International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 03 , March - 2026

Experimental Study on Development of Sustainable Vitrified Tiles using Bio-Waste Materials

Mr. Sahukari Avinash
Assistant Professor
Department of Civil Engineering
Dadi Institute of Engineering and Technology,
Vishakapatnam - Autonomous

Ms. Polamarasetty Mohitha, Ms. Vommi Sri Lakshmi,
Mr. Sadarla Rajkamal
UG Students
Department of Civil Engineering
Dadi Institute of Engineering and Technology,
Vishakapatnam - Autonomous

***Abstract*: - This report addresses the growing environmental concerns and increasing construction waste generation in the modern construction industry. The adoption of sustainable alternatives to conventional building materials has become essential to ensure environmental protection, resource conservation, and long-term material availability. The primary objective of this project is to develop eco-friendly and cost-effective vitrified tiles utilizing bio-waste and recycled materials such as coconut coir, recycled tile waste, lime powder, and natural fiber's. A combination of lime powder, fly ash, and cement is used as binding materials to reduce carbon emissions and promote sustainable construction practices. The proposed tiles aim to minimize the disposal of tile waste generated from retrofitting, renovation, and demolition activities, thereby supporting resource recycling and low-carbon construction. This approach contributes to waste reduction, environmental sustainability, and the advancement of green building materials in the construction sector.**

Keywords: Coconut coir, Recycled tile waste, Lime powder, Fly ash, Cement, Sustainable construction.

I. INTRODUCTION

Vitrified tiles are high-performance ceramic materials produced by firing a precisely proportioned mixture of clay, silica, quartz, and feldspar at very high temperatures. This process causes vitrification, forming a dense, glass-like structure with extremely low porosity, minimal water absorption, and superior mechanical strength compared to conventional ceramic tiles. Due to their durability, strength, and aesthetic versatility, vitrified tiles are widely used in modern residential and commercial construction as flooring and wall finishes, often serving as a costeffective alternative to natural stones such as marble and granite.

However, tile manufacturing generates significant waste. In Europe alone, ceramic tile production produces approximately 3 million tonnes of waste annually. Growing environmental concerns have led to increasing research and industrial adoption of recycling methods, where manufacturing scraps, defective tiles, and demolition waste are reused in new construction materials. Earlier studies since the mid-20th century have laid the foundation for sustainable ceramic waste recycling practices.

Objectives:

1. To design and fabricate vitrified tiles utilizing eco-waste and industrial byproducts.

2. To reduce construction cost and carbon footprint by minimizing cement and virgin raw material use.
3. To assess mechanical, physical, and thermal properties (strength, insulation,
durability) of the tiles.
4. To ensure the tiles are lightweight, durable, and eco-friendly

II. METHODOLOGY

Step-1: Collection of materials
Step-2: Defining material properties
Step-3: Preparation of mix design
Step-4: Batching and mixing of materials Step-5: Casting of tiles Specimen
Step-6: Demoulding and curing of tiles
Step-7: Testing of tiles

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 03 , March - 2026

III. MATERIALS

1. *Cement*

Ordinary Portland Cement (OPC) of 53 grade was used throughout this experimental investigation as the primary binding material. OPC 53 grade is widely preferred in structural and high-strength concrete applications due to its high early strength development and superior compressive strength characteristics. It conforms to the requirements specified in IS 12269:2013, which governs the physical and chemical properties of 53 grade Ordinary Portland Cement in India.
In this investigation, OPC 53 grade was selected to ensure uniformity in the experimental work and to obtain reliable strength and durability characteristics for the prepared specimens.

Fig -1 Cement

Table-1: Properties of Cement

S.NO	Description	Values
1	Normal consistency	31%
2	Specific gravity	3.14
3	Fineness	95%
4	Initial setting time	94 minutes
5	final setting time	197 minutes

2. *Fly Ash:*

Fly Ash is a sustainable, recycled by product of coal combustion used widely in civil engineering for its pozzolanic properties, which enhance the strength, durability and workability of construction materials. Its spherical, fine particles fill concrete voids, leading to denser, more impermeable structures.

Fig-2 Fly ash

Table-2 : Properties of Fly Ash

S.NO	Description	Values
1.	Fineness	78%
2.	Soundness	0.65 mm
3.	Specific gravity	3.02

3. Coconut Coir:

Coconut coir is an eco-friendly and sustainable material with numerous application in civil engineering, primarily
or soil stabilization, erosion control, and as a component in construction materials. Its fibrous nature, high lignin content, and durability make it a viable alternative to synthetic products.

