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Plastic Waste Management in Construction: Exploring the Potential of Plastic Bricks

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Abstract-*The increasing generation of plastic waste, driven by population growth, urbanization, and changes in lifestyle, has become a significant environmental challenge. This study focuses on addressing this issue by exploring the use of plastic waste in brick production. The objective is to reduce plastic waste and its environmental impact while creating a sustainable alternative for construction materials. The research methodology involves conducting compression and tension tests on plastic and conventional bricks, as well as designing a three-floor building structure using computer-aided software. The results of the testing and analysis indicate that plastic bricks exhibit superior mechanical properties, including higher yield stress, elongation, and tensile strength, compared to conventional bricks. Moreover, cost analysis reveals the potential for economic benefits in utilizing plastic waste for brick manufacturing. This research contributes to the field by providing insights into the feasibility and benefits of incorporating plastic waste into construction materials, thereby addressing the environmental challenges associated with plastic waste and promoting sustainable building practices.*

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

1. INTRODUCTION

The generation of plastic waste is on the rise, with an exponential increase occurring every decade due to factors like population growth, urbanization, and changes in lifestyle. India's high population density poses a particular challenge in managing this plastic waste, which not only persists in the environment but also contributes to land and water pollution. Polyethylene (PE) is a commonly used plastic, especially in single-use items like carry bags and bottles, further impairing the issue. To address this problem, recycling plastic waste into plastic bricks presents a viable solution. However, certain plastics, such as HDPE and PTE, are hazardous, and the presence of microplastics below 50 microns in soil threatens its fertility. The improper disposal of plastic waste also pollutes the oceans and endangers marine life. Consequently, recycling plastic waste into bricks can help mitigate the environmental impact of plastic by reducing pollution and the demand for traditional building materials, leading to environmental benefits.

1.1. Research gap

The literature review revealed that several studies have been conducted on the utilization of plastic in brick production to reduce soil content. These studies involved experiments using plastic to plastic brick for analyses the strength characteristics. Additionally, experimental studies have explored the use of different materials as binders for plastic bricks. The current study aims to focus on producing plastic bricks without soil content and subjecting them to testing using a Universal Testing Machine (UTM).

1.2. Objectives of proposed study

1) To validate the formulation of a problem statement, development of methodology, and defining performance objective for analysis.
2) To characterize the plain plastic brick through experimental studies.

1.3. Scope of work

The methodology for this study was developed based on a thorough literature review, which revealed a gap in the existing research. This review helped to identify the need for further investigation in the field. The methodology was then designed to address this research gap and contribute new insights and solutions. The study aimed to conduct a comprehensive investigation by casting bricks using different types of plastic and subjecting them to testing using a Universal Testing Machine. The objective of the testing was to assess the strength of the plastic bricks. The procedure involved moulding the plastic into brick shapes, allowing them to set and dry. The results obtained from this testing process were utilized to evaluate the feasibility of utilizing plastic materials in brick manufacturing.

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 test on plastic bricks and conventional bricks and tension tests on bamboo to evaluate the strength feasibility of plastic bricks in construction.

2.2. Mould preparation for casting plastic bricks

The preparation of the mould was a crucial step in ensuring the quality of the plastic bricks. This involved cutting and welding pieces of mild steel plate to create a mould with the required dimensions of 250 x 120 x 200 mm, internal dimensions of 230 mm x 100 mm x 200 mm, and a thickness of 10 mm. Additionally, a handle rod and a hammer were formed to aid in the brick-making process.

Fig -1: Procedure for preparation of mould

2.3. Plastic Selection and Preparation for Brick Making

HDPE and PP were selected as suitable materials for making plastic bricks due to their specific properties and the availability of bottle caps and used pieces for recycling. The plastic was heated to the correct temperature using a household induction system, and shredded samples of HDPE and PP measuring 20 mm were used. Up to 3.5 kg of plastic was used per brick, with a total of 10.5 kg used for 3 samples, and the softened plastic was poured into a mould to shape the bricks.

