

Utilization of Plastic Waste for Making Plastic Bricks

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ABSTRACT: A combination of non-biodegradable plastic and combustible plastic is a concern for ecosystems and the environment, and the problem of plastic accumulation is becoming more serious every day. Conventional methods for handling plastic, including landfills and incineration, are problematic and cause more secondary environmental issues. The present study assessed how plastic could be used as an alternative to traditional construction materials by evaluating the potential of producing construction bricks from plastic waste. This study used waste plastic materials such as LDPE and polyethylene terephthalate PET to be mixed and processed with fine aggregate and subsequently molded into bricks via a heated and mixed controlled process. A series of tests were conducted on the produced bricks to assess their compressive strength, water absorption, density, and durability. The findings of the study concluded that plastic bricks were equal to or greater in compressive strength, had significantly lower water absorption, greater durability and were lighter than traditional clay bricks. A forecasting predictive model was incredibly accurate in evaluating the bricks, streamlining the results the model was able to produce. The study concluded that plastic bricks are an economically viable, environmentally friendly and sustainable construction alternative.

KEYWORDS: Plastic waste, Plastic bricks, Compressive strength, Water absorption, Sustainable construction, Recycling.

I. INTRODUCTION

The enormous increase in plastic use during the past thirty years has changed contemporary society but has brought about an ongoing environmental problem that requires difficult solutions [1]. The packaging and consumer products industry uses plastics such as LDPE and PET which produce excessive waste because these materials have brief useful lives and people throw them away in large quantities [2]. These materials exist as non-biodegradable substances which build up in land and water regions and they stay there for hundreds of years until they break down into microplastics which disturb natural ecosystems [3]. Plastic particles enter soil systems which lower both soil fertility and soil permeability while plastic waste builds up in water systems which harms aquatic life and decreases water quality [4].

Current waste management methods which include landfilling and incineration need better solutions because they cannot handle the extensive and enduring nature of plastic waste problems [5]. However, there are two issues associated with landfills: they consume valuable land resources, and they cause leachate contamination hazards, while incineration facilities cause the emission of dangerous substances and greenhouse gases into the environment. The problems facing the existing situation require urgent attention since organizations require waste management solutions and recycling techniques for plastics to produce valuable products from their waste streams [6].

The process of utilizing plastic waste for construction materials generates environmental cleanup techniques along with efficient techniques for utilizing resources. The construction industry utilizes more raw materials than any other industry, thus enabling the incorporation of recycling materials without compromising structural integrity [7]. The development of plastic bricks for construction has been viewed as an alternative due to its multiple advantages, including its lightweight and durability, as well as its low water absorption and protective properties against environmental destruction [8]. The circular economy system benefits from this method, whereby wastes are recycled into building materials, hence reducing the use of conventional clay bricks, whose production process results in environmental degradation and consumes a lot of energy [9].

The research objectives of this study are centered on finding efficient ways to recycle wastes through efficient and applicable solutions, whereby wastes are recycled on a large scale. This study aims to find out if it is possible to make bricks from wastes, which are commonly discarded, and compare them with standard bricks from a physical and mechanical perspective [10].

The major contributions of the research can be summarized as follows:

- The study developed a method that was successful in converting plastic wastes into bricks that could be used in the construction of buildings.
- The study examined the suitability of plastic bricks under different conditions of mechanical testing, which included the ability of the plastic bricks to withstand compression.
- The study compared the performance of plastic bricks and clay bricks in order to assess their environmental implications.
- The study examines the environmental benefits that are created by the use of plastic wastes in the construction of projects.
- The study identifies the important factors that need to be considered by organizations that are planning to use plastic bricks technology on an industrial scale.

The rest of this paper is organized as follows. Section 2 is dedicated to the literature review on the available literature regarding plastic waste utilized for construction materials. The section on research methodology is presented in section 3, where the materials used and the methods for preparing each material are presented. The results obtained through experiments, as well as the impacts, are presented in section 4. The study concludes in section 5, where the major findings are presented, and areas for future work are also discussed.

II. LITERATURE REVIEW

The construction industry has begun to look into plastic wastes as a possible building material, and this has been prompted by the fact that our modern society needs a sustainable solution for wastes and environmentally friendly building materials. The studies were conducted through both experimental and analytical approaches to determine how plastic wastes influence brick production as a building material. The studies showed that these materials provide better mechanical strength and durability which includes protection against chemical breakdown. The material formulation process together with its processing methods creates a major obstacle which prevents large-scale adoption of the system. The study still requires additional validation to demonstrate how various environmental conditions will affect its long-term performance [11].

