Performance Analysis of Plastic Bricks for Structural Applications: A Combined Experimental and Software-based Investigation

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Abstract- *The intensifying generation of plastic waste presents a significant environmental challenge worldwide. Plastic waste, due to its non-biodegradable nature, contributes to land and water pollution, requiring the exploration of sustainable waste management solutions. Recycling plastic waste into building materials, such as bricks, offers a potential solution to mitigate environmental impacts. This research aimed to investigate the integration of plastic waste into building materials through a comprehensive study using experimental testing, software analysis, and structural design. The study focused on two main objectives: performing modeling and stress analysis of plain plastic bricks using ANSYS software and designing a G+2 room model using ETAB software for components like slabs, beams, and columns. The research addressed the research gap in the integration of experimental data, stress values, and modeling techniques for optimizing building structures. The results showed that the experimental values obtained from compression testing were generally higher than those from ANSYS software, with ANSYS providing closer approximations for certain plastic types. The ETAB analysis demonstrated that the HDPE model exhibited lower bending moments and axial loads compared to the concrete model, suggesting superior mechanical properties and load-carrying capacity. This research contributes to the understanding of the behavior and performance of plastic bricks in structural applications, enabling the development of sustainable and efficient building designs that incorporate plastic waste materials. The findings emphasize the importance of considering physical conditions during testing and highlight the accuracy and utility of ANSYS and ETAB software in structural analysis and design optimization. Future research can build upon these findings to establish design guidelines and further optimize modeling techniques in this field.*

***Key Words*: Plastic Waste, Environmental Challenge, Non-Biodegradable, Sustainable Solutions, Experimental Study, Plastic Bricks, Alternative Building Materials, Methodology, Comparable Strength, Plastic Waste Crisis.**

1. INTRODUCTION

The continuous increase in plastic waste generation, driven by factors like population growth, urbanization, and changes in lifestyle, poses a significant environmental challenge. Plastic waste, being non-biodegradable, contributes to land and water pollution, exacerbating the problem. Polyethylene (PE), widely used in single-use products, such as bags and bottles, is among the most commonly used plastics. Recycling plastic waste into plastic bricks presents a potential solution to this issue. However, certain plastics, like HDPE and PTE, are highly hazardous, and particles smaller than 50 microns adversely affect soil fertility. The improper disposal of plastic waste into oceans further jeopardizes aquatic life and water quality. Though challenging to decompose, plastic is extensively utilized in various daily applications, necessitating the exploration of sustainable waste management solutions. Researchers have investigated incorporating plastic waste into building materials, like bricks, to mitigate environmental impacts and reduce waste. While conventional building materials remain in high demand, the integration of waste materials in construction can alleviate environmental concerns, including greenhouse gas emissions and the excessive use of clay and cement. However, it is crucial to acknowledge the environmental drawbacks associated with traditional red clay bricks, such as emissions from combustion. Therefore, exploring plastic bricks as an alternative building material offers a promising avenue to effectively tackle plastic waste and its environmental consequences.

1.1. Research gap

Although several studies have investigated the utilization of plastic in bricks and explored its effects on strength parameters and soil content, there is a research gap in the integration of experimental data, stress values, and modeling techniques for optimizing building structures. Previous research has primarily focused on experimental investigations and small-scale models to compare plastic bricks with conventional bricks. However, there is a lack of comprehensive research that combines the analysis of stress values from software like ANSYS with the design of multi-story buildings using software like ETAB. This research aims to bridge this gap by utilizing ANSYS software to create brick models using different types of plastic and extracting stress values from these models. The obtained data, along with compression testing data, will then be integrated into the design process of a G+2 building using ETAB software, enabling the development of an optimized structural design. This research will contribute to the understanding of how plastic bricks can be effectively incorporated into building structures, taking into account their strength and performance characteristics.

1.2. Objectives of proposed study

1) To performing modelling and stress analysis of plain plastic brick using ANSYS software.
2) To design a G+2 room model using ETAB software for the components of Slab, Beam, and Column.

1.3. Scope of work

The scope of this research work encompasses addressing the research gap identified in the integration of experimental data, stress values from ANSYS software, and compression testing to design a G+2 building model using ETAB software.

The first objective of this study involves performing modeling and stress analysis of plain plastic bricks using ANSYS software. This will entail creating brick models using different types of plastic and conducting a comprehensive analysis of their behavior under various stress conditions. The stress values obtained from ANSYS software will be a critical component in assessing the structural integrity and performance of the plastic bricks.