Fig -2: Different types of plastic

Fig -3: Plastic brick manufacturing process

2.4. Material Testing and for Bricks and Bamboo

The compression tests were conducted on plastic bricks made of HDPE and PP, as well as ACC blocks and burnt clay bricks, revealing comparable strength. Each material experienced testing with three samples, and careful observation and analysis were performed. The Universal Testing Machine (UTM) was calibrated the load was applied at a rate of 14 $N/mm^2/min$. Additionally, the bamboo used in the tensile strength test had a defect-free diameter of 25.4 mm and a length of 1 meter, and three samples of each material were tested and analysed for compression and tension. Multiple repetitions were conducted, and average values were recorded to ensure result accuracy.

Fig -4: ACC Brick & BCB sample for testing

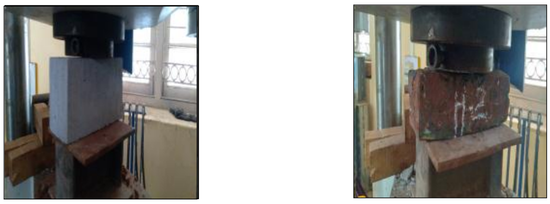

Fig -5: HDPE and PP Brick sample for testing

Fig -6: HDPE and ACC for testing

Fig -7: BCB and PP for testing

Fig -8: tensile testing of Bamboo

3. EXPERIMENT INVESTIGATION

The purpose of this paper was to conduct an experimental study on the properties and behavior 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
3	Brick size	220 X 95 X 70 mm	223 X 100 X 100 mm	230 X 100 X 100 mm	230 X 100 X 100 mm
4	Size of materials	<0.002 mm	0.002 to 0.075 mm	20 mm	21 mm
6	Cracks evolving	from diagonally towards centre	vertical from center of brick	from diagonally towards centre	from diagonally towards centre
8	Compress ion 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
10	Applicabil ity	Load and framed structure	Framed structure	Load and framed structure	Load and framed structure
12	Benefits	locally available	Reusable materials used	Waste utilises	Waste utilises
13	Disadvant ages	Non reusable	Non reusable	Material costlier	Material costlier
14	Process of manufact uring	conventio nal	Chemical process	Heating and compressi on	Heating and compressi on
15	Bonding	Good bonding with mortar	Good bonding with chemical	Interlocki ng	Interlockin g

4. RESULT AND DISSCUSSION

4.1. Result of compression test

4.1.1. Compression testing in HDPE specimens

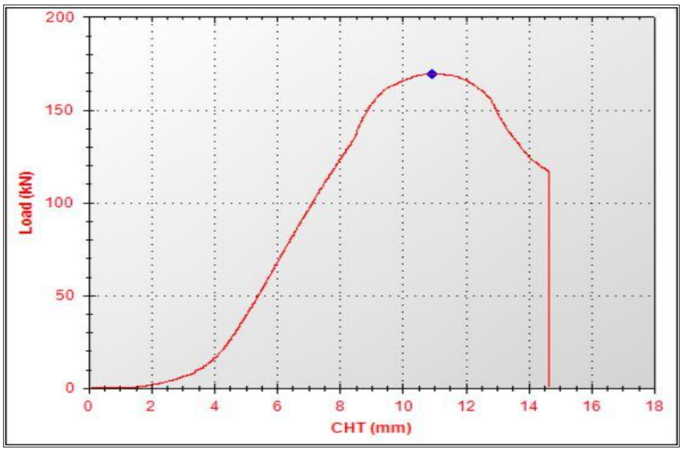

Chart -2: Compression testing of HDPE specimen

During the testing of specimen number 01, the maximum compression load achieved was 169.12 KN, which was 22.47% lower than the maximum average compression load. Similarly, the maximum elongation recorded was 11.1 mm, representing a 9.90% decrease compared to the maximum average elongation. The maximum compressive strength measured was 10.067 units, indicating a reduction of 22.47% in relation to the maximum average compression load.

In contrast, for specimen number 02, the maximum compression load obtained was 255.42 KN, surpassing the maximum average compression load by 17%, and the maximum elongation recorded was 14.58 mm, exceeding the maximum average elongation by 18%. The maximum compressive strength measured was 15.20 units, showcasing a 17% increase compared to the maximum average compression load.

Finally, for specimen number 3, the maximum compression load achieved was 229.89 KN, indicating a 5.4% increase compared to the maximum average compression load, while the maximum elongation recorded was 11.29 mm, displaying an 8.4% decrease in comparison to the maximum average elongation. The maximum compressive strength measured was 13.68 units, reflecting a 5.4% increase when compared to the maximum average compression load.

