

To Study and Development of Hybrid Rubber Tiles using Waste Tyre Rubber Composites

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Abstract - The rapid increase in end-of-life tyres has created serious environmental challenges, especially in developing countries like India. Since waste tyres are non-biodegradable, they occupy large landfill spaces and can cause soil and groundwater contamination. This study proposes a sustainable solution by developing hybrid rubber tiles using recycled tyre rubber combined with fillers such as glass powder, silica sand, and fly ash, aiming to improve mechanical properties, durability, and cost-effectiveness while supporting circular economy principles.

The research utilizes shredded and granulated tyre rubber bonded with a two-component polyurethane binder. Unlike traditional vulcanization, this method avoids sulphur and high-temperature curing, instead using moisture-curing polyurethane chemistry. The addition of waste materials like fly ash and glass powder enhances compressive strength, surface hardness, and dimensional stability.

Experimental results show that optimized filler combinations significantly improve load-bearing capacity and wear resistance. The study also examines the influence of particle size distribution, binder ratio, and compaction pressure on overall performance. The developed hybrid tiles are suitable for applications such as playground flooring, industrial surfaces, and pedestrian pathways.

Overall, the research demonstrates a low-cost, eco-friendly approach to material development using waste resources, offering both environmental and economic benefits while contributing to advancements in sustainable composite technologies.

Key Words: Rubber tiles, glass powder, composite material, polyurethane resin, flexible rubber powder, waste management and vulcanized rubber etc.

1. Introduction

1.1 Recycling Overview

The recycling of waste tyres into value-added products has gained considerable attention in recent years. According to studies by World Health Organization, improper disposal of tyres leads to environmental hazards and health risks. Researchers have explored multiple techniques to reuse tyre rubber, including pyrolysis, devulcanization, and mechanical recycling.

One of the most widely adopted methods is the production of rubber crumb composites bonded with polyurethane adhesives. Polyurethane-based binders are preferred due to their excellent adhesion, flexibility, and resistance to environmental degradation. The chemistry of Polyurethane enables the formation of a strong elastomeric network without the need for high-temperature processing.



Figure 1: Fine Rubber granules

Traditional rubber processing involves Vulcanization, where sulphur is used to create cross-links between polymer chains. However, this method is energy-intensive and not suitable for recycled rubber particles. Modern approaches utilize cold-curing polyurethane systems that react with atmospheric moisture, eliminating the need for additional curing agents or heat.

1.2 Present Time Scenario

Several studies have focused on improving the mechanical properties of rubber tiles by incorporating fillers. Silica sand has been widely used as a reinforcing agent due to its high compressive strength and compatibility with polymer matrices. Similarly, fly ash, a byproduct of thermal power plants, has been identified as a cost-effective filler that enhances rigidity and reduces material costs.

Recent research has also explored the use of glass powder derived from waste glass. The addition of finely ground glass improves surface hardness and abrasion resistance, making it suitable for high-traffic applications. However, excessive use can lead to brittleness, necessitating careful optimization.



Chart 1: Tires industrial production in India from 2015 to 2025

ELT (End-of-Life)— it refers to tires that have reached the end of their usable lifespan and are no longer suitable for vehicles. These tires become industrial waste but can be reused or recycled.

1.3 Hybrid Composite Insight

Natural fibers such as coir and jute have been investigated for their reinforcing capabilities. These fibers improve crack resistance and

flexibility but may introduce moisture sensitivity. Advanced materials such as graphene oxide have shown significant improvements in mechanical performance, although their high-cost limits practical applications.

