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A PARAMETRIC STUDY ON STABILIZED MUD BLOCKS

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***Abstract*— Stabilized Mud Blocks (SMBs) are eco-friendly building materials made from soil mixed with stabilizers like cement or lime. They are strong, durable, and require less energy compared to traditional burnt brick's provide good thermal insulation, helping maintain comfortable indoor temperatures. They reduce construction costs by using locally available materials and labour. Overall, SMBs promote sustainable and affordable construction practices.**

I. Introduction

Sustainable building materials, stabilized mud blocks emerge as a humble yet powerful solution, bridging ancient wisdom with modern engineering. Imagine villages across India and Africa, where homes have stood for centuries using sun-dried earth—simple, local, and in harmony with nature. But these traditional mud bricks often crumbled under heavy rains or earthquakes, prompting innovators to "stabilize" them by adding just enough cement, lime, or even fly ash to boost strength without losing their eco-friendly soul. This parametric study dives into how tweaking ingredients and processes can turn fragile earth into robust blocks, perfect for affordable housing in a warming world.


What makes stabilized mud blocks so appealing is their low carbon footprint compared to fired bricks or concrete. Producing them skips energy-guzzling kilns; instead, a simple mix of soil, sand, water, and 5-10% stabilizer gets compressed under pressure into dense units. Researchers have long experimented with these variables—soil type, stabilizer dosage, compaction force—revealing blocks that rival conventional masonry in compressive strength, often hitting 4-7 MPa after curing. It's like giving mud a superpower, making it viable for load-bearing walls while slashing construction costs by up to 30%.

II. TYPES OF STABILIZED MUD BLOCKS TABLE

Stabilized mud blocks (SMBs) come in several types, differentiated by stabilizers, production techniques, and additives, each tailored for specific construction needs like strength, cost, or sustainability.

1.CEMENT – STABILIZED MUD BLOCKS :

Cement-stabilized mud blocks use 5-10% Portland cement mixed with soil, sand, and water, then compressed into dense units for rapid strength development. This type achieves compressive strengths of 4-7 MPa after 28 days, making it suitable for load-bearing walls in multi-story buildings, while its low water absorption enhances durability in moderate climates.

2.LIME- STABILIZED MUD BLOCKS :

Lime-stabilized variants incorporate 5-8% hydrated lime or quicklime, which reacts slowly with soil clay to improve workability and long-term erosion resistance, ideal for wet or humid regions. These blocks offer good flexibility, with strengths around 2-5 MPa, and excel in seismic areas due to lower brittleness than cement types.

3.FLY- ASH STABILIZED MUD BLOCKS:

Fly ash-stabilized mud blocks blend 10-20% industrial fly ash (a coal combustion byproduct) with minimal cement (3-5%), promoting eco-friendly reuse while boosting compressive strength by 50-100% over plain soil blocks.

4.FIBER – REINFORCED MUD BLOCKS :

Fiber-reinforced SMBs add natural (coir, sisal) or synthetic (plastic, polypropylene) fibers at 0.5-2% to a base stabilized mix, significantly improving tensile and flexural strength while curbing shrinkage cracks.

5.INTERLOCKING STABILIZED MUD BLOCKS:

Interlocking SMBs feature moulded shapes like dovetails or knobs for mortar-free stacking, using cement or lime stabilization (5-8%) to ensure precision and bondless assembly.

III. FEATURES OF STABILIZED MUD BLOCKS

1.High compressive strength: Stabilized mud blocks achieve 1.5-10 MPa compressive strength, suitable for load-bearing walls in multi-story structures, rivalling conventional bricks.
2.Low water Absorption: Typically under 15% after 24-hour immersion, ensuring durability against moisture and erosion in various climates.
3.Eco-friendly Composition: Made from 70-90% local soil/sand with 5-10% stabilizers like cement or lime; no firing required, reducing CO2 emissions by up to 70% compared to fired bricks.
4.Thermal insulation: Excellent thermal mass regulates indoor temperatures, minimizing HVAC needs and keeping buildings cool in summer, warm in winter.
5.Acoustic Performance: Dense structure provides superior sound insulation, ideal for noise reduction in residential or urban settings.