Table -3: Table of HDPE specimen

Sr. No.	Parameter	Values		
		Specimen 01	Specimen 02	Specimen 03
1	Max. Load (KN)	169.12	255.42	229.89
2	Elongation at Peak (mm)	11.1	14.58	11.29
3	Compression strength (N/mm^2)	10.067	15.204	13.684

4.1.2. Compression testing in ACC specimens

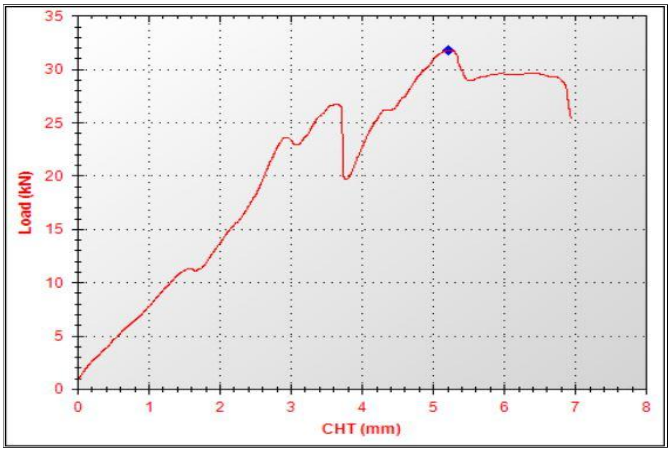

Chart -2: Compression testing of ACC specimen

During the compression testing, it was observed that specimen 01 had a maximum compression load of 31.73 KN, which was 26% lower than the maximum average compression load. The maximum elongation recorded for this specimen was 5.24 mm, indicating an 11% decrease compared to the maximum average compression load. Furthermore, the maximum compression strength measured for specimen 01 was 1.423 N/mm^2, showcasing a reduction of 26% in relation to the maximum average compression load.

In contrast, specimen 02 exhibited different characteristics, with a maximum compression load of 56.43 KN, which was 31% higher than the maximum average compression load. The maximum elongation recorded for this specimen was 5.9 mm, showing no deviation from the maximum average compression load. Additionally, the maximum compression strength measured for specimen 02 was 2.53 N/mm^2, representing a significant 31% increase compared to the maximum average compression load.

Similarly, specimen 03 displayed distinct properties, with a maximum compression load of 40.71 KN, 5% lower than the maximum average compression load. The maximum elongation recorded for this specimen was 6.51 mm, reflecting an 11% decrease compared to the maximum average compression load. Furthermore, the maximum compression strength measured for specimen 03 was 1.82 N/mm^2, indicating a 5% reduction when compared to the maximum average compression load.

Table -2: Table of ACC specimen

Sr. No.	Parameter	Values		
		Specimen 01	Specimen 02	Specimen 03
1	Max. Load (KN)	31.73	56.43	40.71
2	Elongation at Peak (mm)	5.24	5.9	6.51
3	Compression strength (N/mm²)	1.423	2.53	1.826

4.1.3. Compression testing in Brunt clay brick specimens

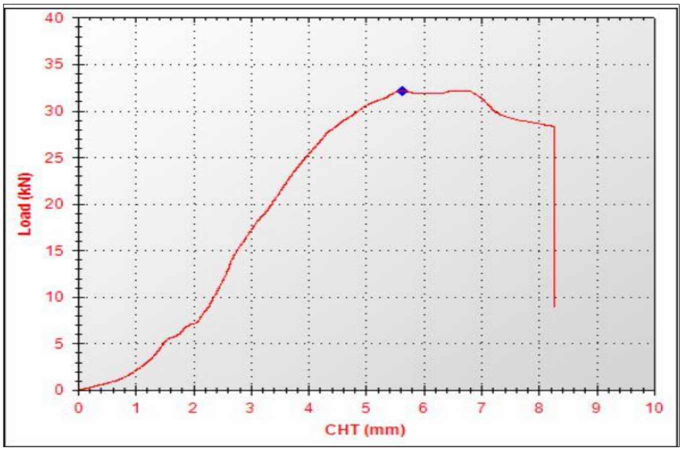

Chart -3: Compression testing of BCB specimen

During the compression testing, it was found that specimen 01 exhibited a maximum compression load of 32.15 KN, surpassing the maximum average compression load by 32%. The maximum elongation recorded for this specimen was 5.65 mm, representing a 3% increase compared to the maximum average compression load. Furthermore, the maximum compression strength measured for specimen 01 was 1.39 N/mm², showcasing a significant 20% increase in relation to the maximum average compression load.