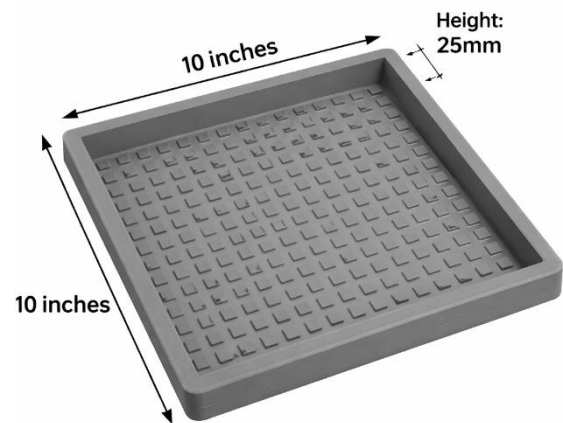


Figure 2: Rubber Tile Mold

The literature also emphasizes the importance of particle size distribution. A combination of coarse and fine rubber granules leads to better packing density and reduced voids, resulting in enhanced structural integrity. Researchers have reported that an optimal binder content of 5–10% ensures sufficient bonding without compromising flexibility.

Overall, previous studies highlight the potential of hybrid composites in improving the performance of recycled rubber products. However, there is limited research on combining multiple waste fillers such as fly ash, glass powder, and silica sand simultaneously, which forms the basis of the present study.

2. Problem Specifications Results

The purpose of this research is to develop a composite material that effectively combines the desirable properties of rubber and mineral fillers. The study aims to create tiles that are not only strong and durable but also flexible and lightweight.

Another important objective is to demonstrate that waste materials can be transformed into high-value engineering products through simple and efficient

processes. By optimizing the mix design and fabrication method, the study seeks to provide a practical solution for both waste management and material development.

The working principle of the developed rubber tile is based on composite material behavior. Rubber granules form the primary phase, while the polyurethane binder acts as the matrix that binds all components together. When the binder components (Part A and Part B) are mixed, they undergo a chemical reaction that results in the formation of a strong elastic network.

Fillers such as silica sand and fly ash occupy the void spaces between rubber particles, increasing density and strength. The mixture is placed in a hand-made metal die (10×10 inches) and subjected to cold pressing, which compacts the material and removes air gaps.

3. Materials and Mix Design

Three compositions are prepared to study performance variation.

Basic Composition

Rubber: 90–92%

Binder: 8–10%

Glass Powder Composition

Rubber: ~85%

Glass powder: ~7%

Binder: ~8%

Fly Ash Composition

Rubber: ~82%

Fly ash: ~10%

Binder: ~8%

These ratios are selected based on previous research to balance flexibility and strength.

3.4 Assembly and Fabrication Process

- Step 1: Material Preparation
Rubber granules cleaned and dried.
Fillers sieved to uniform size.
- Step 2: Dry Mixing
Rubber and fillers are mixed thoroughly to ensure even distribution.
- Step 3: Binder Mixing
Part A and Part B are mixed in required ratio just before use.
- Step 4: Wet Mixing
Binder is added to the dry mixture and mixed until uniform coating is achieved.
- Step 5: Mould Filling
The mixture is placed into the plastic die and leveled.
- Step 6: Cold Pressing
Pressure is applied to compact the mixture.
- Step 7: Curing
Curing takes place at:
Temperature: 25°C to 35°C
Time: 24–36 hours
- Step 8: Demoulding

Workpieces /specimens are removed and edges are finished.

4. Results and Discussion

4.1 The developed hybrid rubber tiles exhibited significant improvements in mechanical and physical properties compared to conventional rubber tiles.

4.2.1 Tensile Behavior of Control Sample

(Specimen 1)

The control sample consisted only of waste tyre rubber particles bonded with polyurethane binder. During loading, the specimen exhibited a gradual increase in load with increasing

displacement. The Feed Rate of Force is 2mm/min.

Table 1: Material Composition (Rubber + PU Binder)