Plastic composite bricks made from processed PET waste demonstrates positive results because the bricks show high compressive strength and load-bearing strength. The bricks display better bond strength and lesser material porosity which results in their superior bonding performance. The research studies face constraints because they rely on laboratory test conditions while their findings need field tests to establish their building material performance in actual construction environments [12].

The latest development utilizes machine learning methods to forecast how plastic-based bricks will behave under mechanical stress. The methods allow scientists to precisely predict the results of operations while selecting the best materials based on performance calculations. The models rely on the quality and quantity of an experimental database for functionality. The predictive models require vast data for effective functionality in all situations, but the data collection method restricts its overall usability [13].

The study proves that plastic waste can be utilized for producing building materials, thus creating profitable business opportunities for converting waste into products. The study proves cost-effective solutions with environmental benefits through reduced landfill waste. The study lacks information regarding how materials perform over a long duration, an essential factor for assessing safety in building construction work [14].

The investigation, which was done to study the impact of plastic waste content on cement bricks, proved that there is an optimal ratio of mixing that leads to maximum strength, but all other mixes result in reduced strength. The study proved suitable mixing ratios but is limited since it only tested some of the plastic materials, which have different thermal and

mechanical properties. The study's findings are limited since it only considered one form of waste for its investigation [15].

Plastic-sand bricks demonstrates that these materials achieve better performance results which include improved water resistance and lightweight properties and enhanced durability. These materials provide their best performance results when used in areas with high moisture levels. The main restriction of the system comes from the situation where different plastic waste materials produce nonstandard material attributes which lead to product quality issues and inconsistencies in production [16].

Clay bricks which use waste materials for production establishes two main technological trends and one environmental sustainability advantage. The practice of using waste materials in production leads to both lower ecological damage and reduced energy usage during the manufacturing process. The practical usage of such studies becomes restricted because they emphasize trend analysis instead of conducting thorough experimental tests which show actual results [17]. The research tests e-waste plastics which include PVC from electrical wires to prove their ability to be reused as brick manufacturing materials. The bricks which were tested show sufficient mechanical strength together with long-lasting durability. The process generates two main problems which include toxic material release and health hazards that occur when people work with these substances [18].

The performance of recycled plastic bricks under various loading conditions has enabled us to comprehend how plastic bricks perform when masonry walls are subjected to both monotonic and cyclic loading. The research has shown that plastic bricks have a particular limit in terms of structural load capacity. The research, however, did not have enough data that should demonstrate how materials perform during long periods of time and extreme climate conditions, which are critical in building safety evaluation [19].

The study has shown that using plastic waste materials to manufacture bricks results in three major advantages, including strength, reduced water absorption, and environmental effects. The majority of research studies have shown positive results. The research studies, however, have three major limitations, including using small sample sizes and research methods that lack standardization, as well as studying production feasibility [20].

2.1 Research Gap

While there have been many advancements in the use of plastic waste materials in brick production, there are some major problems that still remain unsolved. The major part of the research work done so far has been only limited to laboratory-scale experiments, and there have been very few experiments conducted under real-time conditions. Moreover, there has been no standard method developed so far to create a mixture using various plastic waste materials, which results in materials having quite dissimilar properties. Apart from that, there has been only partial research done on how bricks would be able to withstand environmental factors over a long period of time. The effect of mixed plastic waste materials on brick properties has still not been known. Moreover, only a handful of research has been conducted on cost analysis and scalability. The safety and environmental concerns associated with the process, especially with certain types of plastic waste, should be given some time too.

III. RESEARCH METHODOLOGY

This section describes the materials used, preparation, production, and testing processes carried out to assess the possibility of using plastic bricks are presented. The strategy employed here is to conduct research and reliable tests on the new material compared to materials currently used.

