Engineering Properties of Composite Masonry Units Developed from Municipal Solids Waste, Stone Dust and Recycled Materials

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ABSTRACT
In order to protect the environment and bridge the gap between demand and supply of bricks, different waste materials have been utilized to replace either soil, sand or water in the production of bricks. The primary objective of the present study is to manufacture a composite brick from waste materials, without adding any soil or water. Melted polyethylene terephthalate (PET) and Polypropylene (PP) bottles were mixed with MSW ash, stone dust and glass bottles powder Silicon Dioxide (Silica) in varying percentages by weight for the manufacturing of bricks. Various physical, mechanical and micro-structural investigations were carried out on the composite brick to observe the effect of these properties on the behaviour of brick under different weathering conditions. The microscopic images taken through scanning electron microscope (SEM) revealed that the presence of micro-voids and cracks affects the structural density and efficiency of brick, which ultimately impacts the compressive strength and water absorption of brick. The compressive strength of 11.57 N/mm^2 was achieved by composite brick, which was 12.19 % higher as compared to conventional brick having a compressive strength 11.02 N/mm^2 whereas the water absorption of composite brick was 0.75 % which was 92.46% lower as compared to conventional brick having a water absorption 11.48 %. The study concluded that composite plastic bricks, which address both the need for building materials for construction and municipal plastic waste (MPW) reduction, can be one of the biggest developmental goals of the world that encourages sustainability and environmental safety.

Keywords: Composite brick; Plastic Waste; MSW ash, Stone Dust, Glass Powder, MSW

INTRIDUTION

Brick is one of the most commonly used building materials in the construction of buildings. Over centuries, the process used to manufacture bricks has remained largely unchanged across the world. More than 140,000 to 200,000 brick kilns are registered in India, making it the world's second-largest brick manufacturer after China. India produces over 250 billion bricks annually, which requires more than 30 to 35 million tons of coal, around 10 million tons of biomass annually and 600 million tons of clay annually. Bihar's red brick industry destroys an estimated 65 million tons of fertile soil annually. India's using 0.7 million hectares of agricultural land. It is projected that approximately a 300-millimeter depth of fertile soil will be consumed within the next 60 years (Babu and Krishnaiah, 2018).

For the manufacturing of 400 clay bricks, it requires 1 cum of clay soil, 0.2 tons of silt, 0.1 tons of coal and 1200 liters of water, which emits 230 kg of carbon dioxide and other gases such as carbon monoxide, sulphur dioxide, nitrogen oxides, and suspended particulate matter into the air (Ikechukwu and Naghizadeh, 2022). It is recommended that a brick production of 400 bricks per day will require 700-800 cum of space. The land region surrounding the kiln experiences high temperatures, rendering it unsuitable for agricultural activities after being abandoned. Clusters of these brick kilns are sources of air pollution and contribute to climate change (Dubey, 2013).

Today, due to population growth and urbanization, there is a growing need for residential buildings throughout the globe. A major problem arises in areas where the majority of the population lives below the poverty line, as bricks make up around 15% of the overall cost of construction materials and are a vital fundamental element for building activities. The demand for building materials is predicted to continue growing as India's construction industry develops at a 6% to 8.1% annual rate until 2030 (Institute for Studies in Industrial Development) March 2025.Still, there is a wide gap between the demand and supply of these clay bricks in India. The yearly demand for bricks is projected to reach around 500 billion brick units by 2030 if the construction industry develops as per the predicted annual rate (Maithel, 2013; Aleena et al., 2021). To meet this requirement, new brick kilns are being established every day, which is becoming a significant environmental concern (Maithel, 2013). As per the Central Pollution Control Board, Delhi brick manufacturing has been identified as a resource-intensive, energy-intensive, and environment polluting industry.

Another major source of pollution is plastic. It is non-biodegradable due to its chemical composition, making it extremely difficult to break down. Proper management and disposal of plastic waste are problems that many nations are currently facing. Banning or limiting the usof plastic is not a solution, as plastic is necessary for several industries to function, and single-use plastic has become increasingly in demand across all industries due to population growth, despite low recycling rates (Singh et al., 2023). Polyethylene terephthalate (PET), Polypropylene (PP) and high-density polyethylene (HDPE) are found in the majority of everyday objects and are the main sources of plastic waste. Landfilling, incineration, and careless littering are the most common disposal techniques used at present, all of which have detrimental impacts on the environment and public health (Appiah et al., 2017; Bhat et al., 2020).

To address this waste, incinerators are used, which burn the plastic at extremely high temperatures i.e. 900℃ to 1200℃ (Gupta et al., 2003). The gases released during this burning process pollute both air and water, leading to harmful effects on many people, resulting in various diseases (Singhal and Netula, 2018). Utilizing plastic waste in brick manufacturing can address both municipal plastic waste (MPW) and the requirement for construction material. Composite plastic bricks can be one of the major developmental goals of the world that promotes sustainability and environmental safety (Shakir et al., 2013; Sahani et al., 2022).

RESEARCH GAPS AND PROBLEM FORMULATION

It is evident from the literature presented, that there are some gaps in production of composite bricks manufactured entirely from waste materials. Following is a list of research needs that had emerged from the literature survey.

1. Limited research is available on plastic brick without any soil content.
2. River sand can be substituted with stone dust, marble dust, steel furnace slag or other waste materials to create more cost effective.
3. Further research is required to determine the optimum proportion of different type of plastic with various materials as constituent of building construction materials.

4. Requires further research on studying the effect of environmental factors on the properties and strength of composite brick when exposed to environmental conditions.
5. The micro-structural investigation on composite brick is limited.

RESEARCH SIGNIFICANCE

Using plastic as a brick into construction materials is a novel approach with potential benefits, one of the most significant advantages is the reduction of plastic waste. Plastic is a major environmental concern due to their non-biodegradable nature. Using it in construction can divert this waste from landfills and oceans, helping to mitigate plastic pollution. Producing traditional bricks often requires high temperature firing in kilns, which consumes substantial energy and generates greenhouse gas emissions.