Fig-3 coconut coir

4. Utilized Tile Waste:

Utilized Tile Waste tile, Primarily ceramic, is a significant construction by product that, instead of landfilling, is recycled into new materials like aggregate for concrete, a pozzolanic additive in cement, or feedstock for foam cermaics, supporting a circular economy by reducing waste and conserving resources. It can be crushed into powder or used as aggregate, offering sustainable, cost-effective alternatives to virgin materials, with potential benefits like enhanced concrete strength and reduced pollution

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 03 , March - 2026

Fig-4: Crushed tile waste

5. Lime Powder:

Lime powder, primarily consisting of hydrated lime (calcium hydroxide), is a versatile and traditional construction material that has been used for centuries due to its excellent binding and chemical properties. In construction, lime powder improves the workability and plasticity of mortars and plasters, enabling smoother application and better adhesion with sand and masonry units, while also enhancing durability and reducing shrinkage and cracking during curing

IV. PREPARATION OF MIX DESIGN

Table-3: Mix proportions

S.No	Sample mix 1	Sample mix 2
1	Cement-20%	Cement-20%
2	Flyash-22%	Flyash-17%
3	Lime powder-5%	Lime powder-10%
4	Tile waste-50%	Tile waste-50%
5	Coconut coir-3%	Coconut coir-3%

Convention Tiles:

Conventional tiles are commonly manufactured using a mixture of cement, sand, and aggregates to obtain the required strength, durability, and surface finish. In most cases, cement concrete tiles are prepared by using Ordinary Portland Cement as the main binder combined with fine aggregates such as river sand. The mix proportion generally adopted for conventional cement tiles is about 1:3 (cement : sand) or 1:2:4 (cement : sand : aggregate) depending on the type of tile and strength requirement. Water is added in controlled quantity to achieve proper workability of the mortar mix. The prepared mixture is then placed into moulds, compacted properly to remove air voids, and allowed to set. After casting, the tiles are cured with water for a sufficient period to gain adequate strength and durability before being used for flooring or paving purposes

V. Batching & Mixing of Specimen

The main objectives of the tile motor mix proportions are to select the optimum proportions of various materials to attain the required workability, strength, and durability. On removal from the mould, the tiles shall be kept in moist condition continuously for such a period that would ensure their conformity to the requirements of this standard.

Table-5: Weights of Sample Mix-1

S.No	Material	Proportion	Weight
1	Cement	20%	0.720
2	Flyash	22%	0.792
3	Lime Powder	5%	0.18
4	Crushed Tile Waste	50%	1.8
5	Coconut Coir	3%	0.11

Table-6: Weights of Sample Mix-2

S.No	Material	Proportion	Weight
1	Cement	20%	0.720
2	Flyash	17%	0.612
3	Lime Powder	10%	0.36
4	Crushed Tile Waste	50%	1.8
5	Coconut Coir	3%	0.11

VI. CASTING OF TILES

The prepared mortar was placed into standard moulds suitable for strength and durability testing. Compaction was carried out manually or using vibration to eliminate entrapped air and ensure uniform density. The surface was leveled and finished properly to maintain dimensional accuracy

The dry materials (cement, fly ash, lime powder, and tile waste) were mixed thoroughly to achieve uniform distribution. Coconut coir fibers were added gradually, and water was added slowly until the required workability and consistency were achieved.

Fig:5 Casting Tile Specimens

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 03 , March - 2026

Curing of Specimens

After 24 hours of casting, the concrete specimens were carefully demould to avoid surface damage and edge breakage. The specimens were then immediately transferred to the curing tank to ensure continuous moisture availability Proper curing is essential to promote complete hydration of cement, enhance micro-structural development, and achieve the desired mechanical strength and durability characteristics of concrete.

Fig-6: Curing of Tiles Specimens

VII. TESTS ON SPECIMEN

- ***Transverse Strength Test***

This test was performed to determine the flexural strength and load-carrying capacity of the tile specimens. The tiles were supported at two ends and a gradually increasing load was applied until failure occurred. The maximum load at fracture was recorded to calculate the breaking strength and modulus of rupture.

Fig-7: Transverse strength test on specimen

- ***Resistance To Wear***

This test was conducted to assess the abrasion resistance and durability of the tile surface under frictional forces. The specimen was subjected to controlled abrasive action, and the loss in thickness or weight was measured. The results indicate the suitability of the tiles for flooring applications where surface wear is a critical factor.