IV. ADVANTAGES OF STABILIZED MUD BLOCKS

1.Sustainability and Eco-Friendliness: Stabilized mud blocks use 70-90% local soil with minimal stabilizers, requiring no energy-intensive firing like bricks, cutting CO2 emissions by up to 70% and promoting green construction.
2.Cost – Effectiveness: 20-40% cheaper than traditional materials due to on-site production from abundant local resources, reducing transport and labor costs in rural areas.
3.Thermal Insulation: High thermal mass keeps interiors cool in summer and warm in winter, lowering HVAC energy needs and enhancing comfort without extra insulation.
4.Sound insulation: Dense composition minimizes noise transmission, ideal for residential buildings in noisy environments.
5.Structural Strength: Compressive strength of 1.5-10 MPa supports load-bearing walls comparable to clay bricks, with good durability when cured properly.

V. SCOPE OF STABILIZED MUD BLOCKS

1.Sustainable alternative to fired bricks for low- and mid-rise buildings.
2.Reduces construction cost, making housing more affordable.
3.Enables local, on-site production and rural employment.
4.Supports green building and low-carbon construction goals.
5.Allows reuse of industrial and construction waste in blocks.
6.Suits climate-responsive, energy-efficient building designs.

VI. LITERATURE REVIEW

V. Venkataraman Reddy and A. Gupta, in a (2006) paper "Strength and Elastic Properties of Stabilized Mud Block Masonry Using Cement-Soil Mortars – A Parametric Study the Journal of Materials in Civil Engineering (ASCE), found that 1:6 cement-soil mortars optimized bond strength and elasticity, with masonry prisms showing 2-3 MPa shear capacity suitable for low-rise seismic zones.
V. Prakash and A. Raj, in their (2016) study "Experimental Investigation on Stabilized Mud Blocks with Fibers – A Parametric Study" published in the Journal of Civil Engineering and Technology, tested cement-stabilized blocks with coir and plastic fibers, achieving up to 4.5 MPa compressive strength and 12% water absorption, outperforming plain cement mixes by reducing cracking under load.
Vignesh N.P, Arunachalam N, Mahendran K, Dinesh Kumar B"A Study on Polymeric Fibre Reinforced Stabilized Mud Blocks" , (2021), IOP Conference Series : Materials Science and Engineering. They worked with black cotton soil

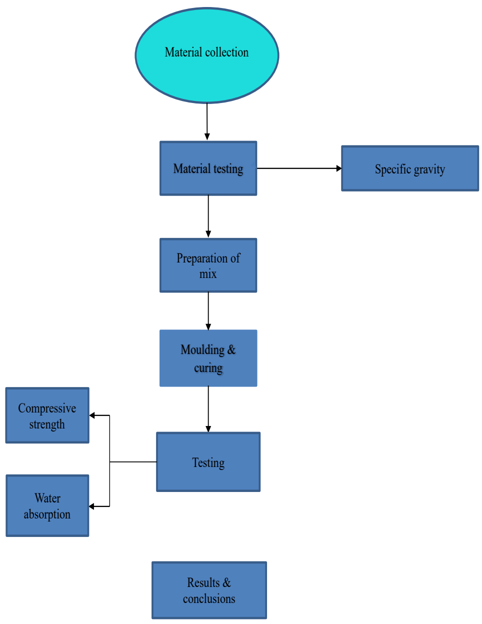
(which is brittle & has poor strength) and tried various fibre additives (polypropylene

Rohith Kumar Reddy, Sangeetha G, Veeresh G M, MeghashreeM Strength Analysis of Stabilized Mud Blocks" (2021). International Journal of Engineering Research and Technology (IJERT). Compressive strength of stabilized mud blocks increased with higher cement content. Cement content in mortar influenced masonry strength significantly

VI. OBJECTIVES

1.To determine the optimum mix proportions of soil, stabilizer (cement).
2.To determine the water absorption of stabilized mud block.
3.To compare the cost effectiveness and strength performance of stabilized mud blocks with conventional burnt clay bricks.