Plastic bricks can be produced at lower temperature, reducing energy consumption and carbon emissions associated with brick production. The process of collecting, cleaning and processing plastic waste for brick production can engage local communities in environmental initiatives. This can create job opportunities and raise awareness about plastic pollution and recycling. The development and use of plastic bricks encourage innovation in sustainable construction materials. Researchers and manufacturers are continually working to improve the properties and applications of plastic bricks, potentially leading to more eco-friendly and efficient building materials.

OBJECTIVES OF THE STUDY

This study presents performance analysis of composite brick fabricated from waste plastic, stone dust and glass powder with micro-structural investigation. Following are the objectives established for the study.

1. To determine the optimum dosage of waste plastic (PET), stone dust and glass powder to use it as building material for construction.
2. To investigate the properties of composite brick (compressive strength, water absorption, efflorescence, hardness and soundness) and compare with conventional brick.
3. To determine the durability behaviour of composite brick under extreme environmental conditions.
4. To investigate the micro-structural properties of brick fabricated from waste plastic, stone dust and glass powder using SEM Analysis.

By accomplishing these objectives, the optimum dosage of composite brick fabricated from waste plastic, stone dust and glass powder will be obtained, which will help in addressing both the need for building materials for construction and municipal plastic waste (MPW) reduction. These initiatives can be one of the biggest developmental goals of the world that not only encourages sustainability and environmental safety but also offer economic benefits by utilizing waste materials in building construction.

METHODOLOGY

This section discusses the methodology employed in the present study for fabrication of composite bricks from waste plastic, stone dust and glass powder.

COLLECTION OF MATERIALS

The materials collected for manufacturing of composite brick includes:

1. Plastic bottles (PET)+ MSW Ash
2. Stone dust
3. Glass powder

Plastic Bottles (PET) + MSW Ash

The most widely produced plastic is Polyethylene Terephthalate (PET) Polypropylene (PP) bottles. PET and PP is commonly used to make bottles for holding liquids such as soda, soft drinks, water, and other beverages. PET and PP is identified by Resin Identification Code (RIC): 1 (Manjarekar et al., 2017). PET and PP possesses numerous advantageous qualities, including its lightweight nature, ease of bonding, recyclability, transportability and ability to be reshaped. Its chemical composition comprises hydrogen, oxygen and carbon. Notably, burning PET only results in the generation of carbon dioxide and water (Hiremath et al., 2014). In present study, only the melting of PET is required, eliminating the risk of emitting harmful gases. Figure 1 (a) & (b) shows the plastic waste sourced from dumping sites of municipal committee, Sunder Nagar, located in Himachal Pradesh, India. Table 1 displays the different engineering properties of PET.

Figure 1 (a) & (b): Waste Plastic bottles.

5.1.1 Stone Dust

Stone dust is another waste material, known as stone screenings, rock dust or quarry dust, is a byproduct of crushing stone, rocks or gravel. Every year, 200 MT of stone dust is generated as waste from quarrying sites (A Singhal et al., 2020), highlighting the need for proper utilization of this waste, especially in developing countries like India. If not utilized, may contribute to waste (Akinyele and Oeylakin, 2020). In the present study, the stone dust was collected from the National Highways Authority of India (NHAI) crusher located near Bagla Kiratpur Manali National Highway district Mandi, Himachal Pradesh. Stone dust passing through a 4.75 mm sieve and retained on a 150 microns sieve was used for manufacturing composite bricks. Various tests were performed in the geotechnical laboratory located at Abhilashi University, Himachal Pradesh to determine the different engineering properties of stone dust. Figure 2 (a) & (b) shows the waste stone dust located at Sunder Nagar, Himachal Pradesh, India.

Figure 2 (a) & (b): Stone dust.

Glass Powder

Glass is primarily composed of silicon dioxide, commonly known as silica, with other elements such as sodium, calcium, aluminum and potassium added to modify its properties and characteristics. It is hard, transparent and brittle in its solid state. Glass can be recycled repeatedly due to its ability to be reheated. It has been used as aggregates in the construction of roads, buildings and masonry materials. For this study, glass powder was obtained by crushing waste glass pieces collected from dumping site of Municipal Corporation Sunder Nagar district Mandi, Himachal Pradesh.
. Figure 3 (a) & (b) shows the collected glass powder.

Figure 3 (a) & (b): Collected glass powder.

TESTING ON COLLECTED MATERIALS

In order to construct a durable structure, materials of excellent quality are required. To choose materials of excellent quality, specific tests must be performed on the collected materials to determine whether their engineering property fall within the Indian standard code range or not. Thus, suitability of stone dust and glass powder for the manufacturing of composite bricks is ascertained by conducting following tests:

1. Grain size analysis
2. Fineness modulus
3. Specific gravity
4. Water absorption
5. Bulk density
6. Percentage of voids.

Fineness Modulus

An index number that represents the average or mean size of the sample particles is known as the fineness modulus. The fineness modulus is calculated by adding the cumulative percentage retained on each sieve and dividing the result by 100. The sample is divided into various zones based on its fineness modulus in accordance with IS 383-1970. Finess modulus of stone dust and glass powder was determined using equation 1.

$$Fineness\ modulus = \frac{Comulative\ percentage\ of\ weight\ retained}{100}$$

Specific Gravity

The specific gravity of a material is calculated by comparing its density with a reference material, usually water. It is a dimensionless quantity. As pycnometer was used to determine the specific gravity of stone dust and glass powder respectively as per IS 2720: 2002 (Part III), the Specific gravity can be calculated using equation 2.

$$Specific\ gravity = \frac{(W_2 - W_1)}{(W_2 - W_1) - (W_3 - W_4)}$$

Water Absorption

The amount of water that a material can absorb in relation to its dry mass is known as its water absorption. This test is crucial to determining durability and suitability of the material for construction purposes. Water absorption of stone dust and glass powder was conducted by standard oven dry method as per IS 2720: 1973 (Part II) specifications. Water absorption was calculated using equation 3.

