International Journal of Advance Research in Science and Engineering
Volume No. 15, Issue No. 06, June 2026
www.ijarse.com
IJARSE
ISSN 2319 - 8354

Compressive Behaviour of Recycled Polypropylene and Concrete Cubes: A Preliminary Study Toward Bamboo-Reinforced Plastic Structural Slabs

Piyush M. Potdar[1], Dr. R. V. Jadhav[2]

[1]*M.Tech Student, Department of Applied Mechanics, Walchand College of Engineering, Sangli, India*

[2]*Professor, Department of Applied Mechanics, Walchand College of Engineering, Sangli, India*

Abstract

The growing environmental concerns associated with plastic waste and conventional construction materials have encouraged the development of sustainable structural alternatives. This study presents the experimental and numerical investigation of recycled polypropylene (PP) as a construction material through a progressive research approach. Initially, standard 150 mm × 150 mm × 150 mm PP and M20 concrete cubes were tested under compression and analysed using Finite Element Analysis (FEA) in ANSYS Workbench. Experimental results showed compressive strengths of 18 MPa and 21 MPa for PP and concrete, respectively, while FEA predictions were in close agreement with the experimental observations.

Based on the material characterization results, a full-scale polypropylene slab was developed and analysed. The unreinforced PP slab exhibited excessive deformation and inadequate structural performance under loading. To improve its behaviour, bamboo strip reinforcement was introduced. A single-layer bamboo reinforcement system provided limited improvement and failed to achieve the desired structural response. Subsequently, a double-layer bamboo reinforcement arrangement was developed, resulting in a significant reduction in slab deflection and improved load-carrying behaviour. The study demonstrates that while recycled polypropylene alone may not be suitable for structural slab applications, its performance can be substantially enhanced through bamboo reinforcement. The findings establish a foundation for the development of sustainable bamboo-reinforced plastic slabs as lightweight alternatives for selected construction applications.

Keywords: *Recycled polypropylene, Bamboo reinforcement, Plastic slab, Compressive strength, Finite Element Analysis, Sustainable construction.*

1. Introduction

The growing demand for sustainable construction materials has encouraged the exploration of alternatives to conventional cement- and steel-based systems. Simultaneously, the increasing accumulation of plastic waste poses significant environmental challenges, necessitating innovative approaches for its beneficial utilization in engineering applications. Recycled polypropylene (PP), owing to its low density, durability, and recyclability, has emerged as a potential material for lightweight construction components.

Despite these advantages, the structural application of polypropylene remains limited due to its relatively low stiffness and strength compared with conventional concrete. Therefore, understanding its mechanical behaviour is essential before considering its use in structural elements. In the present study, the compressive behaviour of recycled polypropylene cubes was experimentally investigated and compared with that of M20-grade concrete cubes. Finite Element Analysis (FEA) was performed using ANSYS Workbench to validate the experimental findings and assess the material response under compressive loading.

Based on the material characterization results, a polypropylene slab was subsequently developed and analysed to evaluate its structural feasibility. To enhance its load-carrying capacity and deformation behaviour, bamboo strips were introduced as reinforcement owing to their high tensile strength, low density, renewability, and local availability. The integration of recycled polypropylene and bamboo presents a sustainable approach toward the development of lightweight structural systems.

This study establishes the fundamental mechanical characteristics of recycled polypropylene and provides the basis for the development of bamboo-reinforced polypropylene slabs as an environmentally responsible alternative for future construction applications.

2. Material

The primary materials used in this study were recycled polypropylene (PP) and conventional M20-grade concrete. Recycled polypropylene was selected due to its low density, durability, corrosion resistance, and potential for sustainable reuse in construction applications. Concrete cubes were prepared using standard materials, including Ordinary Portland Cement (OPC), fine aggregate, coarse aggregate, and water in accordance with conventional mix design practices.

To explore the feasibility of polypropylene as a structural material, bamboo strips were considered as a reinforcement material for subsequent slab development owing to their high tensile strength, renewability, low weight, and local availability.

