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PLASTIC-INFUSED BRICKS: A SUSTAINABLE APPROACH TO CONSTRUCTION

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ABSTRACT
The growing concern over plastic waste has spurred innovative approaches towards recycling, including the development of plastic sand bricks. In this study, plastic sand bricks were meticulously prepared and evaluated to ascertain their structural characteristics, with a focus on determining the optimal mixing ratios for enhanced strength. Utilizing PET bottles as the source of plastic waste, bricks were fabricated with varying proportions of sand, and subjected to rigorous testing including compressive strength, water absorption, efflorescence, and fire resistance. Results revealed promising properties of recycled plastic bricks, showcasing favourable strength and minimal water absorption compared to standard bricks. However, it was noted that as the percentage of infused plastic increased, a gradual reduction in compressive strength was observed. Additionally, slight efflorescence was detected in bricks with higher plastic content, though overall structural integrity remained intact. Notably, all specimens exhibited satisfactory hardness and uniformity, devoid of any significant imperfections. This research underscores the viability of plastic sand bricks as a sustainable solution for mitigating plastic pollution, while emphasizing the importance of optimizing material composition to achieve desired structural performance.

Keywords: Waste Plastics, construction

I. INTRODUCTION

In today's world, plastic has become an incredibly widespread material that is used by people all over the globe. Plastic has the benefit of being compact and lightweight, which makes it highly advantageous. Bottles, containers, food packaging, and purses are all common plastic items found everywhere. Efficient waste management techniques are of utmost importance when it comes to plastic. Plastic is produced using polymer compounds that cannot naturally break down over time. It appears that plastic buried in the ground does not break down over time. Plastic, with its numerous beneficial qualities such as flexibility, durability, and rigidity, unfortunately degrades over time and releases harmful substances into the environment after being used.

Plastic is an artificial substance that was developed in 1907. It is composed of various organic compounds that are characterized by their high molecular weight. Subsequently, it has had a significant influence on various domains. The plastic industry experienced significant growth during World War II due to its ability to replace natural resources in the production of various goods. Notable examples include the use of nylon as a replacement for silk in the production of body armor, headgear, and parachutes. Another example is the use of plexiglass in aircraft as a substitute for glass.

II. LITERATURE REVIEW

Maneeth et al. [2] examined the chemical structure that plays a crucial role in choosing suitable plastic types for manufacturing plastic pavers. Their research focused on finding innovative ways to repurpose waste materials. They assessed the practicality of integrating laterite quarry residue (sand) into construction materials using different methods. It was found that by substituting PET with propylene, a notable improvement in strength of 10 N/mm^2 could be attained. Furthermore, the increase in the plastic component leads to a decrease in water absorption.

Mohan et al. [3] it has been found that when the waste-to-plastic ratio is increased, there is a corresponding decrease in compressive strength. In addition, a thorough analysis was carried out to examine the impact of different waste-to-plastic ratios on water absorption, efflorescence, and compressive strength tests. The researchers determined that bricks made with varying amounts of plastic waste (5%, 15%, 25%, and 35%) had compressive strengths of 9.86 N/mm2, 10.46 N/mm2, 11, and 10.63 N/mm2, respectively. In addition, the blocks were subjected to maximum loads of 172.63, 183.06, 192.55, and 186.14 KN respectively during the crushing process.

Daftardar et al. [4] conducted a study on the recycling of plastic waste by using plastic extrude as a building material. The researchers have determined that the plastic bead brick has a maximal compressive strain of 13.69 N/mm2. The strength of the brick was enhanced by incorporating fly ash and other components, resulting in the production of a plastic composite brick with a range of 11.48 to 10.42 N/mm2. This level of durability surpasses that of traditional masonry. It was determined that as the concentration of fly ash increased, vitality decreased. The aim of this study was to analyze and evaluate the influence of plastic on the compressive strength and density of bricks produced using plastic instead of river sand. HEB introduces a fresh and innovative perspective to the world of masonry construction. Through the process of casting, three layers of HEB are created, utilizing a variety of materials and two different strength ratings [5].

Singhal et al. [6] conducted a study with the aim of minimizing the environmental impact caused by plastic waste generated on land and in water. This was achieved by using plastic as a construction material and testing the effectiveness of plastic pavers through a series of experiments. Based on their research findings, plastic brick has a compressive strength of 5.6 N/mm2 and is resistant to absorbing moisture.