METHODOLOGY



VII. MATERIAL REQUIREMENTS

1.Soil: Clayey or silty soil suitable for making mud blocks. It should be free from organic matter, stones, and large particles.
2.Stabilizer: Cement and lime is used as a stabilizing agent to improve strength and durability.
3.Water: Clean water for mixing the soil, sand, and stabilizer.

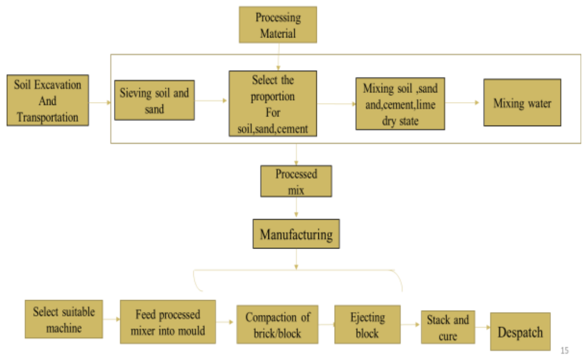
A. MATERIAL SELECTION

First of all, the collection is done for the materials like soil, cement, sand , lime powder, water , mould.

Soil testing

Then, the sieve analysis of soil through 4.75mm sieve is done for particle size distribution test.
Then the required calculation for mix design of mud block is done to develop the test soil.

B. MIX PREPARATION OF A MATERIALS :(IS 17165 : 2020)



VIII. PROCEDURE

1. Take a suitable quantity of oven-dried soil. The mass of soil sample required for each test depends on the maximum size of material.
2.Clean the sieves to be used, and record the weight of each sieve and the bottom pan.
3.Arrange the sieves to have the largest mesh size at the top of the stack. Pour carefully the soil sample into the top sieve and place the lid over it.
4.Place the sieve stack on the mechanical shaker, screw down the lid, and vibrate the soil sample for 10 minutes.
5.Remove the stack and re-weigh each sieve and the bottom pan with the soil sample fraction retained on it.

A. MATERIAL TESTS

1.Specific Gravity of Soil:

Specific gravity of soils, typically ranging from 2.60 to 2.80 for most fine-grained soils used in stabilized mud blocks (e.g., 2.65 for clays, 2.70 for silts), measures the ratio of soil particle density to water density at 4°C or 27°C standard temperature.

B. PROCEDURE

•Clean and dry a 50-100 mL pycnometer with cap; weigh empty (W_1).

•Place 10-20 g air-dried soil (passing No. 4 sieve) into pycnometer; weigh with soil (W_2).

•Dry pycnometer + soil at 105-110°C for 24 hours; cool in desiccator and confirm dry weight.

•Fill with distilled water at 27°C, apply vacuum/boil to remove air bubbles; cap and weigh (W_3).

•Empty contents, rinse thoroughly, refill with water only to mark, cap, and weigh (W_4).

•Use formula Gs=(W2-W1)/((W2-W1)-(W3-W4)) Repeat 3 times for average; note 2.18 indicates potential organics, retest if needed for SMB suitability.

VIII. OBSERVATIONS & CALCULATIONS

Specific gravity is the ratio of the density of a substance to the density of water or air at a specified temperature and pressure.

Observation:

Empty weight of pycnometer with cap lid(W1) =600 gram

Weight of pycnometer + Soil(W2) =1015 gram

Weight of pycnometer + Soil + Water (W3) =1855gram

Weight of pycnometer + Water (W4) =1630 gram

∴ specific gravity of soil is (G) = (W2 – W1)

(W2-W1) - (W3-W4)

= 2.66

Fig: Specific gravity of soil

2.Specific gravity of cement:

The specific gravity of cement measures its density relative to water, typically ranging from 3.1 to 3.16, meaning cement is about three times denser than water. This value is crucial for concrete mix design, as it helps determine proper proportions and assess cement quality.

VIII. PROCEDURE

•Weigh the clean, dry empty flask and record as W1.

•Add approximately 50g of cement to the flask, mix gently, weigh again, and record as W2.

•Fill the flask with kerosene up to the mark (about 24 mm), shake thoroughly to remove air bubbles, then weigh and record as W3.