$$Water\ absorption\ (\%) = \frac{(W_2) - (W_1)}{(W_1)}\ x\ 100$$

Bulk Density

Bulk density can be defined as the sample weight divided by the sample's total volume. Bulk density is divided into two categories: Rodded bulk density and Loose bulk density, based on how the materials are poured and settled into cylindrical metal measurement units.The bulk density of stone dust and glass powder were performed as per IS 2386: 1963 (Part III) specifications. Bulk density was calculated using equation 4.

$$Bulk\ density\ (kg/m^3) = \frac{(W)}{(V)}$$

Percentage of Voids

The volume of void spaces within a material in relation to its total volume is referred as the percentage of voids. Due to its impact on the density, stability and strength of the material, it is a crucial parameter in geotechnical engineering and construction. The percentage voids of stone dust and glass powder were obtained by using equation 5 as per IS 2386: 1963 (Part III) specifications.

$$Percentage\ of\ voids = \frac{(G_s - R)}{(G_s)}$$

Bulk Density

Bulk density can be defined as the sample weight divided by the sample's total volume. Bulk density is divided into two categories: Rodded bulk density and Loose bulk density, based on how the materials are poured and settled into cylindrical metal measurement units. Figure 5.8
(a) & (b) shows the bulk density of stone dust and glass powder were performed as per IS 2386: 1963 (Part III) specifications. Bulk density was calculated using equation 6

$$Bulk\ density\ (kg/m^3) = \frac{(W)}{(V)}$$

Percentage of Voids

The volume of void spaces within a material in relation to its total volume is referred as the percentage of voids. Due to its impact on the density, stability and strength of the material, it is a crucial parameter in geotechnical engineering and construction. The percentage voids of stone dust and glass powder were obtained by using equation 7.as per IS 2386: 1963 (Part III) specifications.

$$Percentage\ of\ voids = \frac{(G_s - R)}{(G_S)}$$

CASTING OF BRICKS

The weighed plastic waste was melted after the batching of materials. A gas burner was used to control the intensity of the flame during the melting process. The plastic waste was melted within 2 minutes, temperature ranging from 200°C to 220°C. The temperature was measured using a digital temperature thermometer equipped with a sensor range from -50°C to 300°C. Following the melting of the plastic, stone dust and glass powder were gradually added and the mixture was continuously stirred using a trowel until it became homogeneous, uniform in colour and consistent in viscosity.

A wooden mould with a standard modular size of 190 mm x 90 mm x 90 mm was prepared for the bricks. Prior to placing the mixture into the mould, proper oil was applied to the walls of the mould to facilitate easy removal of the bricks during the de-moulding process. Subsequently, the mixture was poured in layers into the mould and compacted using a tempering rod. Tempering was performed to ensure that the mixture filled the mould to the appropriate level without any voids. To allow for adequate heat dissipation, the bricks were de-moulded and left to cool for 24 hours. Figure 5.10 provides a detailed illustration of the manufacturing of composite bricks.

RESULTS AND DISCUSSION

TESTING ON MATERIALS

Stone Dust

Three specimens of collected stone dust, each weighing two kilograms were prepared for the grain size analysis which were passed through a range of IS sieve sizes (4.75 mm, 2.36 mm, 1.18 mm, 0.600 mm, 0.300 mm, 0.150 mm and pan), arranged in ascending order from bottom. the weight of stone dust retained on each sieve based on machine weight measurements. The resulting grain size distribution curve is displayed in Figure 4.

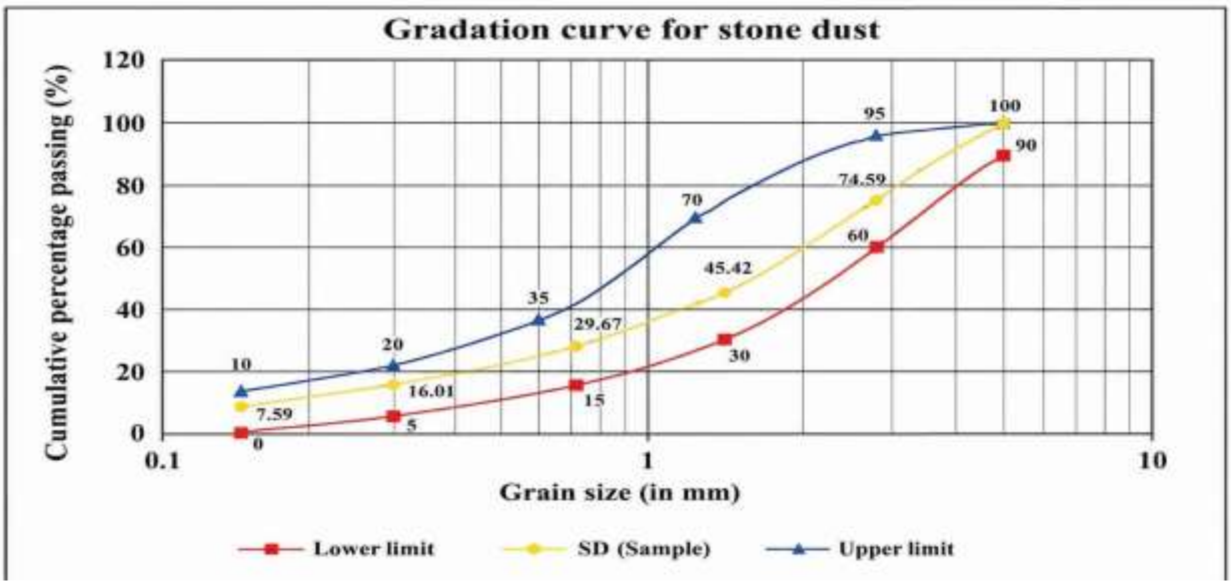
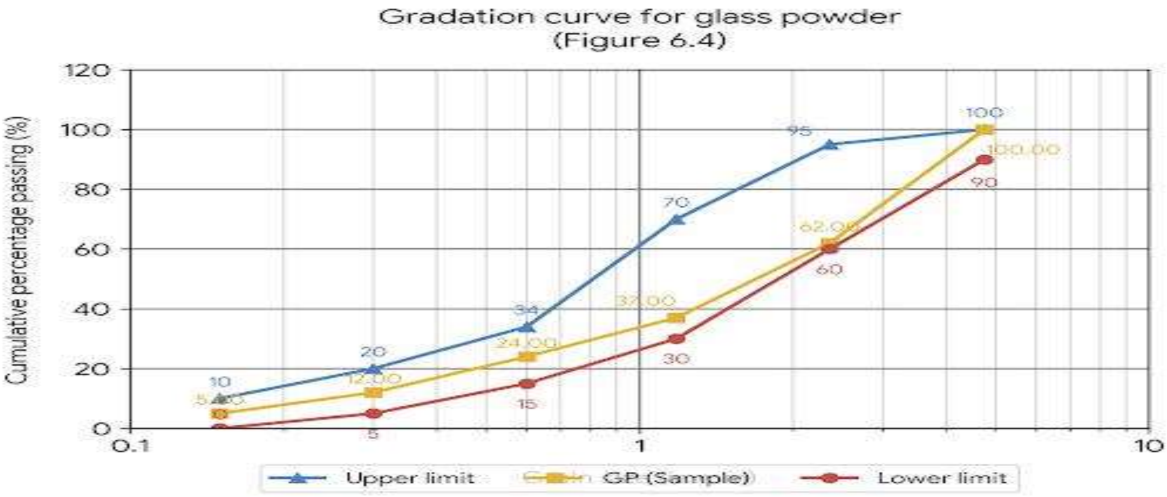