In contrast, specimen 02 displayed a maximum compression load of 17.78 KN, which was 27% lower than the maximum average compression load. The maximum elongation observed for this specimen was 5.73 mm, indicating a 4% increase compared to the maximum average compression load. Moreover, the maximum compression strength recorded for specimen 02 was 0.85 N/mm², reflecting a notable reduction of 24% in relation to the maximum average compression load.

Furthermore, during the testing of specimen 03, it was noted that the maximum compression load achieved was 22.91 KN, signifying a 6% decrease compared to the maximum average compression load. The maximum elongation recorded for this specimen was 5.14 mm, indicating a 7% decrease compared to the maximum average compression load. Moreover, the maximum compression strength measured for specimen 03 was 1.09 N/mm², representing a slight reduction of 2% in relation to the maximum average compression load.

Table -3: Table of BCB specimen

Sr. No.	Parameter	Values		
		Specime n 01	Specimen 02	Specimen 03
1	Max. Load (KN)	32.15	17.78	22.91
2	Elongation at Peak (mm)	5.65	5.73	5.14
3	Compression strength (N/mm²)	1.398	0.851	1.096

4.1.4. Compression testing in PP specimens

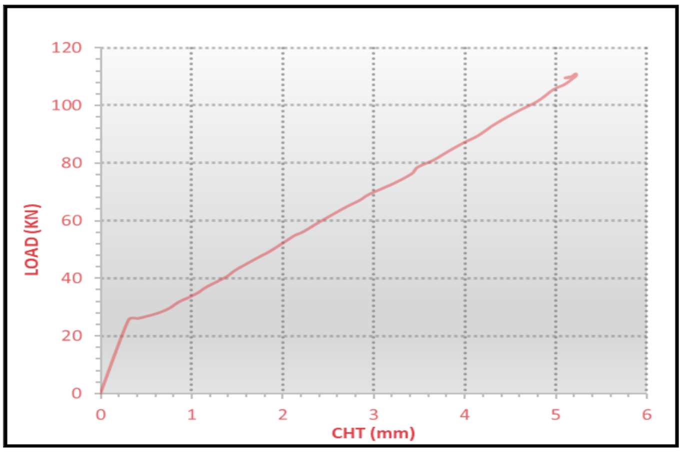

Chart -4: Compression testing of PP specimen

During compression testing, it was observed that specimen 01 had a maximum compression load of 123.15 KN, exceeding the maximum average compression load by 3%, indicating a higher load-bearing capacity. The maximum elongation recorded for specimen 01 was 5.89 mm, showing a 4% increase in deformation compared to the maximum average compression load, suggesting increased flexibility. Additionally, the maximum compression strength measured for specimen 01 was 5.68 N/mm², representing a 4% improvement in its ability to withstand compressive forces.

In contrast, specimen 02 exhibited a maximum compression load of 121.93 KN, surpassing the maximum average compression load by 3%, indicating a higher load-bearing capacity similar to specimen 01. However, the maximum compression strength measured for specimen 02 was 5.45 N/mm², indicating no significant deviation from the maximum average compression load.

Finally, specimen 03 displayed a maximum compression load of 111.45 KN, reflecting a 6% decrease compared to the maximum average compression load, suggesting a lower load-bearing capacity. The maximum elongation recorded for specimen 03 was 5.22 mm, indicating an 8% decrease in deformation compared to the maximum average compression load, suggesting reduced flexibility. Moreover, the maximum compression strength measured for specimen 03 was 5.23 N/mm², representing a 4% reduction in its ability to withstand compressive forces compared to the maximum average compression load.