2.1 Concrete

Concrete is a composite material made by mixing cement, fine aggregates (sand), coarse aggregates (gravel), and water in specific proportions. It hardens over time through a hydration process, resulting in a strong, durable, and solid material capable of bearing heavy loads.

The concrete cubes used in this study were prepared with the following materials:

2.1.1 Cement:

Cement is a fine, gray powder that acts as a binder in concrete. When mixed with water, it forms a paste that hardens through a chemical reaction called hydration. In this study, Ordinary Portland Cement (OPC), Grade 43, conforming to IS: 12269-2013, was used.

2.1.2 Fine Aggregates:

Fine aggregate refers to naturally occurring granular materials, primarily natural river sand, with particle sizes smaller than 4.75 mm as per IS: 383-2016. It fills the voids between coarse aggregates, improves workability, and contributes to the overall strength of concrete. The sand used in this study was clean, well-graded, and free from clay, silt, organic matter, and other impurities.

2.1.3 Coarse Aggregates:

Coarse aggregate consists of granular materials larger than 4.75 mm, typically made from crushed stones. In this study, crushed granite stones with a maximum particle size of 20 mm were used. These aggregates provide bulk, strength, and rigidity to the concrete.

2.1.4 Water:

Water is essential for the hydration of cement and for achieving the desired workability of concrete. Clean, potable water, free from harmful impurities, was used for both mixing and curing the concrete cubes.

2.2 Polypropylene (PP) Plastic

Polypropylene (PP) is a thermoplastic polymer commonly used in household products and various industrial applications. It is lightweight, corrosion-resistant, flexible, and recyclable, making it an attractive material for construction applications focused on sustainability and weight reduction.

For this study, recycled polypropylene granules made from bottle caps were used to fabricate PP cubes.

Key Properties of Polypropylene (PP):

- **Density:** 0.920 g/cm³
- **Compressive Strength:** 20–35 MPa
- **Young's Modulus:** 1,500 MPa
- **Poisson's Ratio:** 0.42
- **Recyclability:** 100%

***Fig 1**: Recycled plastic*

3. Methodology

The research was carried out in two stages. Initially, recycled polypropylene (PP) cubes and conventional M20 concrete cubes of dimensions 150 mm × 150 mm × 150 mm were prepared and tested under compression using a Universal Testing Machine (UTM). The compressive strengths obtained from the experimental investigation were used to evaluate the mechanical behaviour of both materials.

Subsequently, Finite Element Analysis (FEA) was performed in ANSYS Workbench to simulate the compressive response of the cube specimens and validate the experimental results. Based on the material characterization study, a polypropylene slab model was developed and analysed. To improve its structural performance, bamboo strips were incorporated as reinforcement, and the behaviour of the reinforced slab was evaluated through numerical modelling. The overall methodology involved experimental testing, numerical validation, and the development of a bamboo-reinforced polypropylene slab system for sustainable construction applications.

3.1 Preparing cube

Two types of cubes were prepared: conventional concrete cubes and polypropylene (PP) cubes.

- Concrete Cubes: Made from ordinary Portland cement, fine aggregates, coarse aggregates, and clean water, mixed in standard proportions.
- Polypropylene Cubes: Manufactured by melting polypropylene bottle caps and casting them into identical Molds. The granules were melted with the help of an extruder.

3.2 Specimen Preparation

Both the concrete and polypropylene cubes had dimensions of 150 mm × 150 mm × 150 mm.

Fig 2: *Collecting melted plastic from extruder*

Fig 3: *Pouring melted plastic into cube mould*

Fig 4: *Recycled PP casted cube*

Fig 5: *Concrete casted cube*

- Concrete cubes were cured for 28 days under water to standardize strength development.
- Polypropylene cubes were cooled at room temperature after casting

IJARSE
ISSN 2319 - 8354

3.3 Testing Procedure

The compressive strength tests were carried out using a universal testing machine (UTM). Both sets of cubes were placed centrally on the loading platform. A constant loading rate was applied until failure, and the maximum load was recorded. The compressive strength was calculated using the formula:

$$Compressive\ Strenght\ = \frac{Maximum\ load}{Area\ of\ cube\ face}$$

Fig 6: *Recycled PP cube on UTM*

Fig 7: *Concrete cube of UTM*

(a) *Recycled pp cube* ***(b)*** *Concrete cube*

Fig 8: *Comparison of Experimental testing on UTM*

3.4 Finite Element Analysis (FEA)

To complement the experimental tests, ANSYS Workbench was used for finite element modeling. Both cube types were modelled in 3D with the same dimensions and subjected to the same boundary conditions. Material properties for concrete and polypropylene were defined based on literature and experimental data, with a static structural analysis capturing total deformation, stress distribution, and failure characteristics.