Figure 4: Gradation curve for stone dust.

Glass powder

Three specimens of collected glass powder, each weighing one kilogram were prepared for the grain size analysis which were passed through a range of IS sieve sizes (4.75 mm, 2.36 mm, 1.18 mm, 0.600 mm, 0.300 mm, 0.150 mm and pan), arranged in ascending order from bottom. The weight of glass powder retained on each sieve based on machine weight measurements.

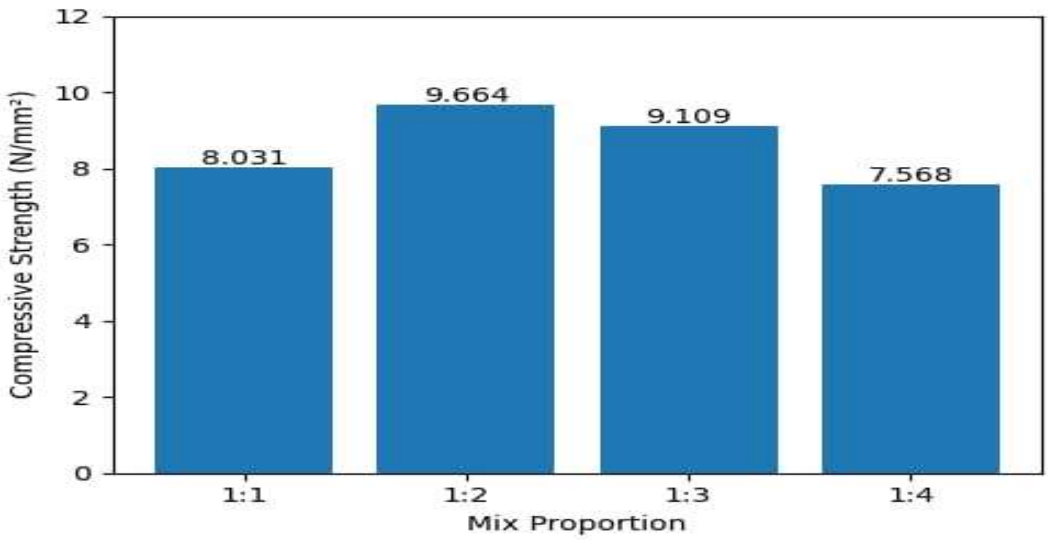


TESTING ON COMPOSITE BRICKS

Compressive Strength Test

Compressive strength test was performed in two stages, following IS 3495:1992 (Part I).

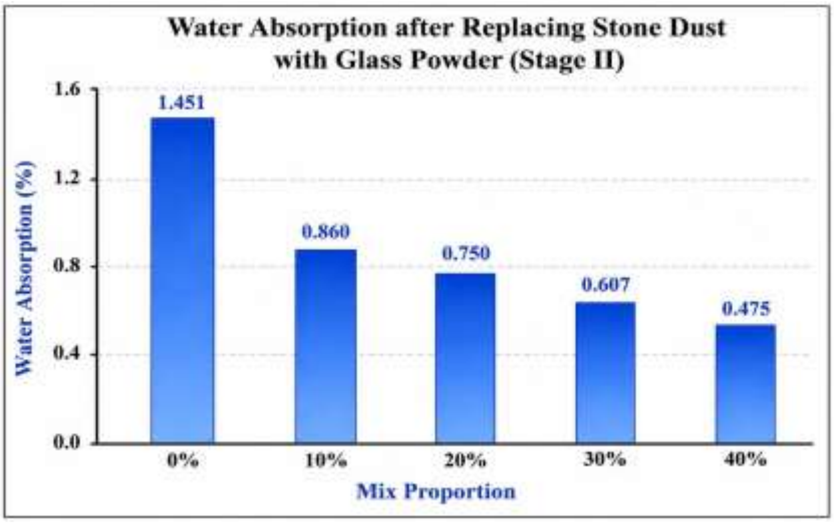
The results of the compressive strength test for first stage are presented . It can be observed from this table that the highest compressive strength was achieved by sample M2 at 9.664 N/mm^2, followed by sample M3 at 9.109 N/mm^2; sample M1 and M4 have compressive strength 8.031N/mm^2 and 7.568 N/mm^2 respectively.



