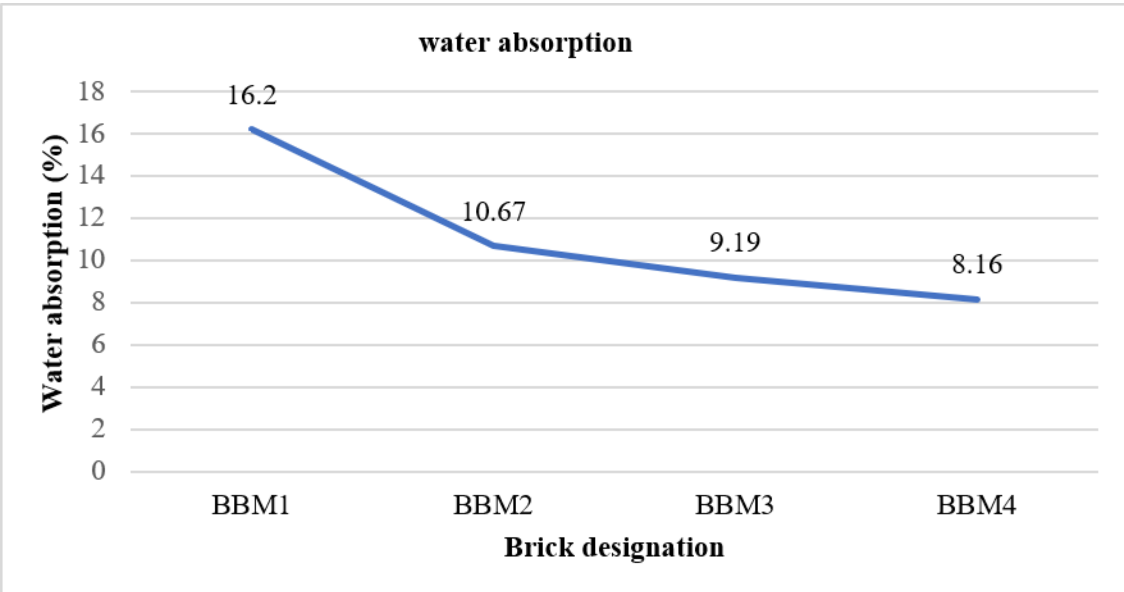
- The water absorption rate has been decreased by adding the admixtures to the soil mix.
- The BB M4 has least water absorption value.
- BB M2, BB M3 and BB M4 are satisfying the water absorption rate required for the 3rd class brick category.

Inference:

- According to IS 3495 (Part 2), the water absorption for a brick should not be more than 20% by weight of the brick.
- Here all bricks satisfies the requirement for third class brick category.

Graph:

Figure 27: Water absorption of bricks.



Efflorescence Test On Bricks

Table 13: Efflorescence test on bricks

Brick designation	% of white layer on the surface (%)	Efflorecsence
BB M1 (Only soil)	10	Slight
BB M2 (85-5-5-5)	10	Slight
BB M3 (80-10-5-5)	10	Slight
BB M4 (75-15-5-5)	10	Slight

Result:

- White deposits are present.
- According to IS 3495(Part 3), the efflorescence value obtained is slight.

Inference:

- According to IS 3495 (Part 3), percentage of surface area covered by white salt deposits is up to 10% of the surface, so slight efflorescence occurs.

Validation of compressive strength by ansys software Result

Table 14: Validation results of ctm and ansys

Brick designation	7 days compressive strength from ANSYS (N/mm^2)	7 days compressive strength from CTM (N/mm^2)	28 days compressive strength from ANSYS (N/mm^2)	28 days compressive strength from CTM (N/mm^2)
BB M1	1.0886	1	2.4904	2.583
BB M2	3.0352	3.125	3.7356	4
BB M3	3.113	3.415	4.0469	4.25
BB M4	2.7607	2.958	3.4445	3.625

Inference:

- The values obtained from ANSYS software are approximately equal to the values obtained from CTM machine.
- Some engineering datas required for validation purpose (Poisson ratio, young's modulus, compressive yield strength and tensile yield strength)of corresponding soil mixes are not practically obtained value. Rather they have been obtained from certain value ranges by refering various journals and website