International Journal of Advance Research in Science and Engineering
Volume No. 15, Issue No. 06, June 2026
www.ijarse.com
IJARSE
ISSN 2319 - 8354

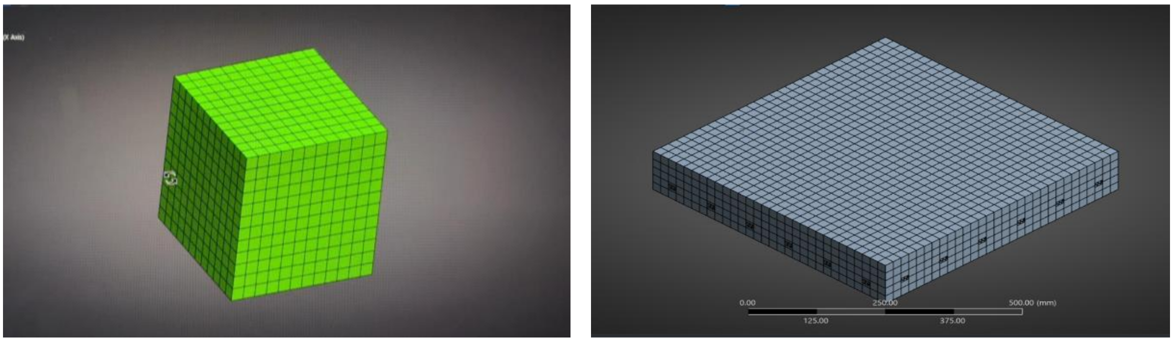

Fig 9: *Model and meshing of cube and slab in ANSYS*

4. Results and discussion

4.1 Experimental Results

The experimental compression tests revealed significant differences between the compressive strengths of concrete and polypropylene cubes. Compression tests were conducted on both concrete cubes and polypropylene (PP) cubes of identical dimensions (150 mm × 150 mm × 150 mm). The primary objective was to compare their compressive strength performance under similar loading conditions.

The results obtained from the experimental tests are summarized below:

Material	**Compressive Strength (MPa)**
Concrete Cube	21 MPa
Polypropylene Cube	18 MPa

Table 1. *Comparison of experimental strengths.*

- Concrete Cubes: The average compressive strength of the concrete cubes was found to be **21 MPa**, with failure occurring at relatively low deformation.
- Polypropylene Cubes: The polypropylene cubes exhibited an average compressive strength of **18 MPa**, significantly lower than concrete but with higher deformation before failure, indicating a more ductile behavior.

4.2 Finite Element Analysis (FEA) Results

The finite element simulations performed in ANSYS provided complementary insights into the mechanical behavior of both materials under compressive loading.

The simulated compressive strengths obtained from the FEA were:

- **Concrete Cubes**: 24 MPa
- **Polypropylene (PP) Cubes**: 21 MPa

IJARSE
ISSN 2319 - 8354

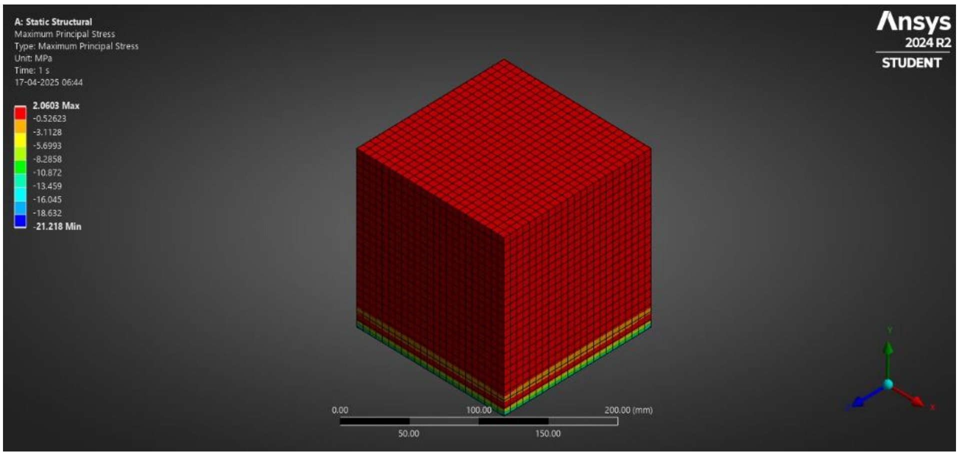

Fig 10: *FEA result of Concrete cube*

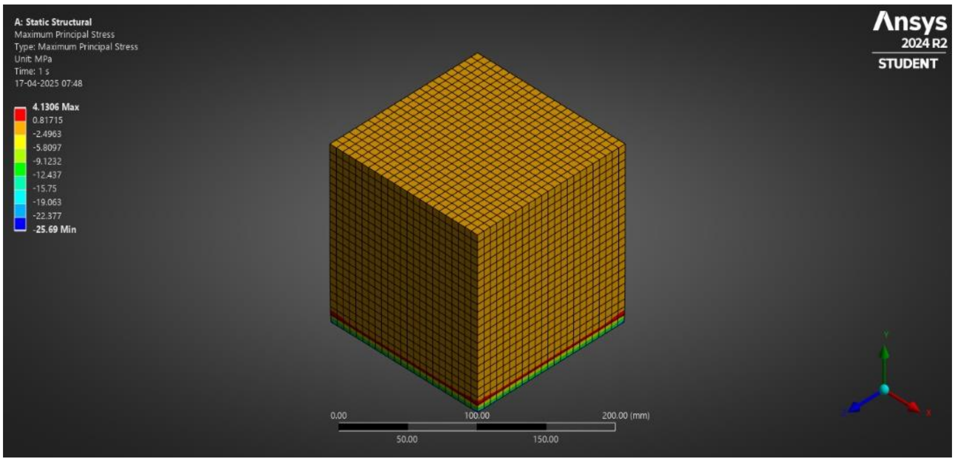

Fig 11: *FEA result of PP cube*

The stress distribution patterns confirmed that concrete cubes experienced high von Mises stress concentrations near the loaded and restrained regions, initiating failure through brittle fracture. In contrast, the stress distribution within the PP cubes was more evenly spread, with larger deformations and delayed failure onset, reflecting their ductile nature.

4.3 Comparative Analysis

The comparison between experimental and FEA results is summarized in **Table 2**.

Material	Experimental (MPa)	FEA (ANSYS) (MPa)
Concrete Cube	21	25
Polypropylene Cube	18	21

Table 2. *Comparison of experimental and ANSYS FEA compressive strengths.*

The FEA simulations provided valuable insights into the stress distribution and deformation patterns of both materials under compression:

- Concrete Cubes: The von Mises stress distribution was concentrated at the centre of the cube faces, with high-stress concentrations at the loaded and restrained regions. Failure initiated at these high-stress areas leads to a brittle fracture.

- Polypropylene Cubes: The stress distribution in the PP cubes was more evenly spread, with greater deformation observed before failure. The simulation also showed that the PP material had a higher tolerance for deformation, supporting the experimental observation of a more ductile behaviour.

The results demonstrate that polypropylene possesses lower compressive strength than conventional concrete. However, during testing, polypropylene exhibited a more ductile response and greater deformation capacity prior to failure, whereas concrete showed comparatively brittle behaviour. This characteristic suggests that polypropylene has the ability to absorb larger deformations without sudden failure, which may be advantageous in lightweight construction applications.

