LOW COST ROOFING TILES USING AGRICULTURAL WASTE

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***Abstract*— The increasing demand for affordable and sustainable construction materials has led to the exploration of alternative resources in building technology. This study investigates the use of agricultural waste, specifically rice husk ash (RHA), as a partial replacement for manufactured sand (M-sand) in the production of low-cost roofing tiles. Various mix proportions were prepared by replacing M-sand with RHA in different percentages, and the resulting tiles were tested for compressive strength . The results indicate that a limited replacement of M-sand with RHA can produce roofing tiles with satisfactory strength while significantly reducing cost and environmental impact. The optimum performance was observed at lower replacement levels, making this method suitable for sustainable and economical construction practices.**

Keywords- Rice husk ash, low-cost roofing tiles, Agricultural waste, Sustainable construction,C compressive strength

1. INTRODUCTION

Roofing tiles are one of the most important components in building construction, primarily used to protect structures from rain, sunlight, and other environmental effects. traditionally, tiles have been manufactured using materials such as clay, slate, and more recently concrete and plastics. these materials, although effective, are often costly and require significant natural resources for production. with the increasing demand for affordable housing, especially in developing regions, there is a growing need to develop alternative roofing materials that are both economical and sustainable.

At the same time, agricultural activities generate large amount of waste such as rice husk, which creates serious disposal and environmental challenges. Instead of treating this waste as useless, it can be processed into valuable construction material. In this study, rice husk ash (rha) is used as a partial replacement for manufactured sand (m-sand) in roofing tiles. The objective is to reduce cost while maintaining sufficient strength and durability. This approach not only lowers the price of roofing materials but also promotes eco-friendly construction practices by converting waste into a useful resource.

1.1. SIGNIFICANCE OF STUDY

The use of m- sand, red soil and clay combined with rha To produce roof tiles will impact significantly in the eeduction of roofing tile construction costs, while still Converting the country's deposits of agricultural waste Which is obviously an environmental health hazard to Economic purposes for national development.

1.2. AIM OF THE PROJECT

The main aim of this study is to develop cost-Effective roofing tiles by utilizing agricultural WASTE MATERIALS.

The objectives are:

- To study the properties of rice husk ash and other Materials
- To replace a portion of m-sand with rha in different proportions
- To prepare roofing tile samples using various mix ratios
- To evaluate compressive strength

To determine the optimum percentage of replacement

2. LITERATURE REVIEW

The use of agricultural waste in construction materials has gained significant attention due to sustainability concerns and resource depletion. Rice husk ash (RHA), a by-product of rice milling, has been widely studied for its pozzolanic properties and suitability in construction applications such as roofing tiles.

A study published in 2016 in the International Journal of Engineering Research & Technology (IJERT) by IJERT Publisher investigated the production of roofing tiles using RHA as a partial replacement for cement. The study reported that optimum replacement improved compressive strength and durability due to the pozzolanic reaction, while higher percentages resulted in reduced strength because of increased porosity.

In 2017, a research article published by Elsevier in the journal Construction and Building Materials examined the incorporation of RHA in clay roofing tiles. The study concluded that RHA improved compressive strength and thermal insulation properties at lower percentages, but excessive addition led to strength reduction due to poor particle packing.

A comprehensive review published in 2021 in the journal Journal of King Saud University – Engineering Sciences by Elsevier discussed the behavior of RHA in construction materials. The paper highlighted that RHA contains a high amount of amorphous silica, which enhances strength through pozzolanic reactions. However, the study emphasized that excessive use of RHA negatively affects strength due to increased porosity and reduced bonding efficiency.

Another review study published in 2021 in the journal Materials by MDPI analyzed RHA-based construction composites. The research concluded that RHA improves compressive strength, durability, and environmental sustainability, but only when used in controlled proportions. Beyond the optimum level, mechanical properties decline.

A recent study published in 2025 in the journal Asian Journal of Civil Engineering by Springer investigated the compressive strength of mortar with partial replacement of fine aggregate using RHA. The study found that strength increased up to an optimum replacement level due to filler effect and secondary hydration, while further addition reduced strength due to increased void content.