Water Absorption Test

Water absorption test was performed in two stages, following IS 3495:1992 (Part II).

The results of the water absorption for second stage test are presented in Table 6.16. It can be observed from this table that sample S5 have the least water absorption 0.475%, followed by sample S4 with 0.607%; sample S3, S2 and S1 have water absorption 0.750%, 0.860% and 1.451% respectively.



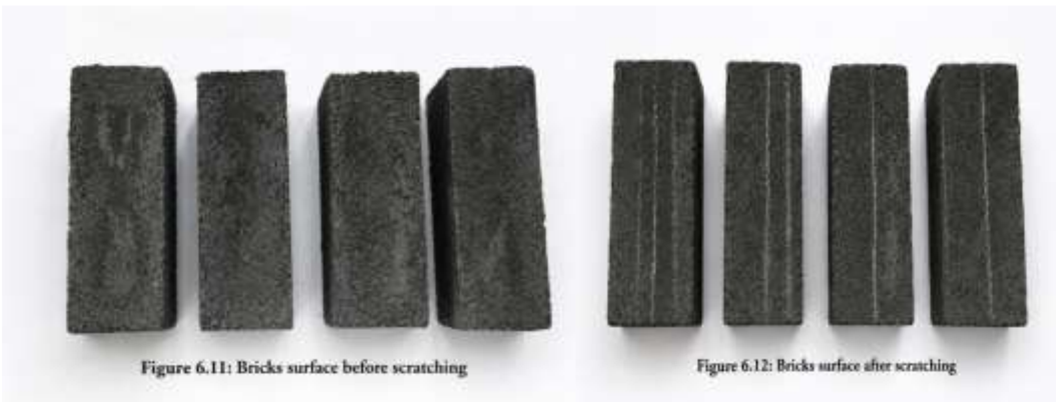
Efflorescence Test

The test was performed following IS 3495: 1992 (Part III). The brick specimens were placed vertically in water at a depth of 25 mm until the water has been absorbed by specimen. Once the water has been absorbed and brick appears to be dry, add another equivalent amount of water to the container. After 24 hours the brick specimen was examined for efflorescence.

Figure 5 (a)&(b): Efflorescence test of conventional brick.

Hardness Test

In this test, the brick's surface was scratched with a sharp steel rod and the depth of the scratch impression was evaluated to determine the hardness of the brick. From Figure 6.it can be seen the composite brick of all ratios were unaffected by the sharp steel rod in this test; only a slight impression was left on the brick's surface, indicates that all bricks samples were tough with the remarks of “Acceptable”. Stone dust and glass powder acts as an aggregate that significantly increases the brick’s hardness and compressive strength



Soundness Test

As shown in Figure 7 soundness test was performed by striking two bricks against each other and determining whether the impact produces a ringing sound or not. The test results revealed that all the composite brick samples produced a ringing sound without breaking or losing any of their edges, classifying them with rating of "Acceptable." Due to the plastic component, the composite brick has excellent resistance to moisture ingress, which is critical for long-term soundness while the stone dust and glass powder improve structural rigidity and surface hardness.

SEM Analysis

Scanning electron microscopy (SEM) was used to examine the microstructures of the composite brick specimen S1 containing 0% glass powder and specimen S2 with 12.2 % glass powder using NOVA NANO SEM 450 machine operated at voltage of 10 kV. Brick fragments were sliced into small pieces, measuring 10 mm x 10 mm x 2 mm as shown in Figure 8.

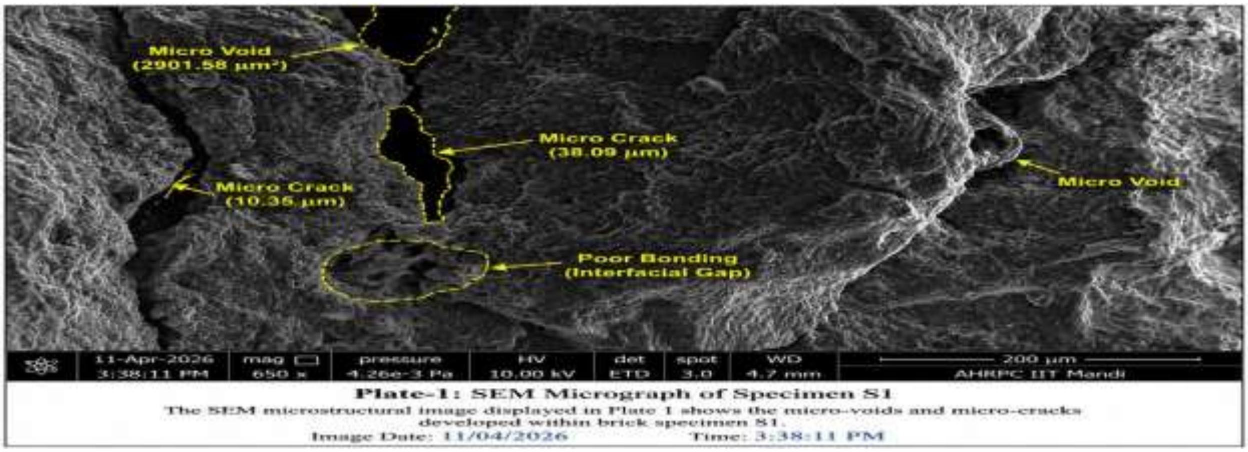
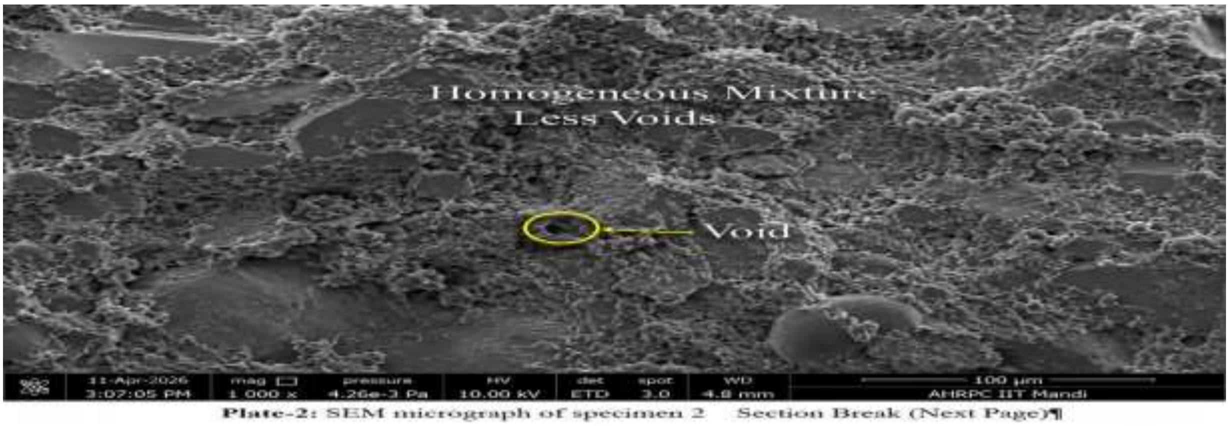