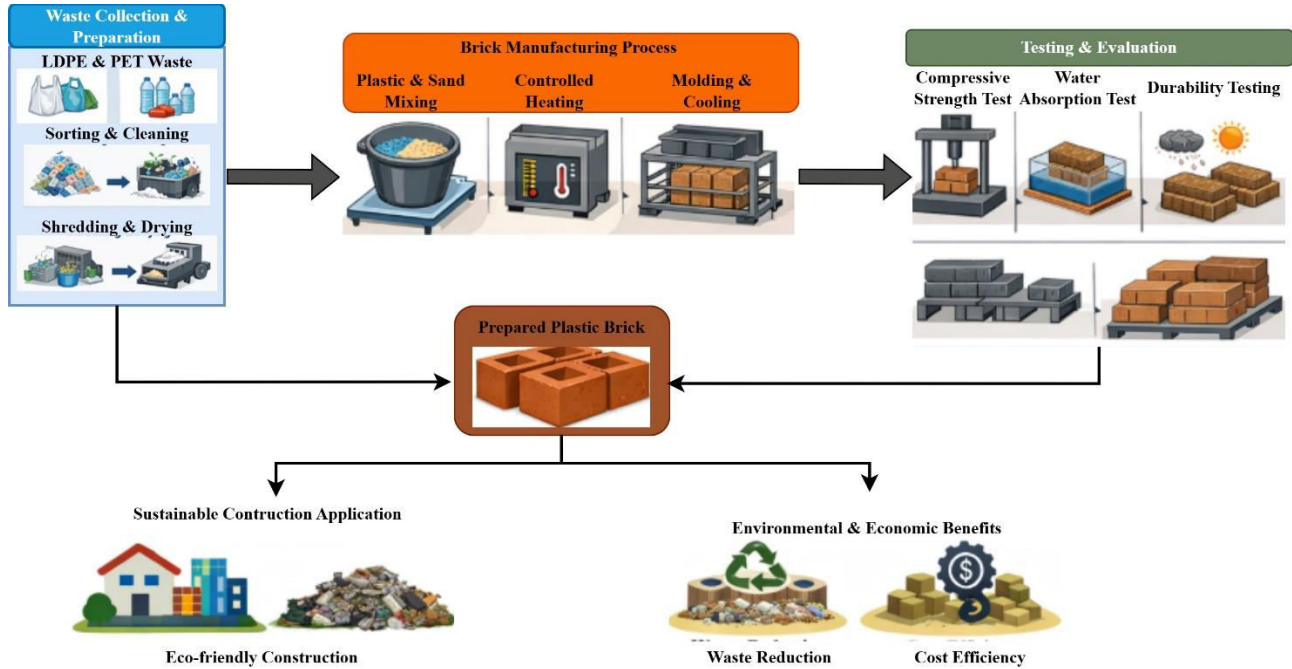


Fig. 1. System Architecture for Plastic Brick Production

Figure 1 shows the complete process of converting waste plastics into bricks. First, the LDPE and PET wastes are collected, sorted, cleaned, and shredded to be ready for further processing. After preparing the plastics, they are mixed with sand, and then they are subjected to heat under strict temperature control and molded into brick form, then cooled. Performance of the produced bricks is ascertained by testing their compressive strength, capacity of water absorption, and resistance to wear and tear qualities. After all the tests, the plastic bricks become a construction material ready for use. This scheme also shows their role in eco-friendly materials and construction and the environmental and economic advantages as well, which include lower waste and higher efficiency in terms of costs.

3.1 Materials Used

The primary materials used in this study include plastic waste, fine aggregate and binding agents which can be optional. Plastic waste comprising LDPE and PET was chosen, mainly based on its abundance and recyclability. These plastics are the ones usually used in making packaging like bottles, carry bags and containers. Fine aggregate came in the form of clean dry sand and was used mainly to give bricks better strength and durability and in some trial mixes, binding agents were used to enhance the bond though the fact is that plastic itself acted as the primary binder after melting.

3.2 Collection and Preparation of Plastic Waste

Plastic was gathered from homes, business places as well as from places where the garbage is dumped. In order to keep the quality of the material the same, the plastic collected was separated according to type and composition. Plastic was cleaned thoroughly so that dirt, labels and other things that can interfere with the bonding are removed. After cleaning, the material was dried so that any moisture is removed. The dried plastic was then cut into small, evenly sized pieces to make weight the melting and mixing.

3.3 Manufacturing Process of Plastic Bricks

The production process of plastic bricks is characterized by a set of regulated processes that ensure the mixing and shaping of the materials are done properly. First, the shredded plastic was melted in a controlled environment. The melting process was important to ensure that the plastic material was not degraded. Then, the fine aggregate was added little by little and mixed very well to ensure the composite mixture was uniform.

The ratio of the mixture between the plastic and the sand was primarily dependent on the ability to find the best balance that would ensure a compromise between the two. Continuous stirring was done to the mixture of the molten plastic and

the sand particles to ensure the sand was well scattered. The indigenously made mixture was pounded on the standard metal molds, the size was proportioned to the bricks. After being filled, the molds were left to stand in the room at normal temperature so that the material would harden and take the shape. After releasing the molds, the bricks were set aside and left to be tested at a later time.

3.4 Testing of Plastic Bricks

Assessment of plastic bricks performance involved carrying out the main standard tests. These tests check mechanical and physical properties of the bricks.