Ghuge et al. [7,8] explored the possibility of using discarded plastic bags as a viable material for creating pavement blocks, with the aim of minimizing plastic waste. The researchers discovered that the plastic block pavements had compressive capacities of 16.05 N/mm2 and 19.52 N/mm2, respectively. These values can be compared to those of traditional pavements.

Kognole et al. [9] examined the effectiveness of various soil types in conjunction with plastic bottles (PET) for producing plastic bricks. There were different types of soil found, including river silt, red soil, and stone pulverize. After careful analysis, it was determined that plastic sand blocks have the ability to reduce environmental pollution. Four compositions were created, each utilizing different types of soil and stone. We evaluated the compressive strengths of the samples. The researchers made an interesting discovery regarding the plastic material when it was mixed with river sediment. It demonstrated a significant compressive strength of 15.50 kilonewtons (KN).

Bhushaiah et al. [10] extensively examined the properties of materials and conducted a series of experiments on cast plastic sand pavers to further their research. Plastic pavers are manufactured with varying proportions and compressive strengths, including percentages of 5%, 10%, 15%, and 20%. Testing of these samples is then carried out using a compressive testing machine (CTM). It was shown that plastic bricks outperformed bricks made of fly ash and low-quality clay.

III. OBJECTIVES

The objective of current research is to prepare and evaluate the structural characteristics of plastic sand bricks. The effect of different mixing ratios on structural strength to get optimum strength is also determined.

IV. METHODOLOGY

The integration of plastics in construction materials presents both opportunities and challenges for the industry. The brick preparation involves different stages i.e. clay preparation, moulding, drying, burning as shown in figure 1.

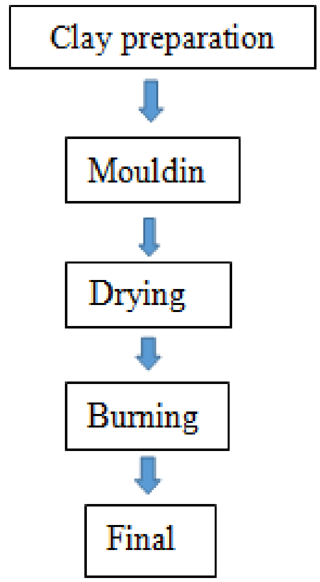

Figure 1: Brick preparation

The first stage involves clay preparation. The soil undergoes a purification process to eliminate any impurities such as debris, stones, and vegetation. After removing impurities, the substance is then left to be exposed to the elements for a long period of time. This phenomenon is commonly known as the weathering process. In order to produce high-quality brick earth, the soil undergoes a weathering process and is then mixed with other substances. At that moment, the coarsely pulverized plastic waste is combined. Afterwards, the soil mixture is made more flexible through careful pulverization, hydration. The IS 1727: 1967 will give the guidelines for the selection of clay for the manufacturing of the various types of bricks.

Figure 2: Brick mould

The manual ground molding process in used. During the manual molding process, the clay is carefully shaped to completely fill the mold. A wire frame or a wooden tool is used to remove any extra clay. Afterward, the mold is lifted, revealing a pile of raw bricks on the floor. Bricks are produced in modular sizes that adhere to the metric measurements specified by the Bureau of Indian Standards (BIS). The bricks have nominal dimensions of 20 cm

X 10 cm X 10 cm to account for the thickness of the mortar. The interior dimensions of the mould are 20 centimeters in length, 10 centimeters in breadth, and 10 centimeters in height.

Figure 3: Natural drying of bricks

The brick specimen is dried using natural air-drying technique. During the natural drying process, freshly molded bricks are exposed to ambient air, initiating the evaporation of moisture present within the clay. The difference in vapor pressure between the wet brick surface and the surrounding atmosphere drives the evaporation process, gradually reducing the moisture content of the bricks. The brick is dried for 3 days as per IS 2117:1991 standards. The bricks undergo a dehydrating process that is initiated and continues until their moisture content reaches the desired range of 5–7%. The curing process is of 14 days. Dry bricks are transported to the kiln in box or platform type wheel barrows running on two or more solid rubber tyred wheels. The process of kiln burning, also referred to as "Bhatta", involves the combustion process in a high-temperature kiln (open kiln is used). Prior to the application of clay, a set of unfired bricks is placed next to fuel, coal, and other materials in clamps. After that, it goes through a gradual exposure to higher temperatures, which can take several days. The Kiln operation is intermittent. Chambers are made up of clay heaps that have been molded and formed. Through a series of processes involving shaping, dehydrating, and igniting in kilns, bricks undergo a transformation that enhances their strength, hardness, and density. Combustion causes distinct physical and chemical transformations in bricks. At a temperature of around 640°C, there are no noticeable physical alterations that take place when heating brick.

