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Development of Cement-Based Floor Tiles Incorporating Sawdust and Glass Waste as Sustainable, Low-Cost Construction Materials

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ABSTRACT: This study tackles global waste management concerns and the challenges posed by excessive sand extraction in the construction industry by developing sustainable cement-based floor tiles. It explores the use of sawdust and crushed glass as alternative fine aggregates in three mix ratios—1:1:2, 1:2:1, and 2:1:1 (cement:sawdust:crushed glass)—for 30 cm x 30 cm x 10 mm tiles.The 1:1:2 mix, which includes 50% crushed glass, delivered the most promising results. It achieved the highest density (2297.778 kg/m³), passed water absorption standards for indoor use, showed excellent fire resistance with only 4.663% weight loss at 650°C, and reached a flexural strength of 4.50 N/mm², meeting European standards for tiles of this size. All samples also passed chemical and impact resistance tests, with findings indicating strong potential for use as indoor flooring material.Economically, the use of locally sourced and recycled materials brought the production cost down to ₱10.55 per tile. With a selling price of ₱20.00, each tile yields a ₱9.45 profit—an 89.6% mark-up—demonstrating strong commercial viability.This research supports four United Nations Sustainable Development Goals (SDGs): SDG 9 (Industry, Innovation, and Infrastructure), SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action), by promoting eco-friendly construction practices, responsible resource use, and waste reduction.

KEYWORDS: Sawdust, Crushed Glass, Alternative Fine Aggregates, Floor Tiles, Eco-Friendly

I. INTRODUCTION

The global construction industry is facing mounting environmental challenges, primarily driven by two critical issues: the overextraction of natural resources and the growing volume of industrial waste. By 2050, municipal solid waste is projected to reach 3.4 billion tons worldwide (Kaza et al., 2018). In the Philippines alone, approximately 61,000 metric tons of solid waste are generated daily—equivalent to filling 37 Olympic-sized swimming pools each day. Simultaneously, the depletion of sand, a key material in construction, poses a severe threat. The United Nations Environment Programme (UNEP) estimates that 50 billion tonnes of sand are extracted annually—enough to construct a nine-story wall encircling the planet—far exceeding nature's ability to replenish it.

This overexploitation not only drives up material costs but also causes significant ecological disruption and long-term resource scarcity. Adding to the crisis is the mismanagement of industrial byproducts such as sawdust and glass, which contribute to environmental degradation when improperly disposed of. These pressing concerns underscore the urgent need for sustainable alternatives in construction.

In response, this study investigates the feasibility of producing cement-based floor tiles incorporating sawdust and crushed glass as partial replacements for natural fine aggregates. The research aims to develop a cost-efficient, durable, and environmentally friendly material that addresses both waste management and resource conservation challenges in the construction sector.

II. OBJECTIVES

A. General Objective

The primary aim of this study is to create a low-cost and eco-friendly substitute for conventional ceramic tiles using sawdust or wood waste and crushed waste glass as substitutes for sand in the fine aggregate, with the goal of addressing waste management challenges and the depletion of natural sand resources, while ensuring that the produced tiles meet the strength, durability, and quality requirements set by the Philippine National Standard (PNS) for tiles.

B. Specific Objective

1.) To determine the effect of varying mix ratios of cement, sawdust, and crushed glass waste (1:1:2, 1:2:1, and 2:1:1) on both the physical properties (texture, appearance, and weight) and performance characteristics (water absorption, fire resistance, flexural strength, chemical resistance, and impact resistance) of cement-based floor tiles in comparison to traditional ceramic tiles.

2.) To identify the ideal mix ratio of cement, sawdust, and glass waste that maximizes structural integrity and performance of the tiles.

3.) To determine the difference in terms of cost in the output of the tile to the conventional ceramic tiles available in the market.

III. METHODOLOGY

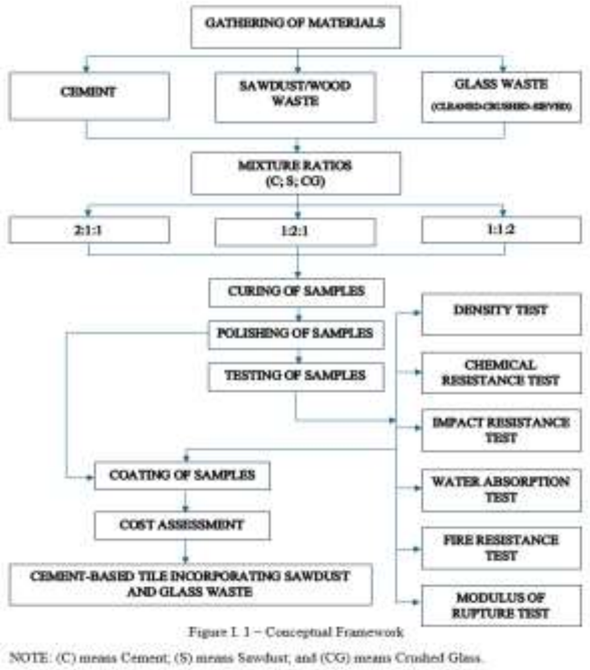

Figure I. Conceptual Framework

This study used an experimental research design to develop cement-based floor tiles incorporating sawdust and glass waste as sustainable alternatives to traditional fine aggregates. The tiles were produced in three different mixture ratios, molded, cured for 28 days, and subjected to a variety of mechanical and physical tests.