Plate 1: SEM micrograph of specimen 1.

The microstructural image displayed in Plate 1 shows the micro-voids and micro-cracks that developed within brick specimen S1. Using 'ImageJ' an image processing software, the dimensions of the micro-voids and micro-cracks were determined. The measured areas of micro-voids 1 and 2 were 2901.58 μm^2 and 2288.45 μm^2 respectively whereas the measured width micro-cracks were 10.35 µm and 38.09 µm. In addition, many places were observed where there was inadequate bonding between the plastic and stone dust, leading to reduced compressive strength and increased water absorption.

Plate 2: SEM micrograph of specimen 2.



Compressive strength for Stage-I

Based on Table 6.23, the R^2 value for compressive strength of Stage-I was found to be R^2 = 94.38%, R^2 (adjusted) = 93.35%, R^2 (predicted) = 91.25% and the difference between R^2 (adjusted) and R^2 (predicted) was less than 20%, moreover the p-value was less than 0.05 indicating that the results are significant. The interval plot between compressive strength and brick samples for Stage-I is shown in Figure 8.

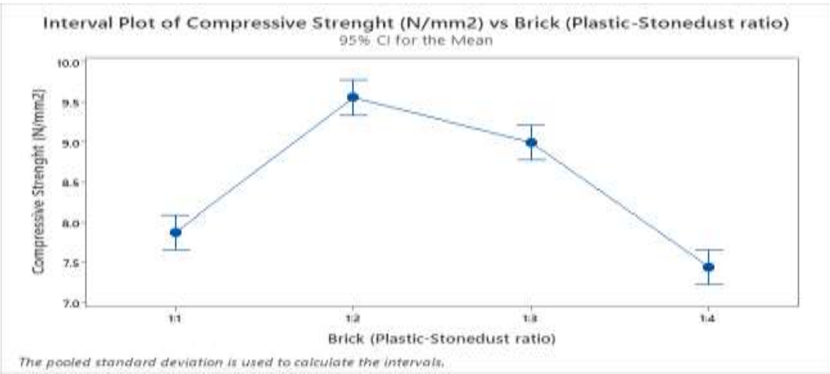


Figure 8: Interval plot between compressive strength and brick samples for stage-I.

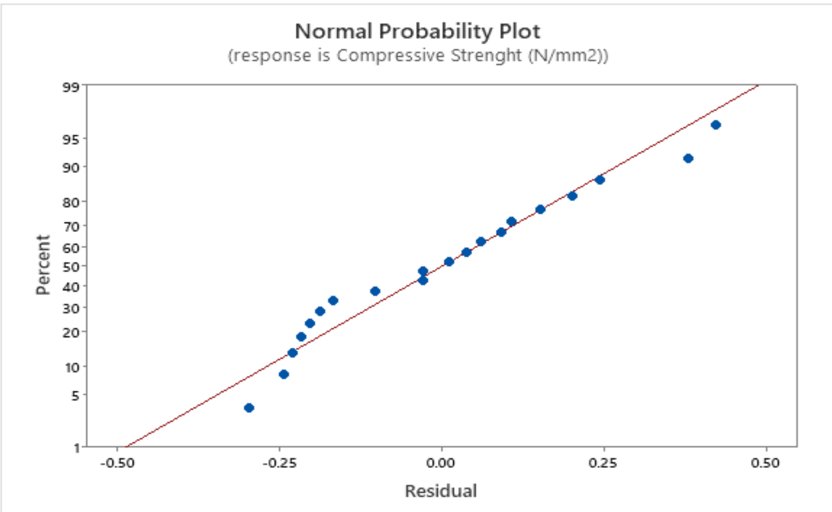


Figure 9: Normal probability plot for compressive strength for stage-I.

In Figure 9 the X-axis shows residuals, the differences between observed and predicted values, while the Y-axis displays their cumulative probability. Blue dots represent residual against expected normal values and the red reference line indicates where normally distributed residuals should lie. The majority of the points lie close to the red line, suggesting that the residuals are nearly normally distributed.

Compressive strength for stage-II

Based on Table 6.23, the R^2 value for compressive strength of stage-II was found to be R^2 = 96.62%, R^2 (adjusted) = 95.86%, R^2 (predicted) = 94.61% and the difference between R^2 (adjusted) and R^2 (predicted) was less than 20%, moreover the p-value was less than 0.05 indicating that the results are significant. The interval plot between compressive strength and brick samples for stage-II is shown in Figure 10.