3. METHODOLOGY

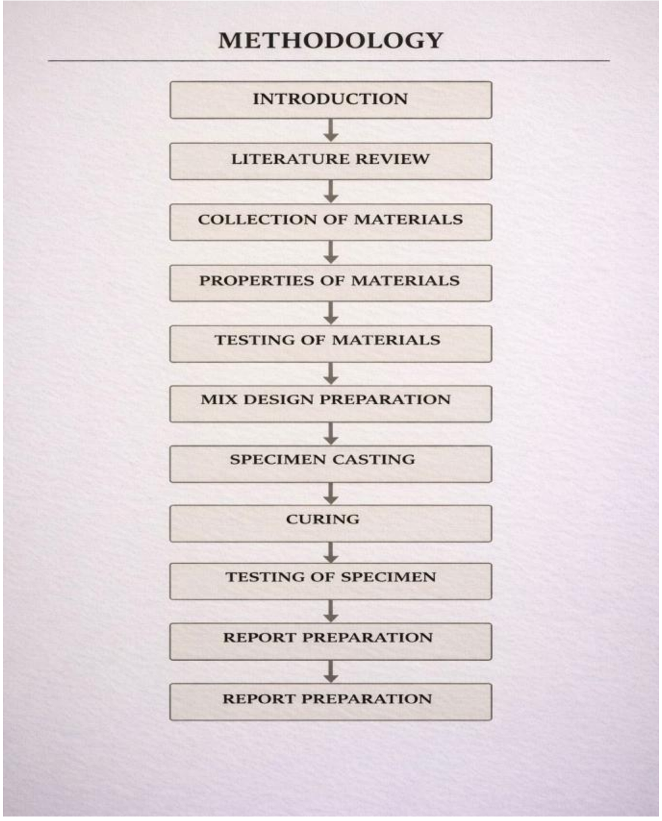


Fig 1. Flow chart of Methodology

4. COLLECTION OF MATERIALS

4.1 M-SAND

M-sand is an artificially produced fine aggregate obtained by crushing hard stones and is widely used as a replacement for natural river sand. It serves as the main base material in the preparation of roofing tiles. Due to its uniform particle size and proper grading, M-sand provides better bonding with other materials, resulting in improved compressive strength and durability. It also helps in reducing environmental damage caused by excessive river sand mining, making it a sustainable construction material.

4.2 CLAY

Clay is a natural material known for its excellent binding and plasticity properties. When mixed with water, it becomes highly moldable, allowing easy shaping of roofing tiles during the casting process. Upon drying and curing, clay hardens and provides cohesion to the tile structure. It plays a crucial role in maintaining the shape and integrity of the tiles, making it an essential component in traditional as well as modern tile production.

4.3 REDSOIL

Red soil is commonly used in construction due to its fine texture and natural binding capacity. It improves the workability and consistency of the tile mixture, ensuring a uniform distribution of materials. The presence of iron oxide in red soil contributes to its strength and stability. In roofing tiles, it helps enhance the overall composition and provides additional support to the structure.

4.4 RICE HUSK ASH

Rice husk ash is an agricultural waste material obtained from the controlled burning of rice husk. It is rich in silica and possesses pozzolanic properties, which allow it to react with binding materials and enhance certain mechanical properties. In roofing tiles, RHA is used as a partial replacement for M-sand to reduce cost and promote sustainability. It also helps in producing lightweight tiles with improved thermal insulation. However, if used in excessive amounts, it can increase porosity and reduce the strength of the tiles.

4.5 WATER

Water is an essential ingredient in the preparation of roofing tiles, as it facilitates proper mixing of all materials and initiates the hydration process required for binding and hardening. The quality of water used should be clean and free from impurities to avoid affecting the strength of the tiles. Proper control of water content is important, as excess water can weaken the mix, while insufficient water can lead to poor workability. Adequate curing with water ensures the development of strength and durability in the final product.

5. EXPERIMENTAL STUDY

5.1 PRILIMINARY TEST FOR MATERIALS

Specific gravity and Sieve Analysis was made for an each materials of Rice husk ash, Clay, Red soil and M-sand.

5.1.1 Specific Gravity of Rice Husk Ash

Aim: To determine the specific gravity of Rice Husk ash.

Apparatus:

1. A Pycnometer
2. A balance of 3kg capacity
3. ½ Litres of capacity glass jar and ground glass dish.
4. A drying duster.

Theory:

The specific gravity of a material is the ratio of its unit weight to that of water. For the purpose of mix design, the specific gravity of saturated and surface-dry basis is used. The specific gravity of Rice husk ashfalls with the range of 2.00
3.00. The specific gravity of an Rice husk ash is an important factor affecting the density of the resulting roof tiles. The specific gravity of a Rice husk ash can be determined from the expression below.