The research was conducted at Wamil-Beltran Residence in Cabanatuan City, with raw materials sourced from local suppliers. Sawdust was sourced from AJM Mini Lumber in Santa Rosa, Nueva Ecija, a local wood production facility. Glass waste was collected from various local sources in Santa Rosa and Cabanatuan City, then cleaned, crushed, and sieved at the Mechanical Engineering Innovation Center of Nueva Ecija University of Science and Technology (NEUST). Advanced tests, such as the modulus of rupture, were performed at FDC Materials Testing Center in Quezon City.

Standardized procedures were followed for mixing, molding, curing, polishing, and coating the tiles. Key testing methods included:

- Density test
- Water absorption (ASTM C373-18)
- Fire resistance (ASTM E119-20)
- Flexural strength/modulus of rupture (ASTM C1505, EN ISO 10545-4)
- Impact resistance (ASTM C1870-18)
- Chemical resistance (ASTM C650)

Data were analyzed using One-Way ANOVA to compare fire resistance across mixtures. Additionally, a cost analysis assessed the economic feasibility of producing these eco-friendly tiles compared to conventional ceramic options.

IV. RESULTS AND DISCUSSION

This chapter presents, analyzes, and interprets the results of the experimental tests conducted on the cement-based floor tiles incorporating cocolumber sawdust and crushed glass as alternative components. The purpose of these tests was to evaluate the physical, mechanical, chemical, and economic performance of the developed tiles in comparison to standard criteria. By applying various standardized procedures, each test provided critical insights into the behavior and suitability of the materials used in the tile production.

- Density Test - Increasing the crushed glass content increases tile density, with the 1:1:2 mix achieving the highest density. This indicates a more compact and rigid structure, suitable for durable flooring applications.
- Water Absorption Test - The 1:1:2 mix exhibits the lowest water absorption, indicating the best moisture resistance among the samples. This makes it most appropriate for indoor flooring use based on established standards.
- Fire Resistance Test - The 1:1:2 mix demonstrates the highest fire resistance with minimal weight loss at elevated temperatures, meeting safety standards for thermal exposure. ANOVA analysis confirms significant differences in fire resistance based on mix ratio.
- Modulus of Rupture Test - The 1:1:2 mix displays superior flexural strength, indicating the highest structural resilience under bending loads. All mixes meet the minimum European standard, but the 1:1:2 mix stands out.
- Chemical Resistance Test - All tested mixes exhibit strong resistance to hydrochloric acid, showing no surface degradation. This confirms their chemical durability for various environments.
- Impact Resistance Test - The 1:1:2 mix has the highest impact resistance, withstanding drops up to 1.0 meters without visible damage. This makes it suitable for heavy-use flooring applications.
- Cost Assessment - Producing a 30cm x 30cm x 10mm cement-based floor tile costs ₱10.55 in direct materials, mainly Portland cement (₱5.95) and acrylic emulsion (₱4.60), with sawdust and glass waste free of charge. Labor and equipment are fixed costs and are excluded. Sold at ₱20.00, each tile

yields a ₱9.45 profit, an 89.6% markup, making it a cost-effective and sustainable alternative to ceramic tiles priced around ₱55. This confirms the product's commercial viability and environmental benefits.

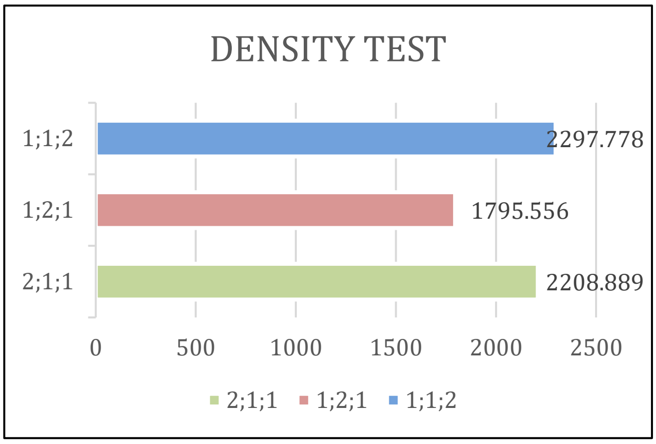

Figure II. Shows the results of Density Test. Ratio 2:1:1 with 2208.889kg, Ratio 1:2:1 with 1795.556 kg, and Ratio 1:1:2 with 2297.778 kg.