Graph:

Figure 28: 7 days compressive strength ctm v/s ansys

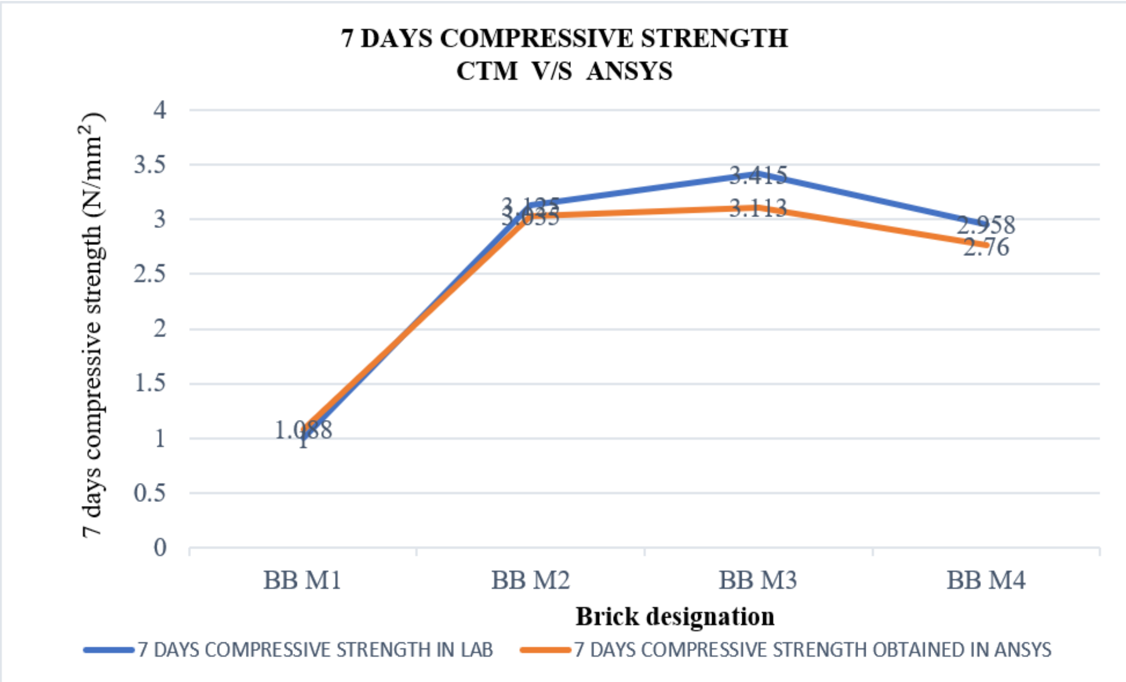
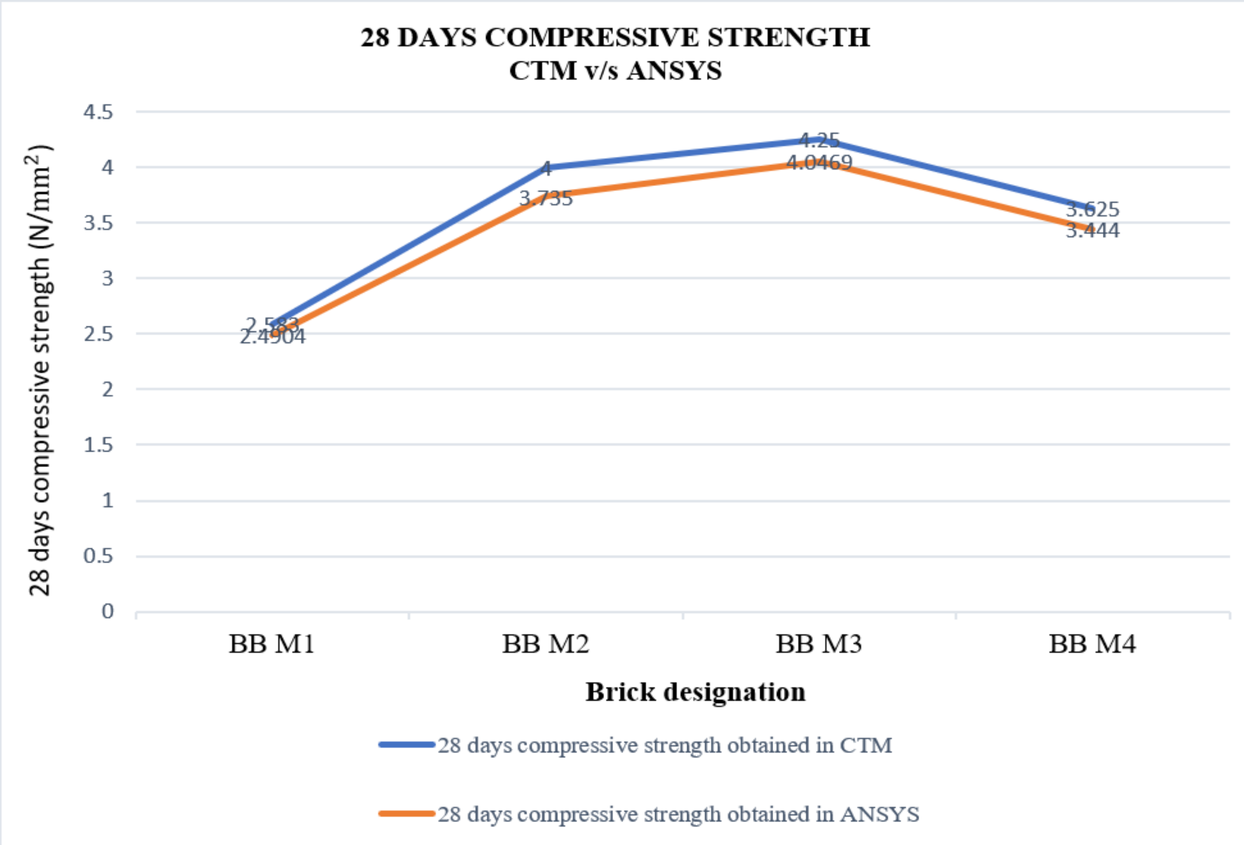