Table -4: Table of PP specimen

Sr. No.	Parameter	Values		
		Specimen 01	Specimen 02	Specimen 03
1	Max. Load (KN)	123.15	121.93	111.45
2	Elongation at Peak (mm)	5.89	5.83	5.22
3	Compression strength (N/mm²)	5.68	5.45	5.23

4.1.5. Tensile testing of bamboo specimens

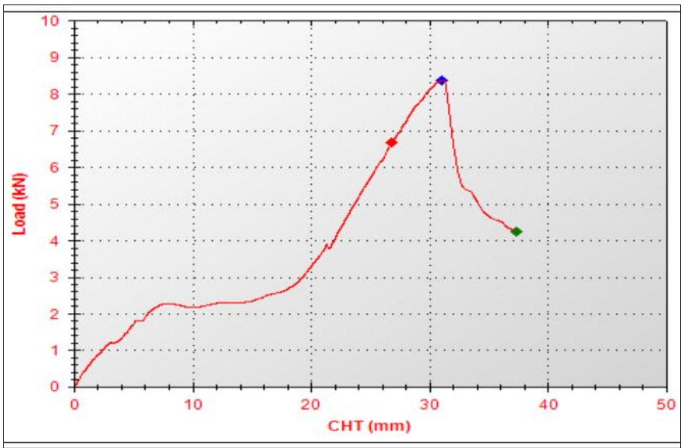

Chart -5: Tensile testing of bamboo

During the tensile testing, specimen 01 exhibited superior mechanical properties compared to the average and maximum values obtained. It displayed a yield stress of 78.63 N/mm², more the maximum average yield stress by 3%. The specimen also showed a maximum elongation of 26.67 mm, exceeding the maximum average elongation by 10%, and a maximum tensile strength of 98.99 N/mm², surpassing the maximum tensile strength by 2%. These exceptional results indicate that specimen 01 had enhanced performance and durability, making it suitable for applications requiring high strength and elongation properties.

In contrast, specimen 02 demonstrated slightly lower mechanical properties compared to the average and maximum values obtained. It had a yield stress of 74.06 N/mm², which was 4% lower than the maximum average yield stress. The specimen showed a maximum elongation of 21.22 mm, 10% lower than the maximum average elongation, and a maximum tensile strength of 93.21 N/mm², 4% lower than the maximum tensile strength. These results suggest moderate strength and elongation properties for specimen 02, making it suitable for applications that require such characteristics.

Similarly, specimen 03 displayed slightly higher mechanical properties compared to the average and maximum values obtained. It exhibited a yield stress of 77.30 N/mm², 1% higher than the maximum average yield stress. The specimen demonstrated a maximum elongation of 24.76 mm, surpassing the maximum average elongation by 2%, and a maximum tensile strength of 98.00 N/mm², exceeding the maximum tensile strength by 1%. These findings indicate high durability for specimen 03, highlighting its suitability for applications requiring higher strength and elongation properties.

Table -5: Table of bamboo specimen

Sr. No.	Parameter	Values		
		Specimen 01	Specimen 02	Specimen 03
1	Yield Stress (N/mm2)	78.63	74.07	77.3
2	Elongation at Peak (mm)	26.67	21.22	24.76
3	Tensile strength (N/mm2)	98.994	93.214	98.004

Table -4: Compression testing of experimental properties for All four types of brick

Sr. No.	Parameter	Testing materials			
		HDPE	ACC	BBM	PP
1	Avg. Max. Load (KN)	218.14	42.96	24.28	118.84
2	Avg. Elongation at Peak (mm)	12.32	5.88	5.51	5.65
3	Avg. Compression strength (N/mm2	12.99	1.93	1.12	5.45

The compression testing results revealed that HDPE material exhibited superior performance compared to other materials, with higher average maximum load, elongation, and compression strength. HDPE had an average maximum load of 218.14 KN, an average elongation of 12.32 mm, and an average compression strength of 12.99 N/mm². In contrast, burnt clay brick showed lower compression strength and load carrying capacity, with a compression strength of 1.12 N/mm² and a maximum load of 24.28 KN. The significant difference in performance between HDPE and other materials, such as PP, highlights the substantially higher compressive strength of HDPE by 58.04%.

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 results emphasized the significance of accounting for physical conditions during testing.

Based on the data obtained from the compression testing. the following conclusions can be drawn:

5.1. Compression Testing:

1) HDPE specimens exhibited higher values for maximum load, elongation, and compression strength compared to other materials.
2) Burnt clay brick specimens demonstrated lower compression strength and load carrying capacity.
3) HDPE outperformed PP in terms of compressive strength.

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