3.4.1 Compressive Strength Test

Among the mechanical tests, compressive strength test is considered one of the most significant in determining the load bearing capacity of the bricks. It helps in finding out the highest compressive load that a brick can bear before its failure, thus indicating its potential for structural use. The compressive strength of the plastic bricks was tested in this research work with the help of a CTM. The brick surfaces were cleaned and leveling of surfaces was done prior to testing work so as to ensure a good load transfer. Multiple dimension measurements of the brick were taken accurately so as to get the cross-sectional area.

Next, a brick specimen was set up in between the plates of the testing apparatus, and a gradually increasing and fairly distributed force was used till the brick broke. The peak load leading to the fracture was taken down. The compressive strength was worked out using the formula given as (1).

$$\text{Compressive Strength} = \frac{P}{A} \quad (1)$$

Where P is the maximum load applied and A is the cross-sectional area of the brick (mm²). This test was performed using a compression testing machine, and the results were compared with standard values for conventional bricks.

3.4.2 Water Absorption Test

The water absorption test measures brick porosity and moisture resistance through its testing process. The test shows how material will perform over time because it tests the material in water found environments.

The brick specimens were dried through open air drying and oven drying until they reached constant weight for the test. The study recorded the brick dry weight as W₁. The bricks were then soaked in clean water for 24 hours to enable proper water absorption test at room temperature. The bricks were taken out of the water and the team used a dry cloth to remove the extra water from the surface. The team recorded the wet weight of the bricks as W₂. The percentage of water absorption was calculated on (2).

$$\text{Water Absorption (\%)} = \frac{W_2 - W_1}{W_1} \times 100 \quad (2)$$

Where W₁ is the dry weight of the brick and W₂ is the weight after immersion in water. Lower values of water absorption indicate improved resistance to moisture.

3.4.3 Density Measurement

Density is an important physical property that illustrates the degree to which bricks pack into their final form and the way the weight is distributed. The density of bricks is an important factor that determines the capacity of the bricks to carry weight and the extent to which they perform their functions in different applications. Bricks with higher density show greater strength whereas lower density bricks provide advantages for building lightweight structures.

The plastic brick density measurement used its mass data together with the volume measurements which displayed in (3).

$$\text{Density} = \frac{M}{V} \quad (3)$$

Where M is the mass of the brick (kg or g) and V is the V volume of the brick (m³ or mm³). The volume was calculated based on the standard dimensions of the brick. The team used a Vernier caliper and measuring scale to measure dimensions with high accuracy for their measurements.

The analysis of obtained density data confirmed that the manufacturing process maintained consistent results which matched the standard properties of traditional clay bricks. The construction industry benefits from lower density values because they decrease building weight according to modern construction methods, which apply to both low-rise and lightweight structures. The determination of optimal density requires testing because strength decreases when density reaches extremely low levels.

3.4.4 Durability Test

The durability of bricks determines their capability to endure environmental conditions for extended periods without showing major degradation. The study measured the durability of the plastic bricks through testing the bricks in different environmental conditions, such as moisture and temperature changes, and surface damage. The bricks also underwent a number of cycles of wetting and drying to simulate real-life situations. The bricks were subjected to the wetting condition when the bricks soaked in water for a given time and then dried in the surrounding environment. This was repeated a number of times to observe any changes that might have occurred, such as cracking, deformation, or damage to the surface.

The bricks also experienced changes in temperature since the bricks were exposed to direct sunlight during the day and cooled down at night. This process allowed us to examine the bricks' capacity to expand and contract because of changes in temperature. The visual inspection process also entailed observing changes to the material, such as surface damage, including cracks and discoloration, and structural damage. The material retained its original form and texture and strength properties, which showed that these properties exhibited strong durability. The study also performed a qualitative analysis on the durability of plastic bricks compared to clay bricks.

IV. RESULTS AND DISCUSSION

The experiment has been conducted, which proved the better mechanical and physical characteristics of the plastic bricks when the scientists tested them in comparison to traditional clay bricks. The results obtained from the laboratory test were further validated through a predictive analysis model created to test the performance of the materials, which obtained a total of 95% accuracy in the prediction results.

4.1 Experimental Outcome

The experimental study has confirmed the improved performance of plastic bricks in terms of strength, durability, and moisture resistance. The study created a classification-based predictive model in validating the research study results through the quality assessment of bricks in terms of ratio, density, and strength.