The second objective focuses on designing a G+2 room model using ETAB software for components such as slabs, beams, and columns. The experimental data obtained from the previous objective, along with the stress values, will be integrated into the design process. This integration will allow for the development of an optimized structural design that considers the unique characteristics and performance of plastic bricks.

By leveraging the capabilities of ANSYS and ETAB software, as well as utilizing experimental data, this study aims to provide valuable insights into the behavior and performance of plastic bricks in structural applications. The findings of this research will contribute to the advancement of sustainable and efficient building designs that incorporate plastic waste materials, thereby promoting environmental conservation and waste reduction efforts.

2. METHODOLOGY

2.1. Introduction

The methodology section outlined the process and techniques used to collect and analyse data in the research study. This involved conducting compression and tension tests on plastic, bamboo and conventional bricks, analysing the data using Ansys software, designing a three-floor building structure using ETAB 17 software to evaluate the economic feasibility of plastic bricks in construction.

2.2. Simulation Analysis of HDPE and PP Bricks Using Ansys Software.

he Ansys software, specifically version 23 R2, was utilized to simulate and analyse the behaviour of HDPE and PP bricks, confirming the normal stresses and deformation values obtained from physical testing. The software provided insights into internal stresses and strains, demonstrating the bricks ability to withstand applied loads without significant deformation or failure. By reducing the reliance on physical testing, the Ansys software offered a cost-effective and efficient means of analysis, while improving the design and development of plastic bricks through computer-based simulation.

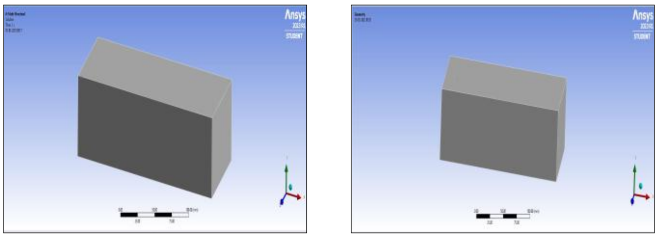

Fig -1: Modelling of HDPE and PP brick in ANSYS software

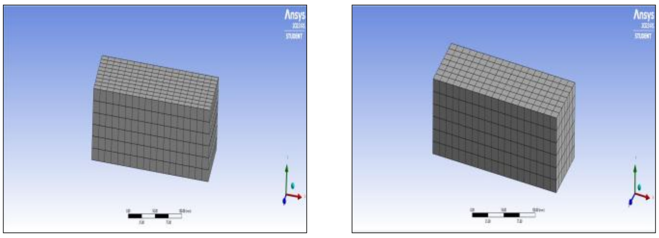

Fig -2: Meshing of HDPE and PP brick in ANSYS

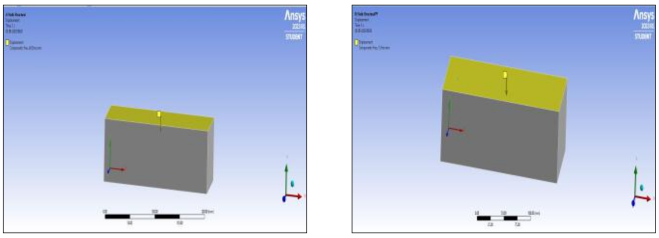

Fig -3: Displacement of HDPE and PP brick in ANSYS software

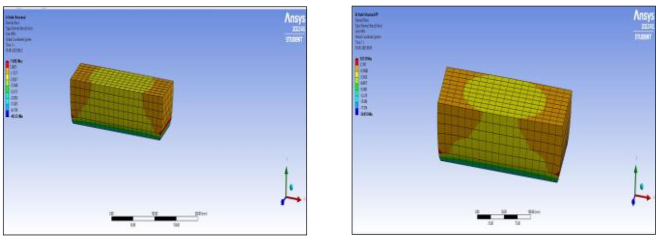

Fig -4: Normal stress of HDPE and PP brick in ANSYS software

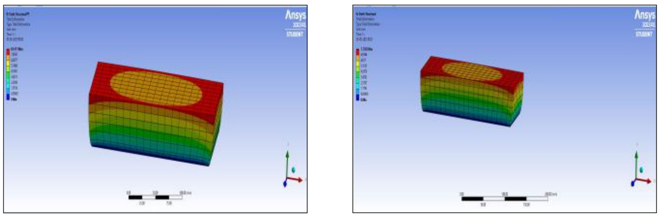

Fig -5: Total deformation of HDPE and PP brick in ANSYS software

2.3. Design of a Three-Floor Building Using ETAB 17 Software.

Using the ETAB 17 software, a three-floor building was designed with 3m x 3m bays and a height of 3m per floor. The design process involved utilizing the tested values of bricks and referring to IS 456:2000 for structural design. Beam, column, and slab components were separately designed for concrete and plastic materials, considering bending and shear stresses. The final design was validated through simulations to ensure compliance with standards and requirements.