Material Composition	Weights (Approx)
Rubber	19.3 g
PU Binder	1.7 g
Total	21 g

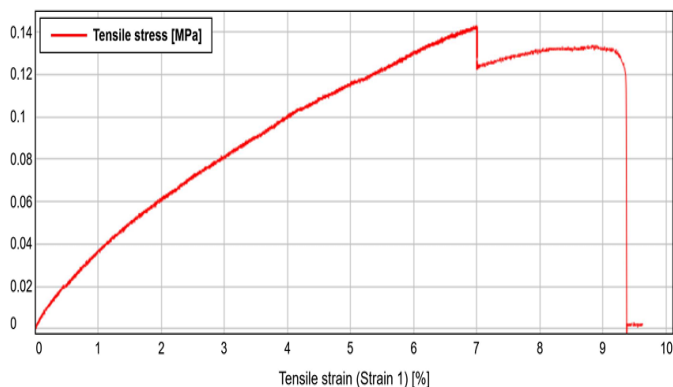


Figure 4.1 Stress-Strain Graph of Specimen 1

	Force at Break (Standard) [kN]	Tensile strain (Strain 1) at Break (Standard) [%]	Tensile stress at Break (Standard) [MPa]	Displacement at Break (Standard) [mm]
1	0.000	9.620	0.00	11.990
	Maximum Force [kN]	Tensile strain (Strain 1) at Maximum Force [%]	Tensile stress at Maximum Force [MPa]	Displacement at Maximum Force [mm]
1	0.021	6.99	0.14	10.669
	Energy at Maximum Force [J]	Force at Yield (Offset 0.2 %) [kN]	Tensile stress at Yield (Offset 0.2 %) [MPa]	Modulus (Automatic Young's) [GPa]
1	0.04	0.01	0.05	0.00
	Elongation after fracture [%]			
1	----			

Figure 4.2 Readings of Specimen 1

4.2.2 Tensile Behavior of Fly Ash Reinforced Sample (Specimen 2)

Table 2: Material Composition (Rubber + PU Binder + Fly Ash)

Material Composition	Weights (Approx)
Rubber	17.2 g
PU Binder	1.7 g
Fly Ash	2.1 g
Total	21 g

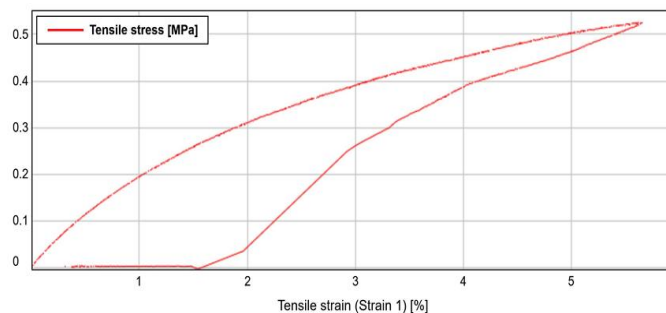


Figure 4.3 Stress-strain

	Force at Break (Standard) [kN]	Tensile strain (Strain 1) at Break (Standard) [%]	Tensile stress at Break (Standard) [MPa]	Displacement at Break (Standard) [mm]
1	0.000	0.311	0.00	12.170
	Maximum Force [kN]	Tensile strain (Strain 1) at Maximum Force [%]	Tensile stress at Maximum Force [MPa]	Displacement at Maximum Force [mm]
1	0.078	5.65	0.53	8.758
	Energy at Maximum Force [J]	Force at Yield (Offset 0.2 %) [kN]	Tensile stress at Yield (Offset 0.2 %) [MPa]	Modulus (Automatic Young's) [GPa]
1	0.15	0.03	0.21	0.02
	Elongation after fracture [%]			
1	----			

Figure 4.4 Readings of Specimen 2

4.2.3 Tensile Behavior of Glass Powder Reinforced Sample (Specimen 3)

Material Composition	Weights (Approx)
Rubber	17.9 g
PU Binder	1.6 g
Glass Powder	1.5 g
Total	21 g

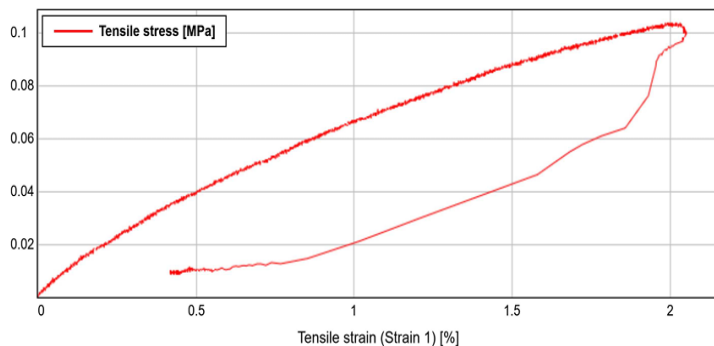


Figure 4.5 Stress-Strain Graph of Specimen 3

	Force at Break (Standard) [kN]	Tensile strain (Strain 1) at Break (Standard) [%]	Tensile stress at Break (Standard) [MPa]	Displacement at Break (Standard) [mm]
1	0.002	0.417	0.01	5.558