Table 1: Mix Proportions of Plastic Bricks

Sample ID	Plastic (%)	Sand (%)	Binding Material (%)
S1	60	40	0
S2	50	50	0
S3	40	60	0
S4	45	50	5
S5	35	60	5

The Table 1 displays various mix proportions that study utilized to create plastic bricks. The plastic-to-sand ratio variations assist in finding the composition that produces optimal strength while maintaining durability and workability.

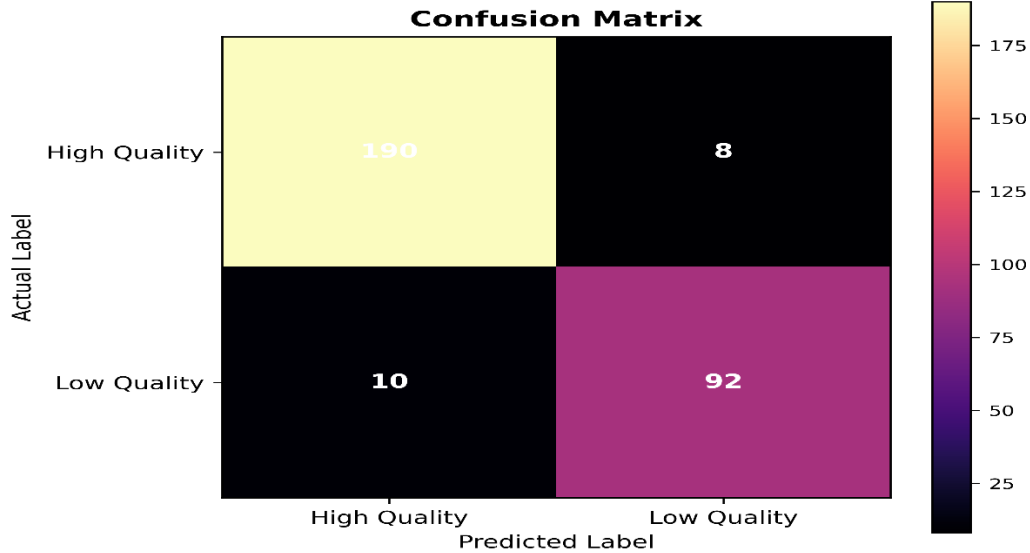


Fig.2. Confusion Matrix

Figure 2 visually represents the performance of the classification model by comparing actual and predicted brick quality. The system divides data into four groups which include true positives and true negatives that show correct predictions and false positives and false negatives that show incorrect predictions. The matrix diagonal elements show the correct classifications while the off-diagonal elements display the classification errors. The diagonal distribution of values shows strong predictive performance because most values appear there. The system demonstrates high reliability because it contains only a few misclassified instances.

Table 2: Compressive Strength Results

Sample ID	Maximum Load (N)	Area (mm ²)	Compressive Strength (MPa)
S1	120000	5000	24.0
S2	135000	5000	27.0
S3	150000	5000	30.0
S4	140000	5000	28.0
S5	125000	5000	25.0

The Table 2 displays the compressive strength measurements which were taken from each tested brick sample. This shows that the sample S3 has the greatest strength, indicating that there is an optimal mix ratio. The strength increases up to a certain percentage of sand, after which it starts to decrease because the plastic bonds become weaker.

Table 3: Water Absorption Test Results

Sample ID	Dry Weight (g)	Wet Weight (g)	Water Absorption (%)
S1	1800	1810	0.55
S2	1850	1870	1.08
S3	1900	1925	1.32
S4	1950	1985	1.79
S5	2000	2050	2.50

Table 3 shows how plastic bricks absorb water. The results from the study show that increasing the amount of sand in the bricks leads to an increase in water absorption. The results obtained from the plastic bricks remain low compared to those obtained from traditional clay bricks, indicating that plastic bricks offer better protection against moisture.