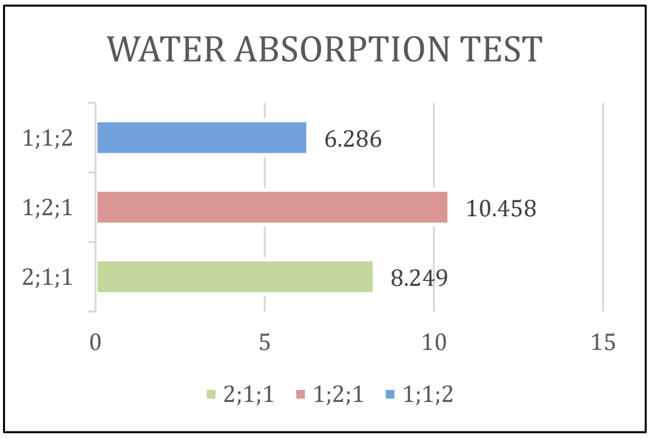

Figure III. Shows the results for Water Absorption Test. Ratio 2:1:1 with a percentage of 8.249 for its water absorption, Ratio 1:2:1 with a percentage of 10.458, and Ratio 1:1:2 with a percentage of 6.286.

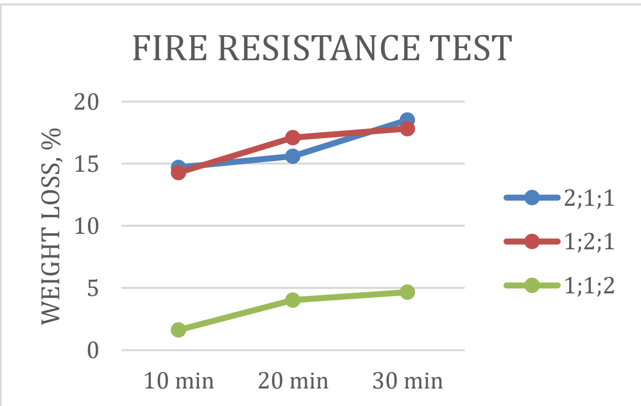

Figure IV. Shows the line graph of the results of Fire Resistance Test.

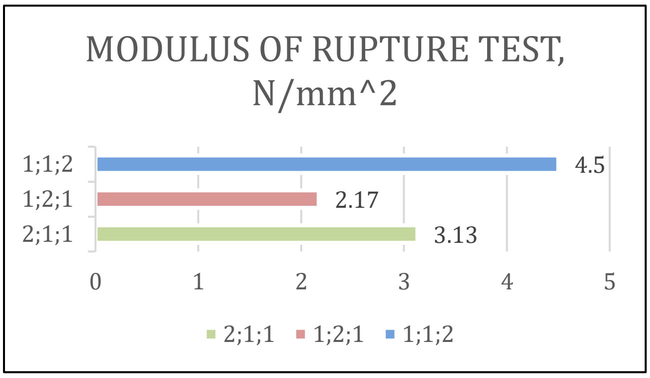

Figure V. Shows the test results of modulus of rupture. Ratio 1:1:2 with 4.5 N/mm^2, Ratio 1:2:1 with 2.17 N/mm^2, and Ratio 2:1:1 with 3.13 N/mm^2

Table I. Shows the Chemical Resistance Test

Sample Ratio (Cement: Sawdust: Crushed Glass)	Chemical Agent	Observation
2:1:1	Hydrochloric Acid	Passed
1:2:1	Hydrochloric Acid	Passed
1:1:2	Hydrochloric Acid	Passed

Table I. Presents the data collected for the Chemical Resistance Test of Cement-based tiles. The chemical agent used for the test was Hydrochloric Acid (commonly referred to as Muriatic Acid), a widely used household chemical agent. The pencil mark removal test was performed to assess the surface integrity of the samples. The results indicate that all sample ratios successfully passed the pencil removal test, as no residual marks were observed on the exposed surface to the chemical agent.

Table II. Shows the Impact Resistance Test

Sample Ratio (Cement: Sawdust: Crushed Glass)	Height, m	Observation
2:1:1	0.2	No Visible Fracture
	0.4	No Visible Fracture
	0.8	Breaks
1:2:1	0.2	No Visible Fracture
	0.4	No Visible Fracture
	0.8	No Visible Fracture
	1	Breaks
1:1:2	0.2	No Visible Fracture
	0.4	No Visible Fracture
	0.8	No Visible Fracture
	1	No Visible Fracture
	1.6	Breaks

The impact resistance of the tile samples is presented in Table II. The test results indicate that the 1:1:2 mix ratio (25% cement: 25% sawdust: 50% crushed glass) exhibited the highest resistance to impact. This composition showed no visible damage up to a drop height of 1.0 meter and only fractured at 1.6 meters. As specified by ASTM standards, floor tiles are expected to withstand impact from a 1.0 meter drop without failure (Dondi et al., 2016). Given its performance, the 1:1:2 mix satisfies this requirement, indicating its potential suitability for use in flooring applications.