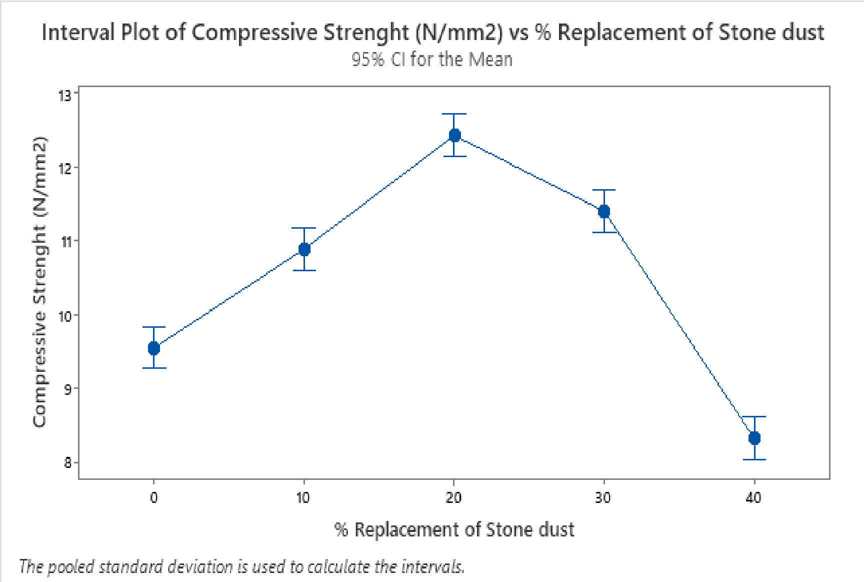


Figure 10: Interval plot between compressive strength and brick samples for stage-II.

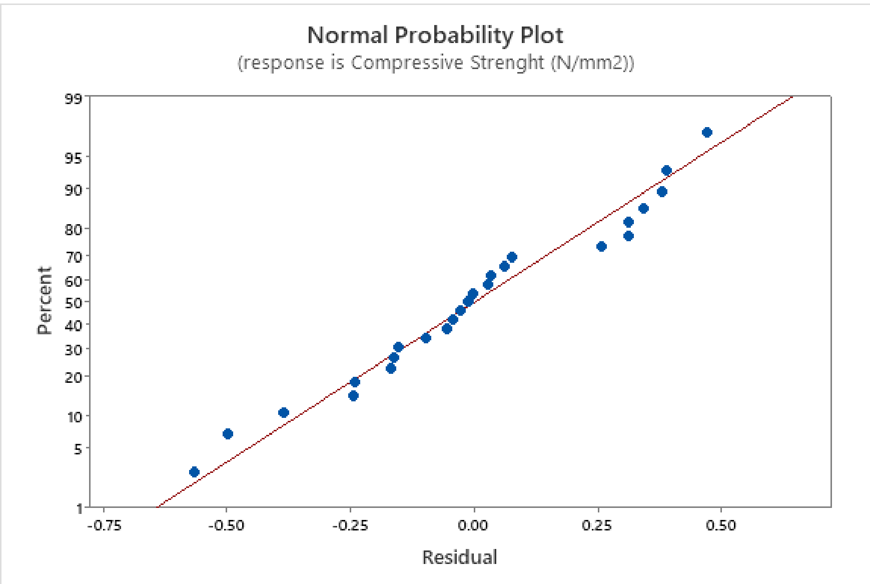


Figure 11: Normal probability plot for compressive strength for stage-II.

The normal probability plot in the Figure 11 indicates that the residuals of compressive strength measurements are almost normally distributed which meets and supports the validity of statistical analysis of the test.

Water absorption for Stage-I

Based on Table 6.23, the R^2 value for water absorption of stage-I was found to be R^2 = 94.92%, R^2 (adjusted) = 94.01%, R^2 (predicted) = 92.12% and the difference between R^2 (adjusted) and R^2 (predicted) was less than 20%, moreover the p-value was less than 0.05 indicating that the results are significant. The interval plot between compressive strength and brick samples for stage-I is shown in Figure 12.

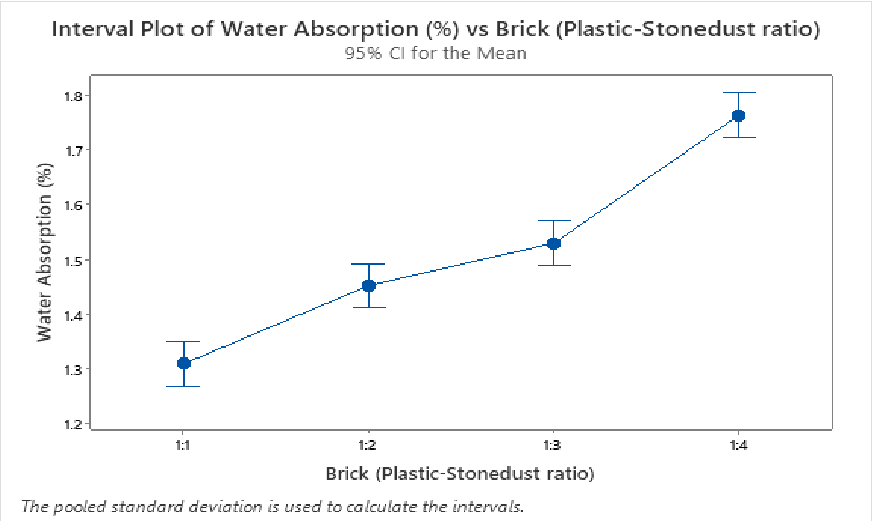


Figure 12: Interval plot between water absorption and brick samples for stage-I.