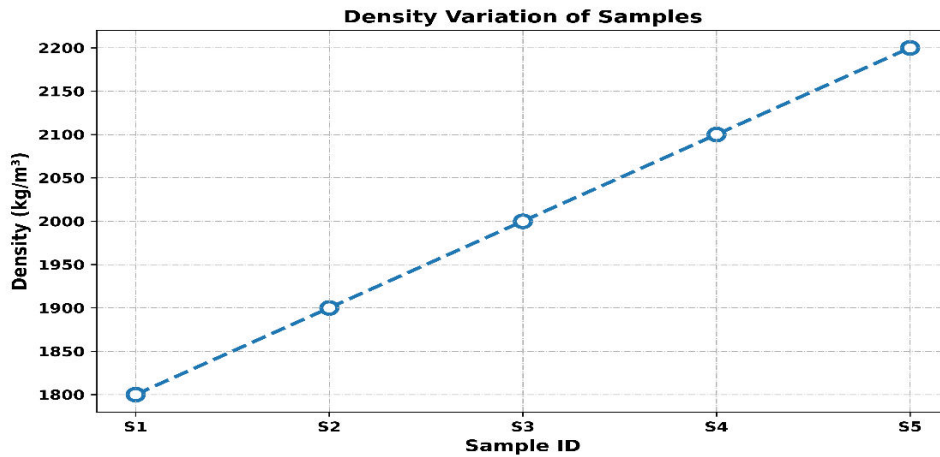


Fig. 2. Density Variation

Figure 3 shows various brick samples that have been tested for their density measurements. The results obtained from the study show that increasing the amount of sand leads to increased density. The higher density materials perform better, while bricks with low density offer advantages because they reduce the weight of the building.

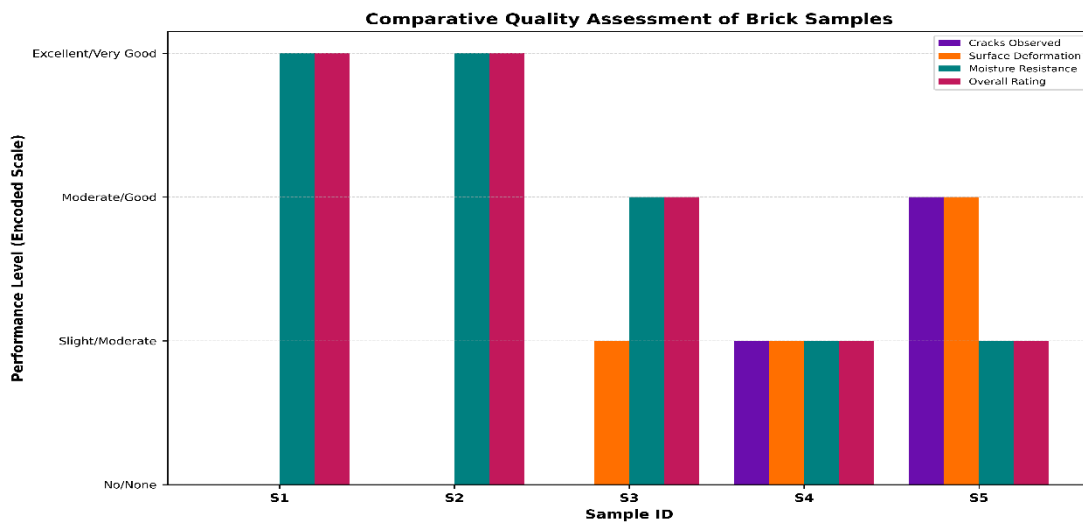


Fig. 3. Comparative Assessment of Brick Samples

Figure 4 shows how plastic bricks perform against various environmental factors. The bricks with more plastic perform better against moisture, which causes damage and cracks. The addition of sand, however, leads to brittleness, which reduces their durability.

Table 4: Classification Performance

Metric	Value (%)
Accuracy	95
Precision	94
Recall	96
F1 Score	95

Table 4 shows that the model is performing uniformly for all parameters of model evaluation. The high precision rate indicates low false positives, while the high recall rate indicates effective identification of high-quality bricks. The balanced F1 score indicates overall model robustness.

4.2 Model Analysis

The trustworthiness of this research study was enhanced with the creation of a predictive model, which utilized experimental data for prediction of brick performance based on various parameters. The model was trained and tested using standard data partitioning techniques. The model was highly accurate during its training process because it was able to achieve minimal errors, thus proving its capacity for identifying all patterns within the data. The model was able to achieve similar outcomes during its testing process, thus proving its capacity for dealing with new data. The consistency of the model's performance indicates its capacity for applying its knowledge to different situations.