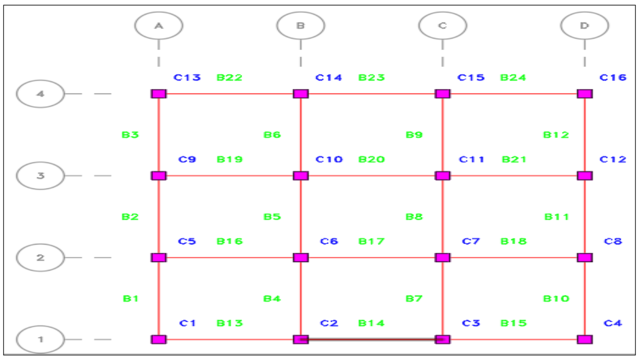

Fig -6: Centre to center plan layout for ground floor

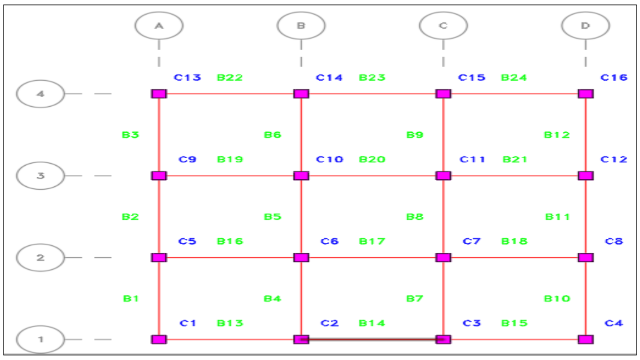

Fig -7: Centre to center plan layout for second floor

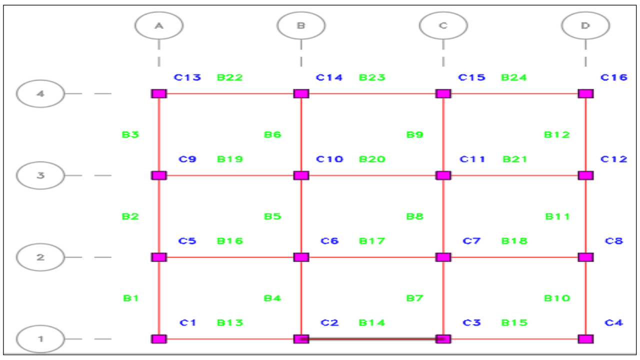

Fig -8: Centre to center plan layout for third floor

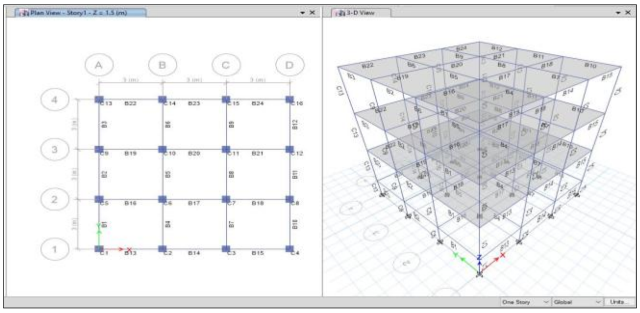

Fig -9: Centre to center plan layout & 3D model in ETAB

2.4. Results and Analysis

The results of the compression testing and Ansys software analysis were compared for different brick materials, including HDPE, PP, ACC block, and burnt clay bricks. The strengths of the concrete and plastic material structures were compared to determine the most economical material for construction. A comprehensive report documenting the methodology, results, conclusions, and recommendations for further research was prepared and subsequently published in a journal.

3. EXPERIMENT INVESTIGATION

The purpose of this paper was to conduct an experimental study on the properties and behaviour of plastic bricks made from recycled HDPE and PP materials, focusing on determining their compressive strength and other important parameters.

3.1. Types of Plastic

Plastic is a versatile material with various types, including PET, HDPE, PVC, LDPE, PP, PS, PU, PMMA, PE, ABS, PC, and Nylon, each with unique properties and applications. In this study, HDPE and PP were specifically selected for making plastic bricks due to their suitability for recycling plastic waste and their availability.