	Maximum Force [kN]	Tensile strain (Strain 1) at Maximum Force [%]	Tensile stress at Maximum Force [MPa]	Displacement at Maximum Force [mm]
1	0.017	2.02	0.10	4.971

	Energy at Maximum Force [J]	Force at Yield (Offset 0.2 %) [kN]	Tensile stress at Yield (Offset 0.2 %) [MPa]	Modulus (Automatic Young's) [GPa]
1	0.01	0.01	0.05	0.01

	Elongation after fracture [%]
1	----

Figure 4.6 Readings of Specimen 3

4.3.1 Compression Behavior of Control Sample (Specimen 4)

Table 4: Material Composition (Rubber + PU Binder)

Material Composition	Weights (Approx)
Rubber	41.4 g
PU Binder	3.6 g
Total	45 g

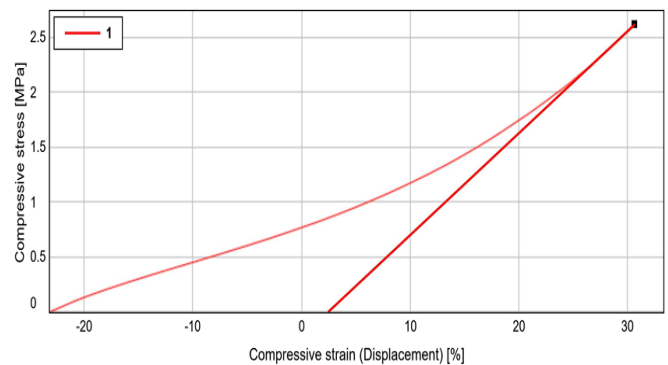


Figure 4.7 Stress-strain Graph of Specimen 4

	Elongation after fracture [%]	Modulus region end point at Modulus (Automatic Young's)	Modulus (Automatic Young's) [MPa]
1	----	16155	9.26

	Diameter [mm]	Final height [mm]	Specimen label
1		64.95	

	Rate 1 [mm/min]
1	1.30

Figure 4.8 Readings of Specimen 4

4.3.2 Compression Behavior of Fly Ash Reinforced Sample (Specimen 5)

Table 5: Material Composition (Rubber + PU Binder + Fly Ash)

Material Composition	Weights (Approx)
Rubber	36.9 g
PU Binder	3.6 g
Fly Ash	4.5 g
Total	45 g

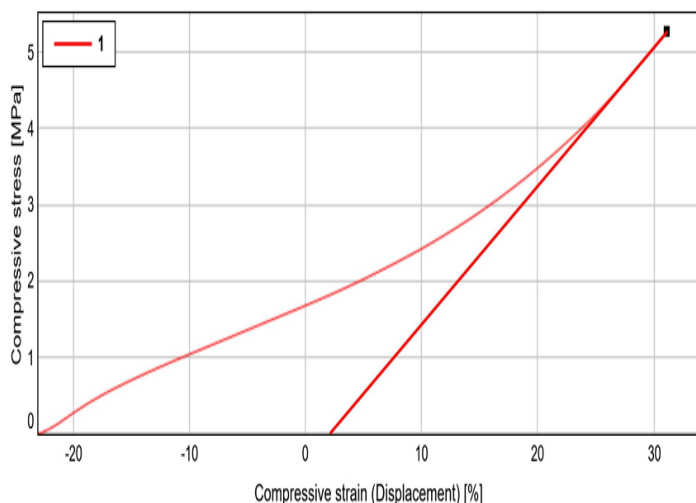


Figure 4.9 Stress-strain Graph of Specimen 5

	Elongation after fracture [%]	Modulus region end point at Modulus (Automatic Young's)	Modulus (Automatic Young's) [MPa]
1	-----	16155	18.12