Figure 29: 28 days compressive strength ctm v/s ans



Appendix-A

Test Result of Material

A.1 Laterite Soil

(i) Specific gravity soil

Weight of soil used = 200g

Table A.1 Specific gravity observation column

SI.No	Description	Value
1.	Weight of pycnometer (W1), g	699.0
2.	Weight of pycnometer + dry soil (W2),g	898.5
3.	Weight of pycnometer + soil + water (W3), g	1772.0
4.	Weight of pycnometer + water (W4), g	1656.5
5.	Specific gravity = $\frac{(W2-W1)}{(W2-W1)-(W3-W4)}$	2.4

Result

Specific gravity of soil sample = 2.4

A.2 Standard Proctor Test

Weight of soil taken = 3kg

Weight of rammer = 2.6 kg

Proctor mould =1000 cc

OBSERVATION COLUMN:

Table.A.2 Standard proctor test observation column.

OBSERVATION No.	1	2	3	4	5
(A)Determination of density					
1.weight of mould (g)	3550	3550	3550	3550	3550
2.weight of mould +compacted soil (g)	5435	5565	5590	5500	5420
3.weight of compacted soil(g)	1885	2015	2040	1950	1870
4.Bulk density γ=w/v	1.411	1.508	1.527	1.460	1.400
(B)Water content determination					
1.container no.	1	2	3	4	5
2.weight of container + moist soil (g)	75	70	65	55	70
3.weight of container + dry soil (g)	70	60	60	50	60
4.weight of container (g)	50	40	45	40	45
5.weight of water (g)	5	10	5	5	10
6.water content w= ww/wd	0.25	0.5	0.33	0.5	0.66
7.dry density=γ/1+w	1.128	1.005	1.148	0.97	0.84

Result:

Maximum dry density : 1.148 g/cc

Optimum moisture content : 33%

A.3 Sieve Analysis

Weight of sample taken =1000g

OBSERVATION COLUMN:

Table.A.3 Observation column for sieve analysis

IS sieve no. (mm)	Particle size (D) mm	Wt. of soil retained (g)	%Wt. retained	Cummulative % retained	% finer (100-cu% retained)
4.75	4.75	48.5	4.85	4.85	95.15
2.36	2.36	106.5	10.65	15.5	84.5
1.18	1.18	211	21.1	36.6	63.4
600	0.60	340.5	34.05	70.65	29.35
300	0.30	191.5	19.15	89.8	10.2
150	0.15	99	9.9	99.7	0.3
75	0.075	3	0.3	100	0
Pan		0	0	100	0

Result

- $D_{10} = 0.3$
- $D_{30} = 0.64$
- $D_{60} = 1.1$
- $Cu = D_{60}/D_{10} = 3.98$
- $Cc = D_{30}^2 / D_{60} \times D_{30} = 1.248$

Appendix B

Test result on brick

B.1 compressive strength of brick

Table.B.1 :7 days compressive strength of BB M1 brick

SI.No	Dimesion of brick (mm)	Average area of bed face (mm^2)	Maximum load (N)	Compressive strength ((N/mm^2)
1	300×200×150	60,000	55500	0.925
2	300×200×150	60,000	55000	0.916
3	300×200×150	60,000	70000	1.166

Table.B.2 :7 days compressive strength of BB M2 brick

SI.No	Dimesion of brick (mm)	Average area of bed face (mm^2)	Maximum load (N)	Compressive strength ((N/mm^2)
1	300×200×150	60,000	195000	3.25
2	300×200×150	60,000	180000	3

Table.B.3: 7 days compressive strength of BB M3 brick

SI.No	Dimesion of brick (mm)	Average area of bed face (mm^2)	Maximum load (N)	Compressive strength ((N/mm^2)
1	300×200×150	60,000	210000	3.5
2	300×200×150	60,000	200000	3.33

Table.B.4 :7 days compressive strength of BB M4 brick

SI.No	Dimesion of brick (mm)	Average area of bed face (mm^2)	Maximum load (N)	Compressive strength ((N/mm^2)
1	300×200×150	60,000	180000	3
2	300×200×150	60,000	175000	2.916

Table.B.5: 28 days compressive strength of BB M1 brick

SI.No	Dimesion of brick (mm)	Average area of bed face (mm^2)	Maximum load (N)	Compressive strength ((N/mm^2)
1	300×200×150	60,000	150000	2.5
2	300×200×150	60,000	160000	2.66

Table.B.6 :28 days compressive strength of BB M2 brick

SI.No	Dimesion of brick (mm)	Average area of bed face (mm^2)	Maximum load (N)	Compressive strength ((N/mm^2)
1	300×200×150	60,000	240000	4
2	300×200×150	60,000	240000	4

Table.B.7 :28 days compressive strength of BB M3 brick

SI.No	Dimesion of brick (mm)	Average area of bed face (mm^2)	Maximum load (N)	Compressive strength (N/mm^2)
1	300×200×150	60,000	250000	4.166
2	300×200×150	60,000	260000	4.333

Table.B.8 :28 days compressive strength of BB M3 brick

SI.No	Dimesion of brick (mm)	Average area of bed face (mm^2)	Maximum load (N)	Compressive strength (N/mm^2)
1	300×200×150	60,000	210000	3.5
2	300×200×150	60,000	225000	3.75

RESULT:

- The bricks can be compared to third class bricks (having minimum compressive strength 3.5 N/mm^2) according to IS 1077:1992.
- The strength of the brick has been increased by adding the admixtures used (cow dung ash powder, lime powder, coconut coir fibre)

B.2 Tensile Strength of Brick

Table.B.9: Tensile strength of Bricks

Brick designation	Dimension of brick (mm)	Load applied (N)	Length b/w supports (mm)	Width of specimen (mm)	Depth of specimen (mm)	Tensile strength (N/mm^2)
BB M1(Only soil)	300×200×150	8000	200	200	150	0.533
BB M2 (85-5-5-5)	300×200×150	12500	200	200	150	0.833
BB M3 (80-10-5-5)	300×200×150	15000	200	200	150	1
BB M4 (75-15-5-5)	300×200×150	17500	200	200	150	1.166

Result :

- Tensile strength of stabilized laterite soil bricks is generally low.
- Typically ranging between 10% and 20% of its compressive strength.
- Here obtained values falls between the 10-20% of its compressive strength.
- On comparing the tensile strength of normal laterite soil brick ,the tensile strength of brick have been improved by adding the admixtures (cow dung ash powder, lime powder) to the soil mix.