3.2. Properties of selected plastic

Table -1: Table of HDPE & PP properties

Sr. No.	Properties	High density polyethylene (HDPE)	Polypropylene (PP)
1	Melting point	130°C	160°C
2	Young's modulus	273.809 N/mm^2.	97.49 N/mm^2
3	Poisson's ratio	0.406.	0.420
4	Shear modulus	97.372 N/mm^2	34.32 N/mm^2.
5	Density	1129 X 10^6 Kg/mm^3	1121.01 kg/m^3
6	Compressive strength	13.68 N/mm^2	5.45 N/mm^2.

3.3. Comparing other properties of brick material

Table -2: General information of different material

Sr. No.	Points	BCB	AAC	HDPE	PP
1	Weight	2051.83 gm	1291.33 gm	1233 gm	1899 gm
2	Density	2000 Kg/m^3	587 Kg/m^3	1129 Kg/m^3	1121 Kg/m^3
8	Compression strength	1.15 MPa	1.93 MPa	13.64 MPa	5.45 MPa
9	Modulus of elasticity	5000 MPa	340 MPa	273.8 MPa	97.49 MPa

4. RESULT AND DISSCUSSION

4.1. Result of ANSYS Software

The Ansys software was utilized to model and analyze stress in the project. The data from the compression testing machine, including the graph, were integrated into the software to establish parameters for the analysis. This allowed for a comprehensive evaluation of stress distribution and material behavior, providing valuable insights into the structural performance of the model.

Table -3: Material property values for HDPE and PP

Sr No.	Parameters	Material name	
		HDPE	PP
1	Characteristic strength (MPa)	13.64	5.45
2	Weight Density (KN/m^3)	11.08	11
3	Mass Density (Kg/m3)	1129.85	1121
4	Modulus of Elasticity E (MPa)	273.8	97.49
5	Poisson Ratio U	0.406	0.42
6	Shear Modulus G (MPa)	97.37	34.32

Upon comparing the ANSYS software with experimental analysis, it was found that the experimental values were generally higher than those obtained from ANSYS. This discrepancy can be attributed to the specific conditions during the experimental testing. In particular, the percentage difference between ANSYS and experimental values for HDPE exhibited a larger gap compared to PP, indicating that ANSYS provided a closer approximation to the experimental results for PP.

Table -4: Comparison of ANSYS & experimental results of HDPE and PP results

Sr. No.	Parameter	ANSYS		Experimental		% Values	
		HDPE	PP	HDPE	PP	% HDPE	% PP
1	Total deformation (mm)	8.9	4.72	12.32	5.7	38	20
2	Normal stresses (MPa)	11.892	5.053	13.64	5.5	15	8

4.2. Result of ETAB software

4.2.1. Calculation of B.M. of beam and their area of reinforcement

Table No. 5: Table of Bending Moment & Area of Reinforcement Required for beam

Beam Bending Moment & Area of Reinforcement Required					
Floors	BM of Concrete model	Reinforcement	BM of HDPE model	Reinforcement	%
GF	11.2754 Kn-m	301 mm^2	6.2836 Kn-m	920 mm^2	79
FF	11.7688 Kn-m	301 mm^2	6.5164 Kn-m	920 mm^2	81
SF	9.8325 Kn-m	301 mm^2	6.012 Kn-m	920 mm^2	64

In the analysis performed using Etab Software, the concrete and HDPE models were evaluated in terms of bending moment, axial load, and area of reinforcement. The maximum bending moment was found to be 11.76 kN-m for the concrete model and 6.51 kN-m for the HDPE model, with the highest values occurring on the first floor. Interestingly, the HDPE model exhibited less variation in bending moment cross different floors compared to the concrete model, suggesting a more uniform bending behavior. Overall, the results indicate that the HDPE model demonstrated lower bending moments compared to the concrete model.