V. RESULTS AND DISCUSSION

The results obtained from water absorption test, compressive strength test, efflorescence test, hardness test and structure test are presented. The water absorption test is conducted on plastic infused bricks.

Table 1: Water absorption percentage

Sample	W1(kg)	W2(kg)	(W2-W1)/W1	Percentage
Standard Brick	3.100	3.673	0.1848	18.48%
1% plastic brick	3.100	3.800	0.2258	22.58%
3%plastic brick	3.100	3.780	0.2193	18.125%
5%plastic brick	3.100	3.750	0.17187	20.96%

The water absorption for dry bricks should not exceed 20% of the weight of the brick. As per the Indian Standard 3495-1, the 5% plastic brick has moisture content above the permitted limit.

Water Absorption=(W2−W1)/W1×100

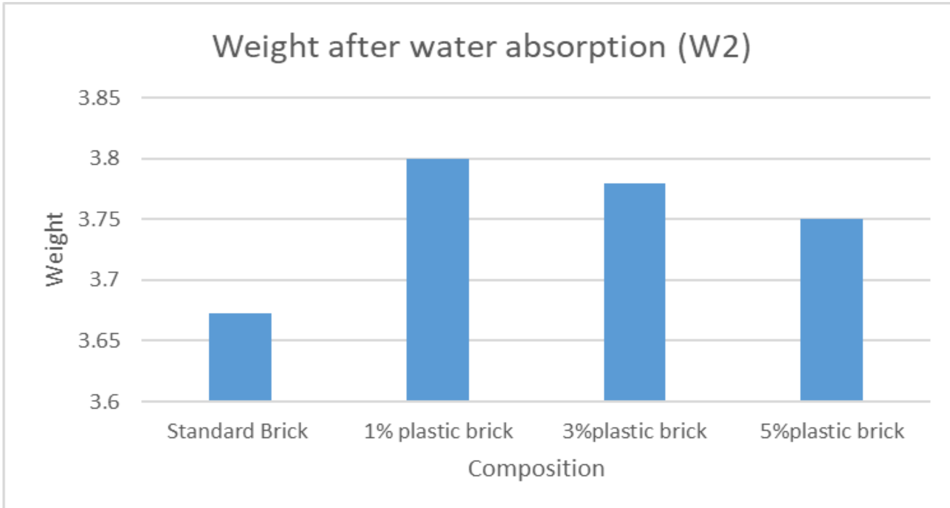

Figure 4: Weight of plastic bricks after water absorption

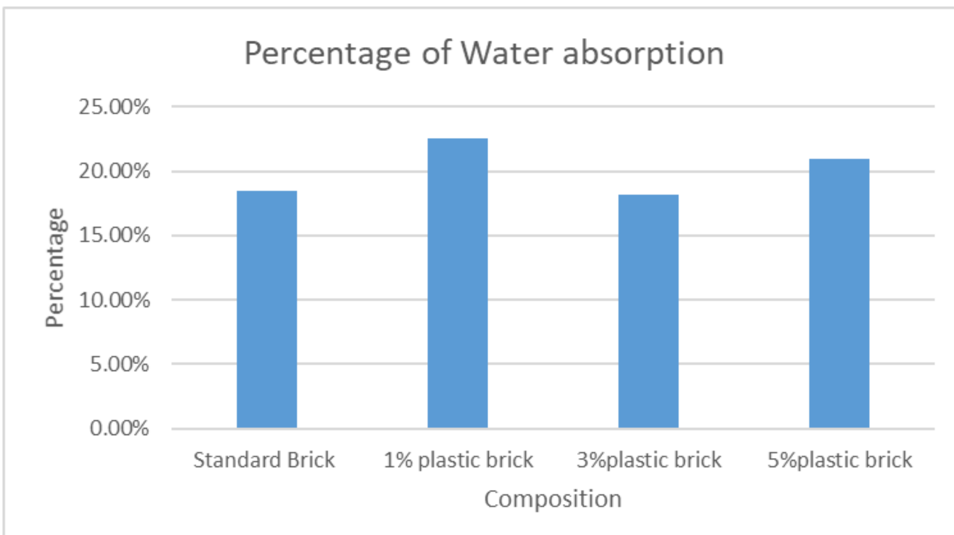

Figure 5: Water absorption chart for different composition

The water absorption test provides valuable insights into the porosity and moisture susceptibility of the bricks, which are essential factors to consider in ensuring the durability and performance of brick structures, particularly in outdoor or moisture-exposed environments. The brick infused with 1% plastic exhibited the highest water absorption percentage at 22.58%, followed by the 5% plastic-infused brick at 20.96%. Interestingly, the brick infused with 3% plastic displayed a water absorption percentage of 18.125%, which is relatively lower compared to the 1% and 5% plastic-infused bricks.

Compressive Strength Test

The results of compressive strength test are shown in table 2

Table 2: Compressive strength test

Sample	Strength(N/mm2)
Standard brick	12.49
1%plastic brick	12.26
3% plastic brick	12.12
5% plastic brick	11.88

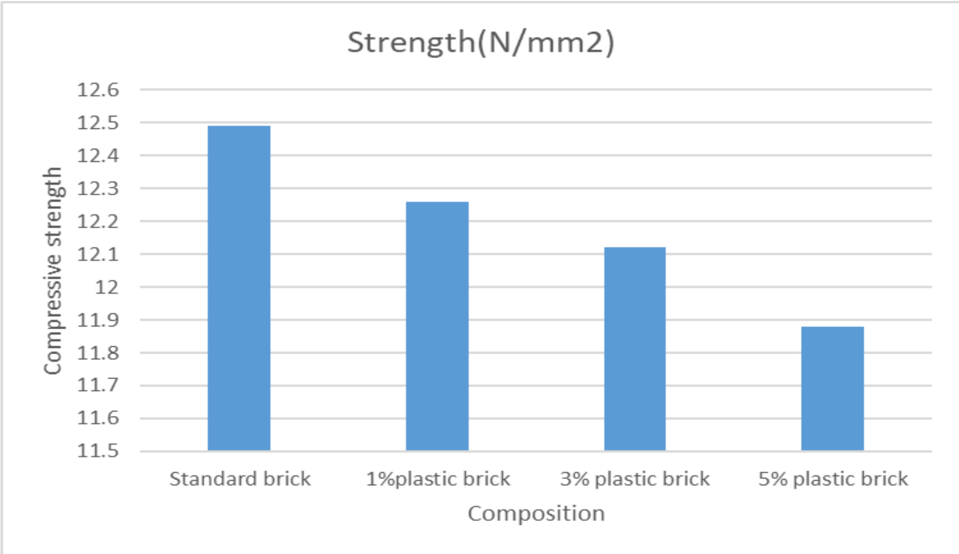

Figure 6: Compressive strength comparison chart