Fig-8: Abrasion test for resistance

- ***Drop Test***

The drop test is a crucial assessment of a tile's ability to resist damage from sudden impacts, making it a vital factor in determining its durability and lifespan. During the test, a tile is typically placed on a hard surface and subjected to a controlled impact, as a steel ball or weight dropped from a specified height. The tile's performance is then evaluated based on the extent of the damage, if any, to determine its suitability for various applications

Fig-8: Drop test

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 03 , March - 2026

- ***Water Absorption Test***

The Water Absorption Test is performed to determine the percentage of water absorbed by a tile when immersed in water. This test helps evaluate the porosity, durability, and quality of tiles used for flooring and wall applications. Tiles with low water absorption generally have higher strength, better durability, and improved resistance to moisture damage.

FIG-9: Obtaining weight of the tile specimen

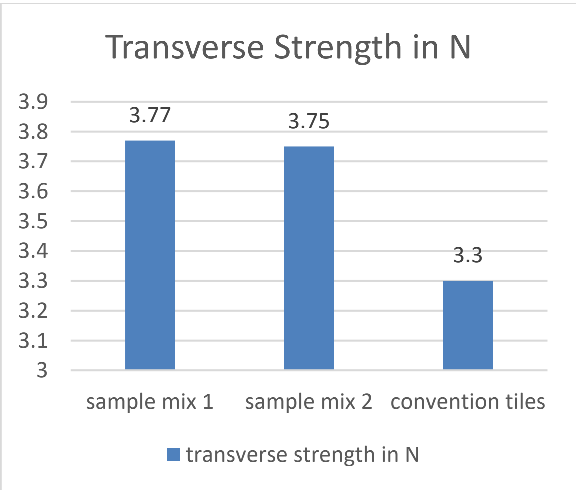
VIII. RESULTS & DISCUSSIONS

i. Transverse Strength

Table-7: Test Results of Sample Mix and Conventional Tile

S.No	Description	Average Transverse Strength
1	Tile with sample Mix -1	3.77
2	Tile with sample Mix -2	3.75
3	Convention tile	3.3

Graph-1 Transverse Strength

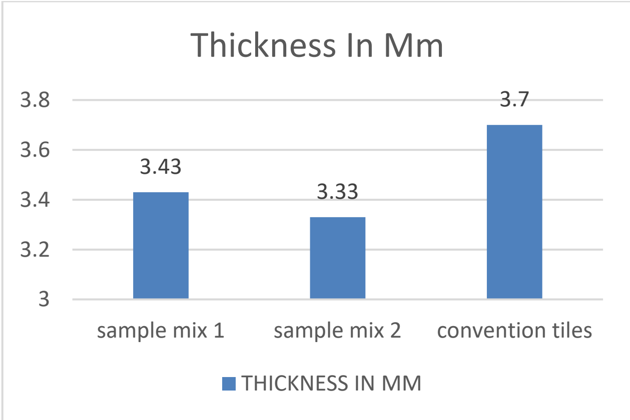


ii. Resistance to wear

Table-8: Test Results of Sample Mix and Conventional Tile

S.No	Description	Difference In Thickness Under Load In mm
1	Tile with sample Mix -1	3.43
2	Tile with sample Mix -2	3.33
3	Convention tile	3.7

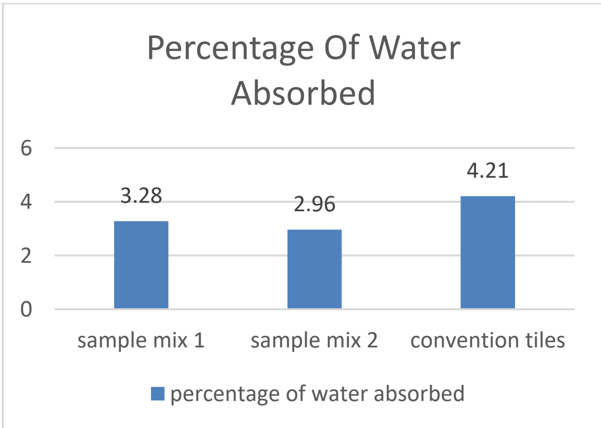
Graph-2 Resistance To Wear



iii. Water absorption

S.No	Description	Percentage Of Water Absorbed
1	Tile with Sample Mix -1	3.28
2	Tile with Sample Mix -2	2.96
3	Convention tile	4.21

Graph-3 Percentage of Water Absorption of Tiles In 24 Hours



International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 03 , March - 2026

CONCLUSION

This study demonstrates that recycled waste tiles can be effectively utilized in the production of vitrified tiles with the incorporation of lime as a fluxing and indicate that an optimized proportion of recycled tile powder and lime improves densification, reduces water absorption, and enhances mechanical properties such as strength and impact resistance. The addition of lime contributes to improved vitrification behavior by promoting calcium–silicate phase formation and lowering the required firing temperature. The findings confirm that recycled tile waste is a sustainable and technically viable alternative to conventional raw materials in vitrified tile manufacturing.