•Empty the flask, clean it, fill completely with kerosene alone, weigh, and record as W4.

•Use the formula: Specific Gravity Sg=W2−W1(W2−W1)−(W3−W4)×0.79 where 0.79 accounts for kerosene's specific gravity. The result should be 3.1-3.16 for quality cement.

A. OBSERVATIONS & CALCULATIONS

Weight of empty bottle (W1) = 40gram

Weight of bottle + water (W2) = 140gram

Weight of bottle + kerosene (W3) =125gram

Weight of bottle + 1/3rd of cement + kerosene (W4) = 160gram

Weight of cement (W5) = 50gram

Results:

Specific gravity of kerosene (Gk) = 0.85

Specific gravity of cement (g) = (W5)

(W5+W3) – (W4)

= 3.33

B. MIX DESIGN ACCORDING TO MATERIALS REQUIREMENT

•Block 1 = 80% Soil, 10% Cement, 5% Sand, 5% Lime (Dimension = 190*90*90 mm)
•Block 2 = 75% Soil, 15% Cement, 5% Sand, 5% Lime (Dimension = 190*90*90 mm)
•Block 3 = 70% Soil, 20% Cement, 5% Sand, 5% Lime (Dimension = 190*90*90 mm)
•Volume of a Mud block = length * wide* thickness
= 190*90*90 mm^3
= 1,539,000 mm^3
•Weight of a Mud block =2.700 KG

Fig: Blocks

Block 1 : Stabilized Mud Block

Block 1 = 80% Soil , 10% Cement , 5% Sand , 5% Lime (Dimension = 190*90*90 mm)

S.NO	MATERIALS	PERCENTAGE	WEIGHT(kg)
1	SOIL	80%	2.16
2	CEMENT	10%	0.27
3	SAND	5%	0.135
4	LIME	5%	0.135
		TOTAL	2.70

Block 2 : Stabilized Mud Block

Block 2 = 75% Soil, 15% Cement , 5% Sand , 5% Lime (Dimension = 190*90*90 mm)

S.NO	MATERIALS	PERCENTAGE	WEIGHT(kg)
1	SOIL	75%	2.025
2	CEMENT	15%	0.405
3	SAND	5%	0.135
4	LIME	5%	0.135
		TOTAL	2.70

Block 3 : Stabilized Mud Block

Block 3 = 70% Soil, 20% Cement , 5% Sand , 5% Lime (Dimension = 190*90*90 mm)

S.NO	MATERIALS	PERCENTAGE	WEIGHT(kg)
1	SOIL	70%	1.89
2	CEMENT	20%	0.54
3	SAND	5%	0.135
4	LIME	5%	0.135
		TOTAL	2.70

VIII. TESTING PROTOCOL

•To find the optimum mix proportions of stabilized mud blocks.
•To determine the water absorption of stabilized mud blocks.
•To determine the compressive strength of stabilized mud blocks.

Water Absorption Test of Stabilized Mud Block:
Water absorption test on stabilized mud blocks is usually done as per IS 3495 (Part 2) for burnt clay/building blocks. The aim is to find percentage water absorbed in 24 hours.

Procedure:

Apparatus and Preparation

•Clean, dry wire brush, tray/tub for water, weighing balance (accuracy 1 g or better).
•Oven capable of maintaining about 105–110°C.
•Take at least 3 representative stabilized mud blocks.
•Dry loose dust from block surfaces with a brush and record block identification.

Step 1: Oven Drying

•Place blocks in a ventilated oven at 105–110°C.
•Dry to constant mass (two consecutive weights at 2–3 hours interval should be the same).
•Remove blocks, allow them to cool to room temperature in dry air.
•Weigh each block and record the dry weight Wd(in kg or g).

Step 2: Immersion in Water

•Fill a tank or tray with clean, room-temperature water so that blocks will be fully submerged.
•Place the dry blocks in water so that water covers them by at least 25 mm.
•Ensure blocks do not touch each other and are fully submerged (use a grille if needed).
•Keep the blocks immersed undisturbed for 24 hours at room temperature.

Step 3: Surface Drying and Weighing

•After 24 hours, remove blocks one by one from water.