	Diameter [mm]	Final height [mm]	Specimen label
1		64.50	

	Rate 1 [mm/min]
1	1.30

Figure 4.10 Readings of Specimen 5

4.3.3 Compression Behavior of Glass Powder Reinforced sample (Specimen 6)

Table 6: Material Composition (Rubber + PU Binder + Glass Powder)

Material Composition	Weights (Approx)
Rubber	38.2 g
PU Binder	3.6 g
Glass Powder	3.2 g
Total	45 g

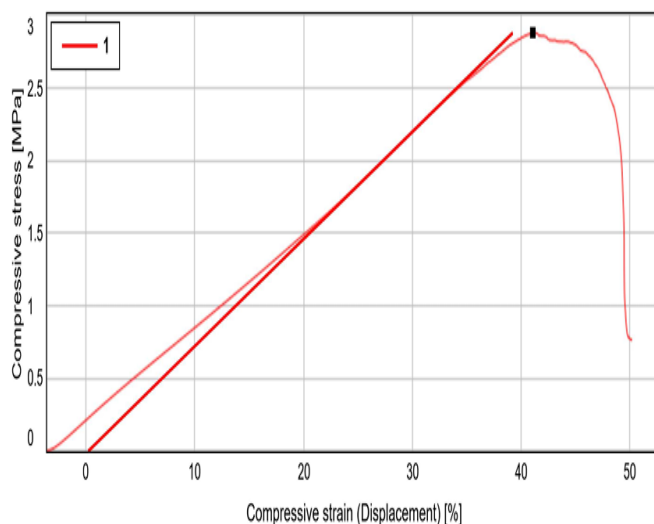


Figure 4.11 Stress-strain Graph of Specimen 6

	Elongation after fracture [%]	Modulus region end point at Modulus (Automatic Young's)	Modulus (Automatic Young's) [MPa]
1	-----	10974	7.38

	Diameter [mm]	Final height [mm]	Specimen label
1		65.00	

	Rate 1 [mm/min]
1	1.30

Figure 4.12 Readings of Specimen 6

5.1 Conclusion

The successful fabrication of rubber tile composites using waste tyre rubber and polyurethane binder demonstrates the feasibility of converting waste materials into value-added products suitable for flooring and construction applications. The addition of filler materials significantly influenced the mechanical properties of the rubber tile composites. Both fly ash and glass powder modified the tensile and compressive behaviour of the specimens when compared to the control sample. The Fly Ash reinforced composite exhibited the highest tensile strength and compressive strength among all the tested formulations. The improved performance was attributed to better particle packing, reduced void content, and enhanced stress transfer within the composite matrix. The Control Sample (Rubber + PU Binder) showed greater flexibility and elongation before failure, indicating superior energy absorption capability. However, its load-bearing capacity and strength were lower than those of the reinforced composites.

Overall, the study confirms that waste tyre rubber combined with fly ash and polyurethane binder can be effectively utilized to develop environmentally sustainable and mechanically reliable rubber tile products, thereby contributing to waste management, resource conservation, and sustainable infrastructure development

5.2 Future Work and Scope

The present work can be further improved by optimizing the composition of rubber, PU binder, and filler materials to achieve better tensile and compressive properties. Additional fillers such as silica sand, carbon black, nano-silica, rice husk ash, or natural fibres may also be investigated to improve mechanical strength and wear resistance.

In future studies, advanced fabrication methods such as hydraulic pressing, controlled curing chambers, and automated mixing systems can be used for producing more uniform and industrial-grade rubber tiles. The developed composite may also be tested for additional properties such as abrasion resistance, thermal insulation, water absorption, fire resistance, and long-term durability under environmental exposure.

The project can further be extended towards commercial applications including industrial flooring, sports surfaces, road safety components,

vibration isolation pads, and eco-friendly pavement blocks. With proper design optimization and large-scale production methods, waste tyre rubber composites can become a sustainable alternative to conventional flooring and polymer-based construction materials.

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