This approach supports waste minimization, resource conservation, and reduction in environmental impact while maintaining required performance standards. Therefore, the proposed method contributes to the development of ecofriendly construction materials aligned with circular economy principles. The experimental investigation conclusively demonstrates that sustainable vitrified tiles can be successfully manufactured using crushed tile waste, fly ash, lime powder, and coconut coir fibers without compromising structural integrity. The developed tiles achieved:

- Required transverse strength as per IS standards
- High compressive load capacity
- Acceptable abrasion resistance
- Controlled water absorption
- Improved toughness due to fiber Reinforcement

REFERENCES-

[1] Abdul & Siddique, Properties of sustainable concrete containing fly ash, slag and recycled aggregate, Construction and Building Materials (2009). (from literature review)

[2] Ali, T., Qureshi, M. Z., Onyelowe, K. C., et al. Optimizing recycled aggregate concrete performance with fly ash and coconut fiber. Scientific Reports (2025).

[3] Anitha Bhatia et al. (2016): Highlighted green concrete technology as a means to conserve natural resources, reduce costs, and promote sustainability.

[4] Carvalho Terra, I. C. de, et al. Mining waste and coconut fibers for ecofriendly concrete blocks. Environmental Science and Pollution Research (2023).

[5] Hong Hao, Wensu chen, 20 April 2024: Prefabricated concrete sandwich and other lightweight wall panels for sustainable building construction.

[6] Huseien, G. F., & Mhaya, A. M. Utilizing waste palm oil fuel ash and tile ceramics for geopolymer composites. Journal of Composites Science (2026).

[7] Imam, M. H., Redwan-ul-Islam, S. R., Roy, S., Siddika, A., Rahman, D., & Sharkar, S. Experimental study on geopolymer concrete with waste tiles powder. Journal of Civil and Construction Engineering (2023).

[8] Innovative utilization of fly ash in concrete tiles for sustainable construction. Materials Today: Proceedings, 33(8), 5301–5305 (2020).

[9] Mirabbos Hojamberdiev 01 April, 2011: Utilization of granite waste in the manufacture of ceramic tiles.

[10] Muhammad Naim Mahyuddin, Sallehan Ismail 03 February 2023: Innovation of eco waste concrete vetrified tiles using hybrid fruit waste binder.

[11] Paul, S. C., Faruky, S. A. U., & Babafemi, A. J. Eco-friendly concrete with waste ceramic tile as coarse aggregate. Asian Journal of Civil Engineering (2023).

[12] Poon, C.-S., Kou, S. C., & Lam, L., Use of recycled aggregates in moldedconcretebricks and blocks, Construction and Building Materials (2002).

[13] Rao, A. U., Shetty, P. P., Bhandary, P. R., et al. Assessment of fly ash and ceramic powder incorporated concrete. Emergent Materials (2024).

[14] Sandro Botas, 01 May 2015: adhesion of Air Lime-Based Mortars to Old Tiles for Moisture and Open Porosity Influence in Tile/Mortar Interfaces.

[15] Saravanakumar, P., & Maruthachalam, D. Structural behaviour of recycled aggregate concrete with waste clay tiles and fly ash. IJCIET 8(7) (2017).

[16] Shanjun Ke 01 Mar, 2016: Recycling of polished tile waste as a main raw material in porcelain tiles.

[17] Sustainable ceramic tiles in corporated with waste fly ash from recycled paper production. Journal of Cleaner Production 425 (2023).

IS CODES

[1] IS: -2000 Code of practice for plain and reinforced concrete

[2] IS:12269-1987 Specification for 53 Grade OPC.

[3] IS: 269-2015 specifications for 33, 43 and 53 grade OPC.

[4] IS: 13801-2013 Tolerances for Ceramic Tiles.

[5] IS 1237 Cement Concrete Flooring Tiles – Specification

[6] IS 3812 Part 1 Pulverized Fuel Ash for Use as Pozzolana in Cement and Concrete

[7] IS 712 Specification for Building Limes

[8] IS 1237 Part 3Resistance to Wear Test for Cement Concrete Flooring Tiles