Table III. Shows the Cost Assessment

Cost Estimate of Tile Production					
Description		**Unit**	**Qty**	**Direct Unit (Php)**	**Amount (Php)**
Material Cost					
Portland Cement	Cost	kg/s	40	238	5.95
	Unit Cost	kg/s	1	5.95	
Acrylic Clear Gloss Emulsion	Cost	liter/s	1	184	4.6
	Unit Cost	liter/s	0.025	184	
TOTAL COST					10.55

Table IV. Shows the Mark-up for Cost

Product/Item	Description	Unit	Production Cost Per Unit (PHP)	Selling Price Per Unit (PHP)	Mark-up (PHP)
Cement-Based Floor Tile	30cm x 30cm x 10mm	pc	10.55	20	9.45

The production cost of a 30cm x 30cm x 10mm cement-based tile is ₱10.55, covering ₱5.95 for cement and ₱4.60 for the clear gloss coating. Since sawdust and glass waste are freely sourced, and molds are reusable, they do not add to the per-tile cost. Labor and equipment are considered fixed expenses. Priced at ₱20.00, each tile yields a ₱9.45 profit and an 89.6% markup.

CONCLUSION

1. The cement-based tiles produced showed clear variations in appearance, texture, and density depending on the proportions of cement, sawdust, and crushed glass. Higher crushed glass content resulted in denser, more compact tiles with a smoother surface, while higher sawdust content yielded a rougher texture. The 1:1:2 mix had the highest density (2297.778 kg/m³), indicating improved material uniformity and structural integrity, making these tiles suitable for durable and visually appealing construction applications.
2. Water absorption decreased as crushed glass content increased, enhancing moisture resistance and durability. The 1:1:2 mix had the lowest absorption, meeting MS ISO 13006 and ISO 10545-3:2018 standards for indoor floor tiles, while the 2:1:1 mix also qualified for indoor use. The 1:2:1 mix exceeded allowable absorption limits and is better suited for wall tiles.

- Fire resistance was highest in the 1:1:2 mix, with only 4.663% weight loss after 30 minutes at 650°C, aligning with ceramic material standards (<5% loss). The 2:1:1 and 1:2:1 mixes had significantly higher weight loss. ANOVA confirmed mix composition significantly affects fire resistance, highlighting the benefit of crushed glass inclusion.
- The modulus of rupture showed the 1:1:2 mix had the greatest flexural strength (4.50 N/mm²), followed by 2:1:1 (3.13 N/mm²), and 1:2:1 (2.17 N/mm²). All met European standards for ceramic tiles. Increased crushed glass improved bending strength, while higher sawdust lowered it due to its weaker structural contribution.
- All mixes demonstrated excellent chemical resistance to hydrochloric acid, with no surface degradation, confirming durability against common household acids.
- Impact resistance testing showed only the 1:1:2 mix met ASTM standards by withstanding a 1.0-meter drop without damage, fracturing only at 1.6 meters. The other mixes broke below 1.0 meter, indicating crushed glass enhances impact strength while excess cement or sawdust reduces it.

3. The 1:1:2 mix (25% cement, 25% sawdust, 50% crushed glass) consistently outperformed other formulations, offering optimal strength, durability, fire resistance, chemical stability, and impact resistance, making it the most suitable for commercial cement-based tile production.
4. Cost assessment revealed a direct material cost of ₱10.55 per tile, excluding fixed labor and equipment expenses. With a selling price of ₱20.00, the profit margin is ₱9.45 per tile (89.6% markup), establishing economic feasibility. This pricing makes the tile an affordable, sustainable alternative to conventional ceramic tiles, typically priced around ₱55, demonstrating strong commercial potential.

The series of tests conducted on the cement-based floor tiles incorporating cocolumber sawdust and crushed glass consistently demonstrated the material's strong performance across key criteria. The optimal 1:1:2 mix showed the highest density, lowest water absorption, superior fire and impact resistance, and excellent flexural strength, all meeting or exceeding relevant standards. Chemical resistance tests confirmed durability against acidic environments. Economically, the tiles proved affordable to produce with a favorable profit margin, positioning them as a sustainable and cost-effective alternative to conventional ceramic tiles. Overall, the results validate the tiles' suitability for durable, safe, and environmentally friendly flooring applications.

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