Specific Gravity(Gs)=B/P+B-Ps

Where B = Weight of Rice husk ash.

P= Weight of Pycnometer

Ps=W eight of Pycnometer + water + Rice husk ash.

Procedure:

Step 1: The Pycnometer was filled with distilled water to full capacity with the screw in position and the outside dried and the weight was recorded (P).

Step2: The cap was unscrewed and a sample of surface dry (oven dry) sand of know weight (600g) or (mg of Rice husk ash) (B) was introduced.

Step 3: The cap was replaced and the Pycnometer refilled to full the Capacity with distilled water. All trapped was eliminated by rotating the Pycnometer on its side whilst covering the hole with finger.

Step 4: The outside of the Pycnometer was dried and reweighed (Ps). The Pycnometer now contained less water than before and the weight of water occupying the same volume as the sample is (P + B + PS).

5.1.2 Specific Gravity Of Clay

Aim: To determine the specific gravity of Clay.

Apparatus:

1. A Pycnometer
2. A balance of 3kg capacity
3. ½ Litres of capacity glass jar and ground glass dish.
4. A drying duster.

Theory: The specific gravity of a material is the ratio of its unit weight to that of water. For the purpose of mix design, the specific gravity of saturated and surface-dry basis is used. The specific gravity of Clay falls with the range of 1.80 — 2.50. The specific gravity of an Clay is an important factor affecting the density of the resulting roof tiles. The specific gravity of a clay can be determined from the expression below.

Specific Gravity(GS)= B/P+B-Ps

Where B = Weight of Clay.

P= Weight of Pycnometer

Ps=W eight of Pycnometer + water + Clay.

Procedure:

Step 1: The Pycnometer was filled with distilled water to full capacity with the screw in position and the outside dried and the weight was recorded (P).

Step2: The cap was unscrewed and a sample of surface dry (oven dry) sand of know weight (600g) of Clay (B) was introduced.

Step 3: The cap was replaced and the Pycnometer refilled to full the Capacity with distilled water. All trapped was eliminated by rotating the Pycnometer on its side whilst covering the hole with finger.

Step 4: The outside of the Pycnometer was dried and reweighed (Ps). The Pycnometer now contained less water than before and the weight of water occupying the same volume as the sample is (P + B + PS).

5.1.3 Specific Gravity of Red Soil

Aim: To determine the specific gravity of Red soil.

Apparatus:

1. A Pycnometer
2. A balance of 3kg capacity
3. ½ Litres of capacity glass jar and ground glass dish.
4. A drying duster.

Theory:

The specific gravity of a material is the ratio of its unit weight to that of water. For the purpose of mix design, the specific gravity of saturated and surface-dry basis is used. The specific gravity of Red soil falls with the range of 1.20 - 1.50. The specific gravity of an Red soil is an important factor affecting the density of the resulting roof tiles. The specific gravity of a Red soil can be determined from the expression below.

Specific Gravity(Gs)=B/P+B-Ps

Where B = Weight of Red soil.

P= Weight of Pycnometer

Ps=W eight of Pycnometer + water + Red soil.

Procedure:

Step 1: The Pycnometer was filled with distilled water to full capacity with the screw in position and the outside dried and the weight was recorded (P).

Step2: The cap was unscrewed and a sample of surface dry (oven dry) sand of know weight (600g) of Clay (B) was introduced.

Step 3: The cap was replaced and the Pycnometer refilled to full the Capacity with distilled water. All trapped was eliminated by rotating the Pycnometer on its side whilst covering the hole with finger.

Step 4: The outside of the Pycnometer was dried and reweighed (Ps). The Pycnometer now contained less water than before and the weight of water occupying the same volume as the sample is (P + B + PS).

5.1.4 Specific Gravity of M-sand

Aim: To determine the specific gravity of M-sand.

Apparatus:

1. A Pycnometer
2. A balance of 3kg capacity
3. ½ Litres of capacity glass jar and ground glass dish.
4. A drying duster.

Theory:

The specific gravity of a material is the ratio of its unit weight to that of water. For the purpose of mix design, the specific gravity of saturated and surface-dry basis is used. The specific gravity of M-sand falls with the range of 2.00 — 2.80. The specific gravity of an M-sand is an important factor affecting the density of the resulting roof tiles. The specific gravity of a M-sand can be determined from the expression below.

Specific Gravity(Gs)=B/P+B-Ps

Where B = Weight of M-sand.