B.3 Water Absorption Test on Brick

i. **BB M1 Brick:**
Sample 1:

- Dry weight of brick (W1)= 15.850 kg
- Wet weight of brick (W2) =18.420 kg
- Water absorption (%) = $\frac{(18.420 - 15.850)}{15.850} \times 100$ =16.2%

Sample 2:

- Dry weight of brick (W1) = 15.450 kg
- Wet weight of brick (W2) = 17.940 kg
- Water absorption (%) = $\frac{(17.940 - 15.450)}{15.450} \times 100$ =16.11%

Average water absorption (%) = 16.2%.

ii. **BB M2 BRICK:**

Sample 1:

- Dry weight of brick (W1) =15.300 kg
- Wet weight of brick (W2) =16.940 kg
- Water absorption (%) = $\frac{(16.940 - 15.300)}{15.300} \times 100 = 10.71\%$

Sample 2 :

- Dry weight of brick (W1) = 15.320 kg
- Wet weight of brick (W2) = 16.950 kg
- Water absorption (%) = $\frac{(16.950 - 15.320)}{15.320} \times 100 = 10.63\%$

Average water absorption (%) =10.67%

iii. BB M3 BRICK:

Sample 1:

- Dry weight of brick (W1) = 15.210 kg
- Wet weight of brick (W2) = 16.610 kg
- Water absorption (%) = $\frac{(16.610 - 15.210)}{15.210} \times 100 = 9.20\%$

Sample 2:

- Dry weight of brick (W1) =15.250 kg
- Wet weight of brick (W2) = 16.650 kg
- Water absorption (%) = $\frac{(16.650 - 15.250)}{15.250} \times 100 = 9.18\%$

Average water absorption (%) = 9.19 %

iv. BB M4 BRICK:

Sample 1:

- Dry weight of brick (W1) =15.400 kg
- Wet weight of brick (W2) = 16.360 kg
- Water absorption (%) = $\frac{(16.360 - 15.400)}{15.400} \times 100 = 6.23\ \%$

Sample 2 :

- Dry weight of brick (W1) = 15.450 kg
- Wet weight of brick (W2) = 17.010 kg
- Water absorption (%) = $\frac{(17.010 - 15.450)}{15.450} \times 100 = 10.09\%$

Average water absorption (%) = 8.16 %

Result :

- % of water absorption for BB M1 brick is 16.2% .
- % of water absorption for BBM2, BBM3, BBM4 is 10.67 %, 9.19 %, and 8.16 % .
- The overall water absorption rate of normal laterite soil block has been decreased by adding admixtures to the soil.

B.4 Efflorescence Test on Bricks

Table.B.10 Efflorescence test on bricks

Brick designation	% of white layer on the surface (%)	Effloreсsence
BB M1 (Only soil)	10	Slight
BB M2 (85-5-5-5)	10	Slight
BB M3 (80-10-5-5)	10	Slight
BB M4 (75-15-5-5)	10	Slight

Result:

- White deposits are present.
- Deposits appear scattered and limited.
- Surface coverage appears less than 10%.
- No visible powdering or flaking.

Appendix C

Validation by ANSYS Software

- The compressive strength of bricks (7 & 28 days) obtained from CTM machine are validated through ANSYS software.
- The values obtained from ANSYS software are approximately equal to the value obtained from the CTM machine.

Result:

Table.C.1 7 days compressive strength validation data.

Brick designation	CTM value (N/mm^2)	Value obtained from ANSYS software (N/mm^2)
BB M1	2.583	2.490
BB M2	4	3.735
BB M3	4.25	4.046
BB M4	3.625	3.444

Table.C.2 28 days compressive strength validation data

Brick designation	CTM value (N/mm^2)	Value obtained from ANSYS software (N/mm^2)
BB M1	1	1.0886
BB M2	3.125	3.035
BB M3	3.415	3.113
BB M4	2.958	2.760

Authors' Biography

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Jibi Kurian is an Assistant Professor in the Department of Civil Engineering at Visat Engineering College, Elanji, Kerala, India.She has several years of teaching and research experience.

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