Based on the material characterization study, a polypropylene slab was subsequently analysed to evaluate its structural feasibility. The numerical investigation indicated that the unreinforced polypropylene slab experienced excessive deformation under loading, highlighting the limitations of polypropylene when used alone as a slab material.

Slab Configuration	Max Deflection (mm)
Plastic Slab (No Reinforcement)	5.8
Plastic Slab with Single Bamboo Layer	4.2
Plastic Slab with Double Bamboo Layers	3.5
RCC Slab (M20 with Steel)	3.7

***Table 3**: FEA Predicted Mid-Span Deflection*

4.4 Observations:

Compressive strength:

- The concrete cube achieved a compressive strength of **21 MPa**, meeting its target strength for structural applications.
- The polypropylene (PP) cube achieved a compressive strength of **18 MPa**, slightly lower than that of concrete but surprisingly close, given its lower density and lighter weight.

Weight-to-Strength Consideration:

While the PP cube showed slightly lower compressive strength, it has a much lower density (0.91 g/cm³) compared to concrete (approximately 2.4 g/cm³). This results in a favourable weight-to-strength ratio for the PP cube, indicating that for lightweight, non-load-bearing, or semi-structural applications, polypropylene could be a practical and sustainable alternative material.

Deformation:

The load–deformation response indicates that the unreinforced polypropylene (PP) slab experienced the highest deformation under loading, demonstrating its relatively low stiffness. The bamboo-reinforced polypropylene slab (PB2) exhibited significantly improved structural behaviour, carrying higher loads at lower deformation levels. enhanced the stiffness and load-carrying capacity of the polypropylene slab.The performance of PB2 was comparable to that of the RCC slab, indicating that bamboo reinforcement ffectively

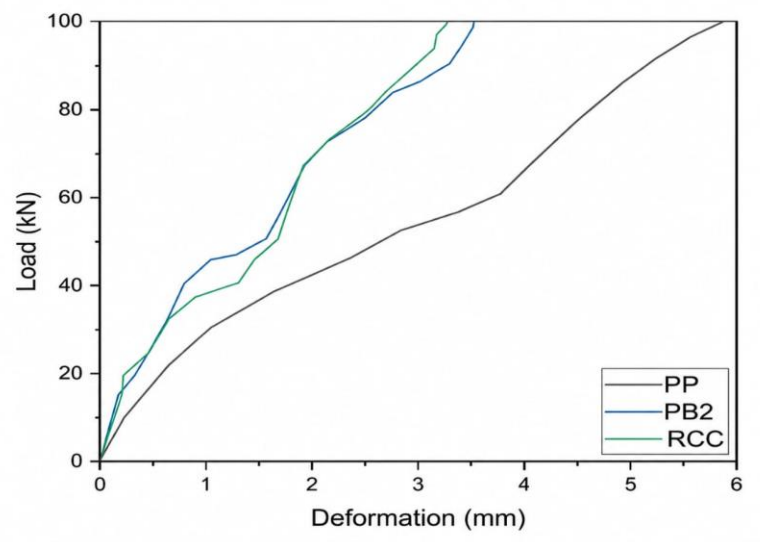

Fig 12: *Load VS Deformation graph*

5. Conclusion:

The study investigated the compressive behaviour of recycled polypropylene (PP) and M20 concrete through experimental testing and Finite Element Analysis (FEA). The results showed that PP achieved a compressive strength of 18 MPa, compared to 21 MPa for concrete, with good agreement between experimental and numerical results.

The load–deformation behaviour indicated that the unreinforced PP slab experienced higher deformation under loading due to its lower stiffness. The incorporation of bamboo strip reinforcement significantly improved the structural response by reducing deformation and increasing load-carrying capacity. The bamboo-reinforced PP slab exhibited behaviour comparable to that of the RCC slab, demonstrating improved stiffness and structural efficiency.

Overall, the findings suggest that recycled polypropylene alone may not be suitable for slab applications; however, bamboo reinforcement effectively enhances its performance. The combination of recycled polypropylene and bamboo offers a promising lightweight and sustainable alternative for future construction applications. Further experimental investigations are recommended to validate the numerical findings and evaluate long-term structural performance.