P= Weight of Pycnometer

Ps=W eight of Pycnometer + water + M-sand.

Procedure:

Step 1: The Pycnometer was filled with distilled water to full capacity with the screw in position and the outside dried and the weight was recorded (P).

Step2: The cap was unscrewed and a sample of surface dry (oven dry) sand of know weight (600g) of Clay (B) was introduced.

Step 3: The cap was replaced and the Pycnometer refilled to full the Capacity with distilled water. All trapped was eliminated by rotating the Pycnometer on its side whilst covering the hole with finger.

Step 4: The outside of the Pycnometer was dried and reweighed (Ps). The Pycnometer now contained less water than before and the weight of water occupying the same volume as the sample is (P + B + PS).

Table 1 : Specific Gravity

5.2 PARTICLE SIZE DISTRIBUTION

Aim: Determination of particle size distribution in a sample of M-sand, Red soil and Clay.

Apparatus:

1. Set of B.S Sieves of sizes (5.0, 3.35, 2.36, 1.70, 1.80, 0.85, 0.60, 0.425, 0.30, 0. 5, 0.075, pan) mm for all sample.
2. Balance readable and accurate to 0.1% of the weight is test samples

Theory:

Sieve analysis involves determination of the size ranges of particle present in all sample expressed as a percentage of the total dry weight. The sieve analysis method is used to determine the particle sizes of aggregate larger than 0.075mm e.g. Sand, gravels, cobbles, pebbles, boulders etc. while the hydrometer analysis are use to determine the particle size soil aggregate less than or smaller than 0.075mm in diameter. In sieve analysis, the soil sample is passed through a series of standard test sieves having progressively smaller openings (smaller mesh sizes). The weight of the soil retained in each of the sieves is determined and the cumulative percentage by weight passing each sieve is calculated mathematically. The sieve analysis procedure were repeated same for all the particles to find the particle size distribution.

5.2.1 Procedure for M-sand

Step 1: AM-sand sample was sun dried to remove all the moisture in the sand.

Step 2: The sample was the weighed 1000g and poured into the mounted set of sieves.

Step 3: The sieves were manually vibrated for 30 seconds.

Step 4: Then each sieve was carefully removed and the retained sample was weighed and recorded.

Step 5: The process in step 4 was continued until all the retained mass on the sieve was recorded.

5.2.2 Procedure for Red soil

Step 1: A Red soil sample was sun dried to remove all the moisture in the sand.

Step 2: The sample was the weighed 1000g and poured into the mounted set of sieves.

Step 3: The sieves were manually vibrated for 30 seconds.

S. N.	MATERIALS	SPECIFIC GRAVITY
1.	Rice Husk Ash	2.3
2.	Clay	2.12
3.	Red Soil	1.53
4.	M-Sand	2.13

Step 4: Then each sieve was carefully removed and the retained sample was weighed and recorded.

Step 5: The process in step 4 was continued until all the retained mass on the sieve was recorded.

5.2.3 Procedure for Clay

Step 1: A Clay sample was sun dried to remove all the moisture in the sand

Step 2: The sample was the weighed 1000g and poured into the mounted set of sieves.

Step 3: The sieves were manually vibrated for 30 seconds.

Step 4: Then each sieve was carefully removed and the retained sample was weighed and recorded.

Step 5: The process in step 4 was continued until all the retained mass on the sieve was recorded

S.ND	IS SIEVE	Weight Retained (grams)			Cum weight retained	Cum (%) retained	Cum (%) retained
		Empty weight of sieve	Retained Weight of sieve	Retained Weight of soil			
1	4.75	0.402	0.419	0.017	0.017	0.017	0.00017
2	2.36	0.356	0.585	0.229	0.229	0.249	0.0249
3	1.18	0.315	0.883	0.568	0.588	0.817	0.0817
4	0.3	0.307	0.308	0.182	0.999	0.999	0.999
5	0.15	0.307	0.308	0.001	1	1	1
6	0.075	0.318	0.300	0.001	1	1	1.05
7	0.033	0.317	0.300	0.033	1.05	1.05	1.0105
8	pan	0.270	0.270	0.305	1.05	1.033	1.0105