•Wipe off surface water quickly with a damp cloth so only free surface water is removed (do not allow water to evaporate significantly).

BLOCK SAMPLE	WEIGHT OF BLOCK BEFORE WATER ABSORPTION (Kg)	WEIGHT OF BLOCK AFTER WATER ABSORPTION (Kg)
1	2.535	3.010
2	2.650	3.120
3	2.700	3.145

•Immediately weigh each block and record the wet saturated weight Ww.

Step 4: Calculation

•For each block, calculate water absorption percentage:

•Water absorption (%)=Ww−WdWd×100

•Take the average of all tested blocks as the water absorption of the stabilized mud blocks.

•Compare the result with the specified limit (for many stabilized blocks, typically not more than about 15–18% by weight, as per project or code requirements).

IX. OBSREVATIONS & CALCULATIONS

Fig: water absorption

Compressive Strength Test of Stabilized Mud Block:

The compressive strength test for stabilized mud blocks measures their load-bearing capacity using standards like IS 3495 or ASTM C67, adapted for earth blocks.

1. ***Sample Preparation***

•Cure blocks for 28 days per specs, then select at least 3 representative samples.

•Immerse in water for 24 hours to saturated surface-dry state, then wipe excess moisture.

•Measure dimensions (length, width, height) precisely to calculate cross-sectional area.

2. ***Machine Setup***

•Use calibrated compression testing machine with platens larger than block face.

•Center block on lower platen for flat, perpendicular contact on molded face.

•Cap uneven surfaces with thin cement mortar or neoprene pads if required.

3. ***Testing Steps***

•Apply continuous load at 2.5-4 N/mm² per second until failure.

•Record maximum failure load and observe failure mode (e.g., shear, splitting).

•Test all samples; average results, excluding outliers.

4. ***Calculations***

•Strength = maximum load (N) / cross-sectional area (mm²), in MPa.

•Target 3-5 MPa for 5-10% cement-stabilized blocks at 28 days.

•Report dimensions, load, strength, and compare to standards like 3.5 MPa minimum (IS 1725).

Calculation:

Sample	Load (in KN)	Area (in mm^2)	Compressive strength (N/mm^2)
1	50	190*90 = 17100	2.923
2	80	190*90 = 17100	4.678
3	110	190*90 = 17100	6.432
Brick	400	200*100 = 20000	20

Fig: Compressive strength of blocks

X. RESULTS

A. FOR WATER ABSORPTION TEST:

The water absorption of stabilized mud block is approximately 16% to 19%,which reflects a moderate level of porosity. These values are slightly higher than those of conventional burnt bricks but still fall within an acceptable range for stabilized earthen construction. The water absorption percentage also suggests that the block would perform satisfactorily in dry and semi- dry climatic conditions, through protective plastering or surface coatings are recommended for enhanced durability in areas exposed to heavy rain fall.

B. FOR COMPRESSIVE STRENGTH TEST

The compressive strength of the stabilized mud blocks range from 2.923 to 6.432 N/mm^2, which although lower than the 20 N/mm^2 strength of burnt brick, are adequate for low-rise buildings, partition wall, and general housing application. The variation in strength highlights the influence of stabilized type, compaction, and curing method, suggesting that improve stabilization and better compaction can further enhance block performance .Overall ,the result confirm that stabilized mud block are a sustainable, economical, and structurally viable alternative for environmentally friendly construction.

XI. CONCLUSIONS

A. WATER ABSORPTION TEST

1. After soaking in water, each stabilized mud block absorbed some water.
2. The absorption value is within the acceptable range.
3. This shows that stabilized mud blocks have moderate water resistance.
4. However, they are less water-resistant than burnt clay bricks.

B. COMPRESSIVE STRENGTH TEST

1. The stabilized mud blocks achieved compressive strength values ranging from 2.9 to 6.4 N/mm².
2. This is significantly lower than the strength of burnt bricks (about 20 N/mm²).
3. Therefore, stabilized mud blocks are suitable for low-load or non-structural applications.
4. They are not as strong as conventional burnt bricks and should not be used for high-load structural elements.

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