The standard brick exhibited a compressive strength of 12.49 N/mm², indicating its robustness and capacity to resist applied loads. it is observed that their compressive strengths generally decrease with increasing percentages of plastic material. The brick infused with 1% plastic displayed a compressive strength of 12.26 N/mm², followed by the 3% plastic brick with 12.12 N/mm², and the 5% plastic brick with 11.88 N/mm².

Efflorescence Test

In the efflorescence test, the standard brick exhibited a low efflorescence rating, indicating minimal salt migration and surface deposition. Conversely, bricks with plastic additives demonstrated varying degrees of efflorescence. The brick containing 1% plastic exhibited a moderate efflorescence rating, suggesting a moderate level of salt migration and surface deposition. Interestingly, as the percentage of plastic content increased, the efflorescence rating intensified. The brick with 3% plastic displayed a high efflorescence rating, indicating significant salt migration and surface deposition. Furthermore, the brick containing 5% plastic showed a very high efflorescence rating, signifying pronounced salt migration and extensive surface deposition.

Table 3: Efflorescence Test

Brick Surface Condition	Degree of Efflorescence
No white substance	Zero efflorescence
10% white substance	Slight efflorescence
50% white substance	Moderate efflorescence
More than 50% white substance	Heavy efflorescence

The standard brick exhibited zero efflorescence, indicating its resistance to salt deposition and or structural concerns associated with efflorescence. However, the plastic-infused bricks displayed varying degrees of efflorescence. The brick infused with 1% plastic material exhibited slight efflorescence, with approximately 10% (figure 7) of the surface covered by white substance deposits. Similarly, the bricks infused with 3% and 5% plastic material also showed slight efflorescence, with 50% and unspecified amounts of white substance deposits.