S.ND	IS SIEVE	Weight Retained (grams)			Cum weight retained	Cum (%) retained	Cum (%) retained
		Empty weight of sieve	Retained Weight of sieve	Retained Weight of soil			
1	4.75	0.402	0.410	0.282	0.282	0.628	0.0028
2	2.36	0.353	0.563	0.210	0.563	0.509	0.0566
3	1.18	0.315	0.430	0.115	0.568	0.0676	0.0676
4	0.5	0.307	0.308	0.033	0.711	0.0711	0.0711
5	0.6	0.307	0.340	0.033	1	1	1
6	0.15	0.307	0.314	0.014	1	1	1.05
7	0.075	0.307	0.314	0.146	0.874	1.05	0.0725
7	0.057	0.230	0.801	0.871	1.131	0.087	0.0138
6	pan	0.230	0.250	0.250	1.156	0.1136	0.1136

S.NO	IS SIEVE	Weight Retained (grams)			Cum weight retained Empty weight of sieve	Cum (%) retained of sieve	retained Weight
		Empty weight of sieve	Retained Weight of sieve	Retained Weight of soil			
1	4.75	0.402	0.399	0.001	0.497	0.497	0.0049
2	2.36	0.353	0.354	0.001	0.498	0.498	0.0049
3	1.18	0.315	0.931	0.616	1.114	0.114	0.0114
4	0.3	0.324	0.641	0.317	1.431	0.0139	0.0139
5	0.15	0.307	0.450	0.143	1	0.0153	0.0153
6	0.075	0.307	0.341	0.034	1	0.0156	0.0156
7	0.075	0.307	0.341	0.034	1.534	0.0156	0.0162
8	pan	0.280	0.340	0.06	1.628	0.0156	0.0162

6. MIX DESIGN

6.1 SPECIMEN SIZE

Length = 20.32cm
Width = 20.32cm
Thickness = 2.54cm
MASS = VOULME (X) DENSITY
= 203.2 * 203.2 * 25.4 * 2.4 = 2.5 KG
TOTAL WEIGHT = 2.5 kg (203.2mm * 203.2mm* 0.0254mm)
The water quantity will be maintain same for all mix ratio : 0.5 kg

Mix Ratio:

1st MIX: Standard Roof Tiles

S.NO	MATERIALS	PERCENTAGE	WEIGHT(kg)
1	M-SAND	50%	1.25
2	RED SOIL	23%	0.575
3	CLAY	27%	0.675
		TOTAL	2.5

2ndMIX: 7% Of RHA and 43% of M-Sand

S.NO	MATERIALS	PERCENTAGE	WEIGHT(kg)
1	M-SAND	43%	1.075
2	RICE HUSK ASH	7%	0.175
3	RED SOIL	23%	0.575
4	CLAY	27%	0.675
		TOTAL	2.5

3rdMIX: 14% Of RHA and 36% of M-Sand

S.NO	MATERIALS	PERCENTAGE	WEIGHT(kg)
1	M-SAND	36%	0.9
2	RICE HUSK ASH	14%	0.35
3	RED SOIL	23%	0.575
4	CLAY	27%	0.675
		TOTAL	2.5

4thMIX: 21% of RHA and 29% of M-SAND

S.NO	MATERIALS	PERCENTAGE	WEIGHT(kg)
1	M-SAND	29%	0.725
2	RICE HUSK ASH	21%	0.525
3	RED SOIL	23%	0.575
4	CLAY	27%	0.675
		TOTAL	2.5

7. EQUIPMENT USED FOR CASTING OF SPECIMEN

These specimens were casted according to the mix procedure by the following equipments and curing were made at the outside of the lab.

A. MOULDS (WOODEN/METAL)

Because clay mortar sets slowly and the tiles need to be left on the moulds at least overnight before they can be removed. Because it is important that roof tiles cure in a damp environment, the enveloping type of mould was used. These moulds were stacked one on top of the other and hence cover the curing tiles and prevent them from drying out too quickly.

Fig 2. Casting Mould

B. PRODUCTION 0F ROOFING TILES

[1] The required materials were collected and properly weighed according to the predetermined mix proportions for each batch.

[2] All the materials were placed into a pan mixer and thoroughly mixed to achieve uniformity. Water was then added gradually while continuously monitoring the workability of the mix. In this study, rice husk ash (RHA) was used as a partial replacement for M-sand at proportions of 7%, 14%, and 21%.

[3] The prepared mortar mix was transferred into a wheelbarrow and transported to the casting area, where it was evenly spread into the moulds.

[4] A tamping rod was used to compact the mortar inside the moulds, ensuring proper settlement and eliminating air voids for better strength.

[5] After initial setting, the tiles were carefully removed from the moulds to avoid any damage. The moulds and tiles were then arranged systematically and allowed to cure for a period of 24 hours under controlled conditions.