Reference

1. [1] Gagg, C. R. (2014). Developments in recycled plastics for construction applications. *Construction and Building Materials*, 72, 1–9.

2. [2] Saikia, N., & de Brito, J. (2012). Use of plastic waste as aggregate in cement mortar and concrete preparation: A review. *Construction and Building Materials*, 34, 385–401.
3. [3] Almeshal, I., Tayeh, B. A., Alyousef, R., Alabduljabbar, H., & Mustafa Mohamed, A. (2020). Eco-friendly concrete containing recycled plastic as partial replacement for sand. *Journal of Materials Research and Technology*, 9(3), 4631–4643.
4. [4] Ghavami, K. (2005). Bamboo as reinforcement in structural concrete elements. *Cement and Concrete Composites*, 27(6), 637–649.
5. [5] Sharma, B., Gatóo, A., Bock, M., & Ramage, M. (2015). Engineered bamboo for structural applications. *Construction and Building Materials*, 81, 66–73.
6. [6] Agarwal, A., Nanda, B., & Maity, D. (2014). Experimental investigation on chemically treated bamboo reinforced concrete beams and columns. *Construction and Building Materials*, 71, 610–617.
7. [7] ANSYS Inc. (2024). *ANSYS Mechanical User's Guide*. ANSYS Inc., Canonsburg, Pennsylvania, USA.
8. [8] Ramesh, M., Deepa, C., Kumar, L. R., Sanjay, M. R., & Siengchin, S. (2020). Life-cycle and environmental impact assessment of natural fibre composites. *Journal of Cleaner Production*, 268, 122–145.
9. [9] Van der Lugt, P., Van den Dobbelsteen, A., & Janssen, J. J. A. (2006). An environmental, economic and practical assessment of bamboo as a building material for supporting structures. *Construction and Building Materials*, 20(9), 648–656.
10. [10] Mohan, D., & Kumar, P. (2021). Sustainable utilization of recycled plastic waste in construction applications: A review. *Materials Today: Proceedings*, 46, 102–108.
11. [11] Wong, M. H., & Tang, P. L. (2014). *Recycling and Reuse of Plastics: A Solution to Reduce Plastic Pollution*. *Procedia Environmental Sciences*, 30, 182-189.
12. [12] Janssen, J. J. A. (2000). *Design and Building with Bamboo*. *INBAR Technical Report No. 20*.
13. [13] Ashori, A. (2008). *Wood-Plastic Composites as Promising Green Composites for Automotive Industries*. *Bioresource Technology*, 99(11), 4661-4667.
14. [14] Sharma, P. R., et al. (2018). *Reinforced Cement Concrete Slabs with Bamboo Strips as Reinforcement for Low-Cost Construction*. *Advances in Civil Engineering*, 2018, Article ID 7920187.
15. [15] Okah-Avae, B. E. (2004). *Bamboo as Reinforcement in Lightweight Concrete Slabs*. *Journal of Sustainable Development in Africa*, 6(4), 21-31.
16. [16] Jalali, S. (2005). *Sustainable Construction Materials: Recycled Plastic in Construction Applications*. *Construction and Building Materials*, 19(6), 528-537.
17. [17] Akash, S. M., & Mahadevan, K. M. (2016). *Finite Element Analysis of Reinforced Concrete Beam Using Bamboo as Reinforcement*. *Procedia Technology*, 24, 137-143.
18. [18] Tittarelli, F., & Moriconi, G. (2008). *Recycling of Waste Materials for Sustainable Concrete Production*. *Advances in Civil Engineering Materials*, 7(1), 45-60.
19. [19] Pickering, K. L., Efendy, M. G. A., & Le, T. M. (2016). *A Review of Recent Developments in Natural Fibre Composites and Their Mechanical Performance*. *Composites Part A: Applied Science and Manufacturing*, 83, 98-112.
20. [20] Van der Lugt, P., & Vogtländer, J. (2015). *Sustainability Characterization of Bio-Based Materials: Bamboo and Bioplastics as Case Studies*. *Industrial Crops and Products*, 77, 987-996.