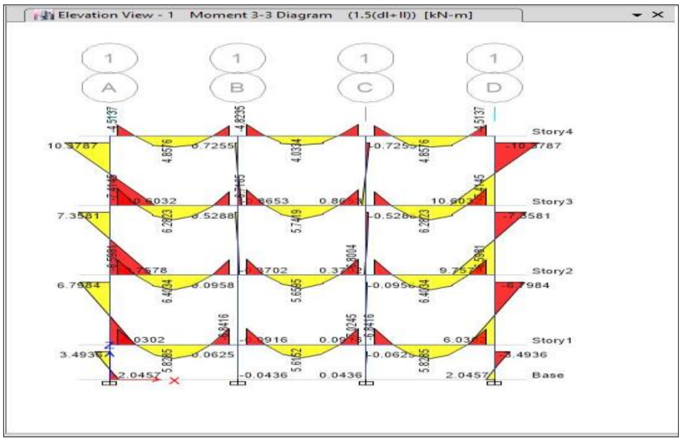

Fig -10: Bending moment for beam and column using HDPE as material

4.2.2. Calculation of axial load of column and their area of reinforcement

Table No. 6: Axial load & Area of Reinforcement Required for beam

Axial load on Column & Area of Reinforcement Required					
Floors	Concrete	Reinforcement	HDPE	Reinforcement	%
GF	- 838.335 KN	2538 mm^2	- 541.007 KN	1280 mm^2	55
FF	- 510.691 KN	720 mm^2	- 336.333 KN	1280 mm^2	52
SF	- 189.774 KN	720 mm^2	- 136.236 KN	1280 mm^2	39

Both the concrete and HDPE models experienced their maximum axial loads on the ground floor, with the concrete model having a higher load of 838.33 kN compared to the HDPE model's 541.00 kN. Surprisingly, there was no significant difference in the area of reinforcement between the HDPE models. These results suggest that the HDPE model demonstrated a lower overall axial load, indicating improved load-carrying capacity and efficiency. Furthermore, the difference in the area of reinforcement between the concrete and HDPE models ranged from 39% to 55% across different floors, with a minimum axial force of 136.33 kN observed on the second floor of the HDPE model and a maximum reinforcement requirement of 2538 mm2 for the ground floor column in the concrete model.

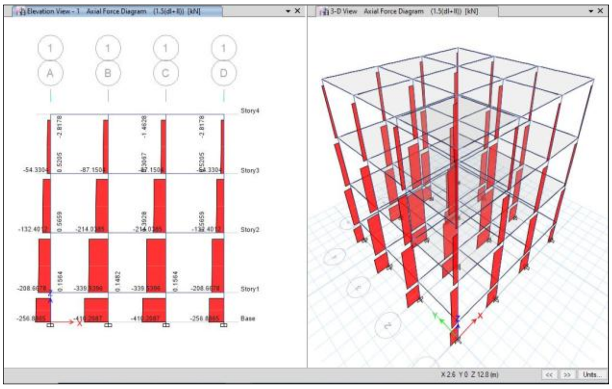

Fig -11: Axial force for column when HDPE as material

4.2.3. Calculation of B.M. of slab and their area of reinforcement

Table No. 7: Table of Bending Moment & Area of Reinforcement Required for slab

Slab Bending Moment & Area of Reinforcement Required					
Floors	Concrete	Reinforcement	HDPE	Reinforcement	%
GF	37.3649 Kn-m	616 mm2	21.2077 Kn-m	462 mm2	76
FF	36.2892 Kn-m	666 mm2	20.2492 Kn-m	438 mm2	79
SF	28.693 Kn-m	465 mm2	18.5701 Kn-m	398 mm2	55

On the ground floor, the concrete model displayed a higher maximum bending moment of 37.36 KN-m compared to the HDPE model's 21.20 KN-m. The area of reinforcement also showed variations, with a maximum difference of 79% on the first floor and a minimum difference of 55%. Overall, the results indicate that the HDPE model exhibited lower bending moments compared to the concrete model, with a minimum bending moment of 18.57 KN-m observed on the second floor.

5. CONCLUSION

In conclusion, this study's analysis and testing shed light on the superior performance and characteristics of HDPE in structural applications. HDPE demonstrated higher load-carrying capacity, compressive strength, and flexibility compared to other materials. The comparison between experimental and software analysis results emphasized the significance of accounting for physical conditions during testing and the accuracy of ANSYS and ETAB software. These findings pave the way for future research on design guidelines and modeling optimization in this field.

Based on the data obtained from the compression testing and the analysis conducted using ANSYS and ETAB software, the following conclusions can be drawn:

5.1. ANSYS Analysis:

1) The experimental values obtained from the compression testing machine were higher than those obtained from ANSYS software.
2) The percentage difference between ANSYS and experimental values for HDPE deformation was higher compared to PP.
3) ANSYS closely approximated the experimental results for PP compared to HDPE.

5.2. ETAB Analysis:

1) The HDPE model exhibited lower bending moments and axial loads compared to the concrete model.
2) The HDPE model displayed more uniform bending behavior throughout its height.
3) The HDPE model showed better load-carrying capacity and performed more efficiently in terms of axial loading.
4) Overall, these findings suggest that HDPE has superior mechanical properties in terms of compression, bending, and load-carrying capacity compared to other materials. The analysis conducted using ANSYS and ETAB software provided insights into the structural behavior and performance of the HDPE model.

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