[6] After 24 hours, the tiles were demoulded and placed in the curing area for further curing to achieve the desired strength and durability.

6.2 EXPERIMENTAL TEST PROCEDURES ON ROOF TILES

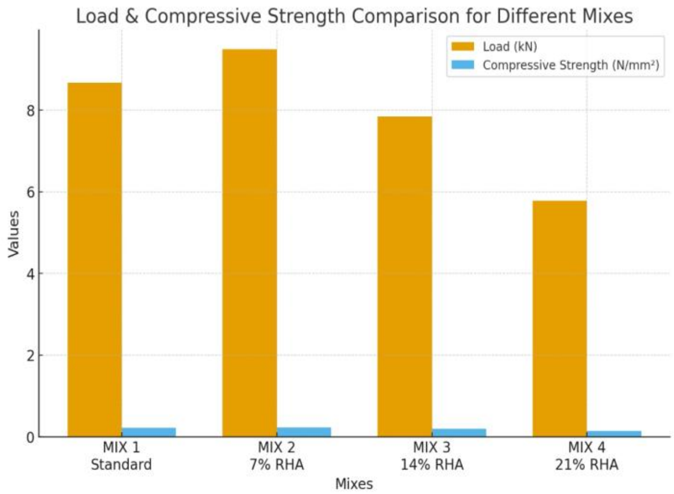
- Due to the level of precision required in the production of roofing tiles and the limited time available for this study, the replacement levels of rice husk ash (RHA) were restricted to a maximum of 21%.
- The dimensions of the test specimens were maintained at 20.32 cm × 20.32 cm × 2.54 cm (length × width × thickness) for consistency in testing.
- The tiles produced were flat and unbevelled in shape, with no specific provision for installation. This limitation was due to restricted funding, as the fabrication of complex formwork for advanced designs was not feasible. Therefore, the study primarily focused on evaluating the material performance rather than installation efficiency.
- The experimental investigation was limited to the determination of compressive strength. No simulation or testing was conducted to evaluate the performance of installed tiles under environmental conditions such as rainfall or wind load.
- A total of four samples were prepared for each mix proportion, including the control mix, to ensure reliable and consistent results.
- For each batch, one sample was tested after a curing period of 7 days to evaluate strength development. Overall, four samples were tested to monitor the variation in strength gain across different mix proportions.

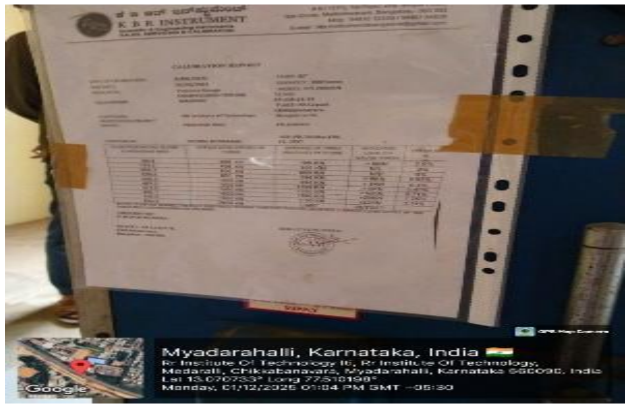
7. TESTING OF LOW COST ROOF TILES
COMPRESSIVE STRENGTH TEST

This test measures the load-bearing capacity of tiles

- Maximum strength was obtained at 7% RHA replacement
- Beyond this level, strength gradually decreased

MIXES	PARTICULARS	LOAD (kN)	COMPRESSIVE STRENGTH TEST (mm^2)
MIX 1	STANDARD TILES	8.67	0.21
MIX 2	7% OF RHA	9.49	0.23
MIX 3	14% OF RHA	7.84	0.19
MIX 4	21% OF RHA	5.78	0.19
pan		2.80	0.16





8. CONCLUSION

From the experimental investigation, it can be concluded that agricultural waste such as rice husk ash can be effectively used in the production of low-cost roofing tiles. The study shows that replacing M-sand with RHA up to a certain limit does not significantly affect the strength of the tiles. The optimum replacement level was found to be around 7%, where the tiles achieved good compressive strength while reducing material cost. Beyond this level, the strength decreases and water absorption increases, making the tiles less durable. Overall, the use of agricultural waste in roofing tiles provides both economic and environmental benefits, making it a promising solution for sustainable construction.

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