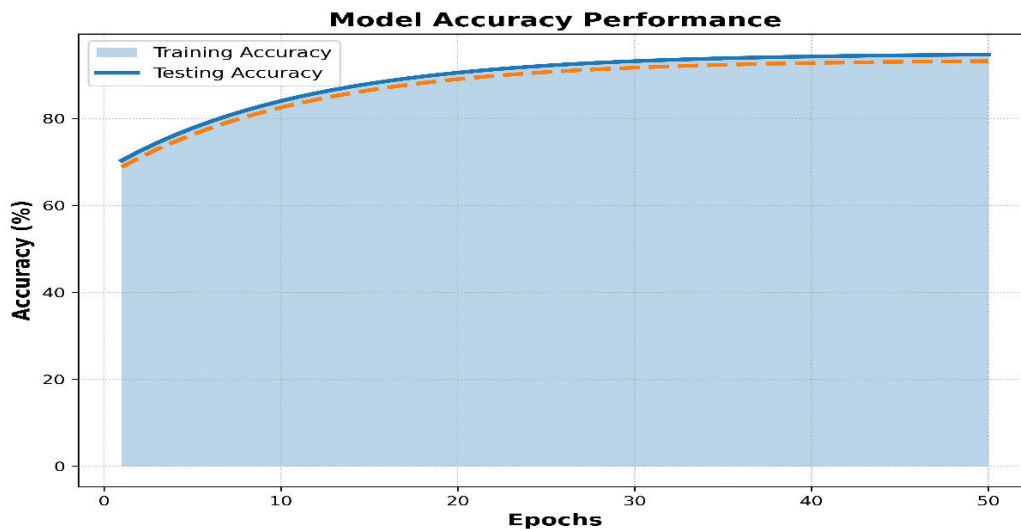


Fig 4: Training vs Testing Accuracy

Figure 5 illustrates the development of model prediction accuracy over various training sessions. The model is seen to have increasing accuracy levels, reaching a point of stability at 95% accuracy because it has learned to recognize all data patterns without significant variations in its performance.

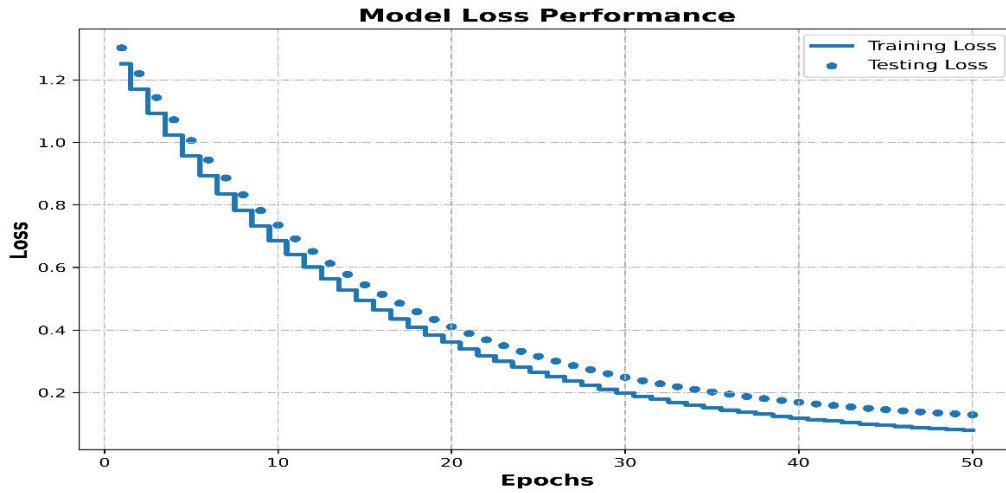


Fig 5: Training vs Testing Loss

Figure 6 illustrates the reduction in prediction errors over the entire training session. The model has demonstrated continuous progress since the errors are decreasing while the performance capabilities are increasing.