Sample	Efflorescence Rating
Standard Brick	Zero efflorescence
1% plastic brick (10% white substance)	Slight efflorescence
3% plastic brick (50% white substance)	Slight efflorescence
5% plastic brick	Slight efflorescence

Figure 7: Efflorescence test results

Hardness Test Results

The brick hardness is determined by scratching of finger nail. All the samples tested showed very slight indentation, which is acceptable. All the brick specimen i.e. standard, 1% plastic, 3% plastic and 5% plastic is sufficiently hard.

Structure Test Results

From the structure test conducted on bricks, the bricks remained compactness, homogeneousness and and free from any imperfections such as lumps, holes, etc as shown in figure 8. This is for all specimens i.e. 1% plastic, 3% plastic and 5% plastic.

Figure 8: Structure test results

Soundness Test

The efficacy of plastic bricks is evaluated using soundness tests. The sound absorption rate of bricks is evaluated and presented in table 3. The building walls should have desired sound absorption characteristics. The acoustic tests of plastic infused bricks indicated high absorption of sound The acoustic experiments conducted on bricks infused with plastic waste shown a significant increase in sound absorption, resulting in reduced noise levels inside structures

Table 3: Absorption of sound levels for different composition of bricks

Brick composition	Standard Bricks	1% plastic	3% plastic	5% plastic
Noise Level (dB)	42.3	33.5	31.1	29.7

Absorption level (%)	39.7%	37.5	39.1	40.3

According to the findings, standard bricks exhibited a noise level of 42.3 dB, with an absorption level of 39.7%. The bricks infused with 1%, 3%, and 5% plastic material displayed noise levels of 33.5 dB, 31.1 dB, and 29.7 dB, respectively, alongside absorption levels of 37.5%, 39.1%, and 40.3%. These results suggest that the addition of plastic material to bricks may have a slight impact on their sound absorption capabilities, with variations observed across different percentages of plastic infusion. While the standard bricks exhibited slightly higher absorption levels compared to some plastic-infused bricks, the differences in absorption levels among the various compositions are relatively minor.

VI. CONCLUSION AND FUTURE SCOPE

The recycling of waste plastic helps alleviate issues related to plastic disposal. Recycled plastic bricks exhibited favorable properties in both strength and water absorption. From the various tests conducted on brick specimen, the following conclusions can be drawn:

1. According to the findings, the standard brick exhibited a water absorption percentage of 18.48%, indicating its inherent porosity and ability to absorb water.
2. Bricks infused with plastic material showed varying degrees of water absorption. The brick infused with 1% plastic exhibited the highest water absorption percentage at 22.58%, followed by the 5% plastic-infused brick at 20.96%.
3. The brick with 1% infused plastic has 1.84% reduction in compressive strength as compared to standard brick.
4. The brick with 3% infused plastic has 2.96% reduction in compressive strength as compared to standard brick.
5. The brick with 5% infused plastic has 4.88% reduction in compressive strength as compared to standard brick.
6. The brick infused with 1% plastic material exhibited slight efflorescence, with approximately 10% of the surface covered by white substance deposits. Similarly, the bricks infused with 3% and 5% plastic material also showed slight efflorescence, with 50% and unspecified amounts of white substance deposits.
7. All the samples tested showed very slight indentation, which is acceptable. All the brick specimen i.e. standard, 1% plastic, 3% plastic and 5% plastic is sufficiently hard.
8. For all the brick specimens i.e. 1% plastic, 3% plastic and 5% plastic, it is observed that the bricks are compact, homogeneous and free from any imperfections such as lumps, holes, etc .

There exists an optimal plastic content that balances the reduction in compressive strength with other desired properties, such as water resistance. The observed decrease in compressive strength could be related to changes in the brick's microstructure, influenced by the presence of plastic. Variations in pore structure, distribution of plastic particles, or the formation of weak points could contribute to the observed differences. The reduction in compressive strength might be associated with the increased porosity of the material due to the presence of plastic. Porous materials typically have lower compressive strengths compared to denser one.

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