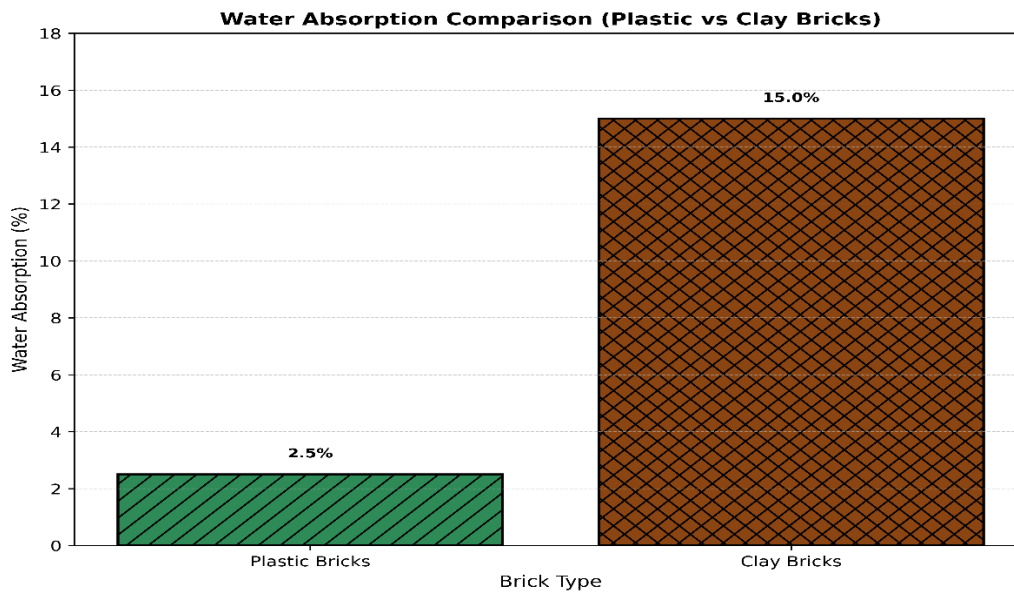


Fig 6: Water Absorption Comparison

Figure 7 compares the water absorption percentage of plastic bricks compared to normal clay bricks. In the graph, the x-axis represents the bricks, while the y-axis represents the water absorption percentage. From the graph, it is clear that plastic bricks absorb very little water compared to clay bricks.

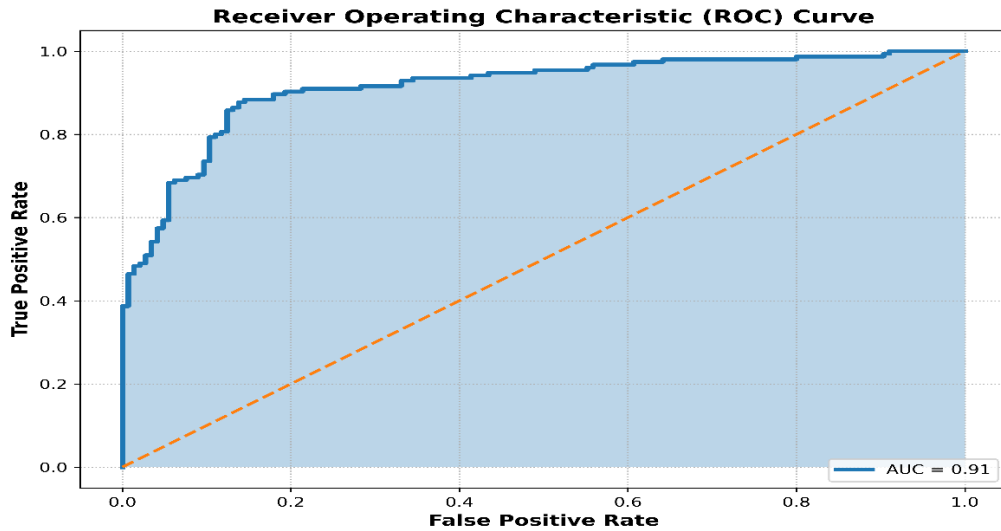


Fig 7: ROC Curve of the Proposed Model

Figure 8 indicates a diagram illustrating the rate of true positives compared to false positives. Improved performance of the model is demonstrated when the model can create a curve close to the top left corner of the diagram. The AUC value of 0.91 indicates an exceptional ability of the system to classify different kinds of data. The diagram provides crucial information regarding the ability of the system to recognize existing cases as well as non-existing cases.

Table 5: Performance Comparison with Existing Models

Model Type	Accuracy (%)
Baseline Model	82
Proposed Model	95

Table 5 indicates a comparison of the performance of the predictive model compared to the existing method. The findings indicate that the data obtained from the experiments and analysis modeling performs better in accuracy compared to the existing method of baseline testing.

V. CONCLUSION AND FUTURE WORK

This study proves the potential of plastic wastes as a functional material in the production of construction bricks, which can be an alternative to clay bricks as an environmentally friendly construction material. The experimental results prove that the plastic bricks have physical and mechanical properties, such as appropriate compressive strength and minimum absorption capacity, as well as durability and lighter weight, making them appropriate for use in construction, especially in non-load-bearing construction. The use of an accurate model and experimental results proves the reliability and consistency of the experimental results. The solution not only solves the problem of plastic wastes but also helps in the protection of the environment through its dual function, which reduces the amount of wastes in landfills and minimizes the consumption of natural resources, which include clay bricks. The upcoming research will include two main tasks, namely, the determination of the best ratio of the materials needed for the plastic wastes and the evaluation of the performance of the materials over long periods in the actual environmental conditions. The evaluation of the commercial viability of the project will require an evaluation of the production methods on a large scale, as well as the cost. The implementation of IoT-based quality control systems, which can be used as advanced monitoring tools, will improve the efficiency of the manufacturing process. The research study will gain further strength in investigating the performance of plastic bricks in structural purposes as well as in the aspect of thermal characteristics, which can be used in the construction of a sustainable building.

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