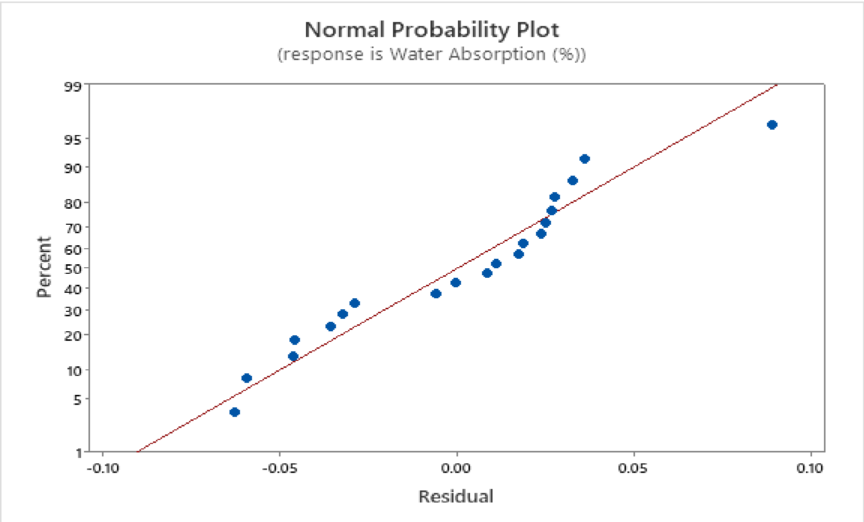


Figure 13: Normal probability plot for water absorption for stage-I.

In Figure 13 the majority of the blue dots lie close to the red reference line, suggesting that the residuals are approximately normally distributed. If the residuals are normally distributed, the statistical tests and confidence intervals based on this model are likely to be valid. The close fit of most points to the reference line suggests that the model's predictions for central data points are reliable.

Water absorption for stage-II

Based on Table 6.23, the R^2 value for water absorption of stage-II was found to be R^2 = 97.67%, R^2 (adjusted) = 96.90%, R^2 (predicted) = 95.97% and the difference between R^2 (adjusted) and R^2 (predicted) was less than 20%, moreover the p-value was less than 0.05 indicating that the results are significant. The interval plot between compressive strength and brick samples for stage-I is shown in Figure 14.

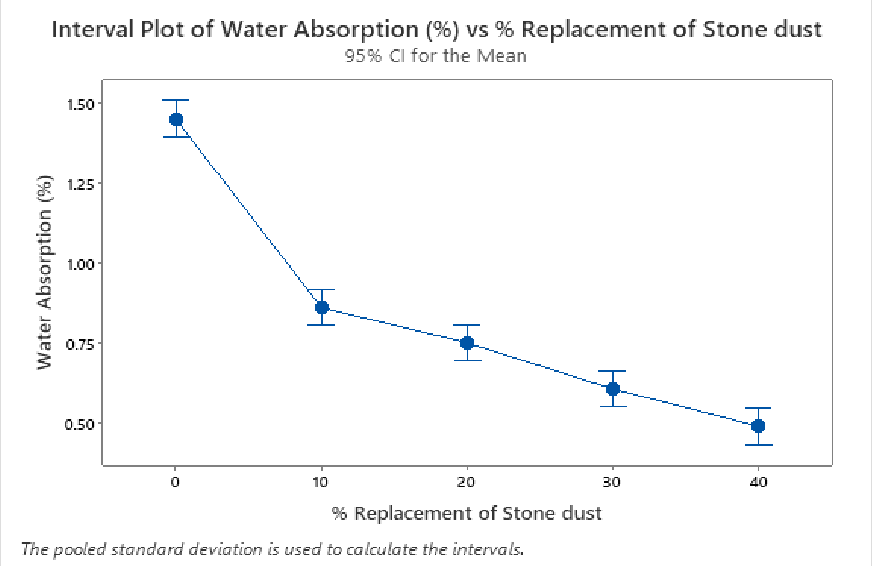


Figure 14: Interval plot between water absorption and brick samples for stage-II.

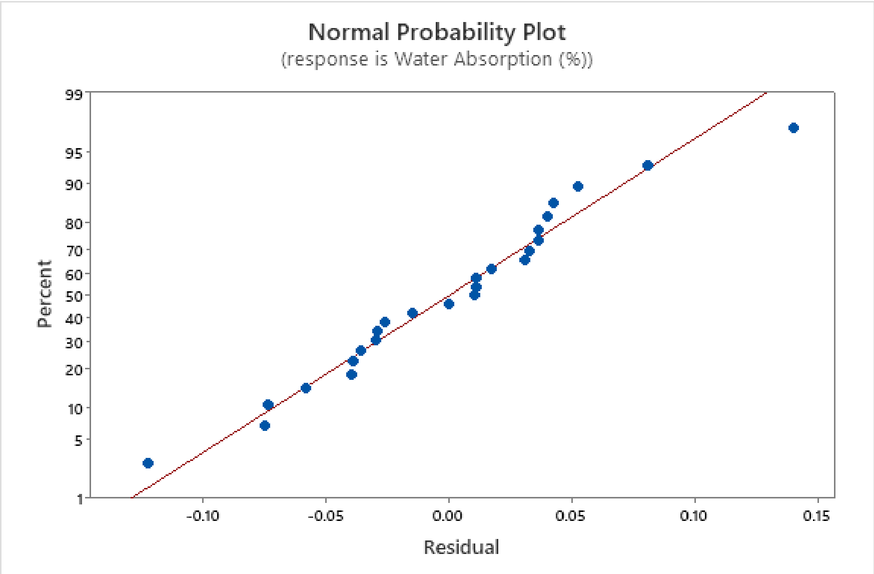


Figure 15: Normal probability plot for water absorption for stage-II.

The normal probability plot in the Figure 15 indicates that the residuals of compressive strength measurements are almost normally distributed which meets and supports the validity of statistical analysis of the test.

Optimization of Various Material Ratios and Their Effect on Composite Brick Response optimizer in Minitab software was used to analyses the optimization and impact of different materials on the properties of bricks Various 3D surface plot graphs were plotted between the properties of bricks, such as compressive strength and water absorption, and their material including plastic (PET), stone dust, and glass powder.

Effect of PET on compressive strength and water absorption

It can be observed from Figure 16, that the compressive strength of brick kept on increasing up to 34% of plastic content but beyond this, the compressive strength decreased on increasing the plastic content. This is because less amount of aggregate material was present in the mix resulting in decrease in compressive strength. However, the percentage of water absorption decreased as the percentage of plastic increased. This is because plastic forms non-polar bond.

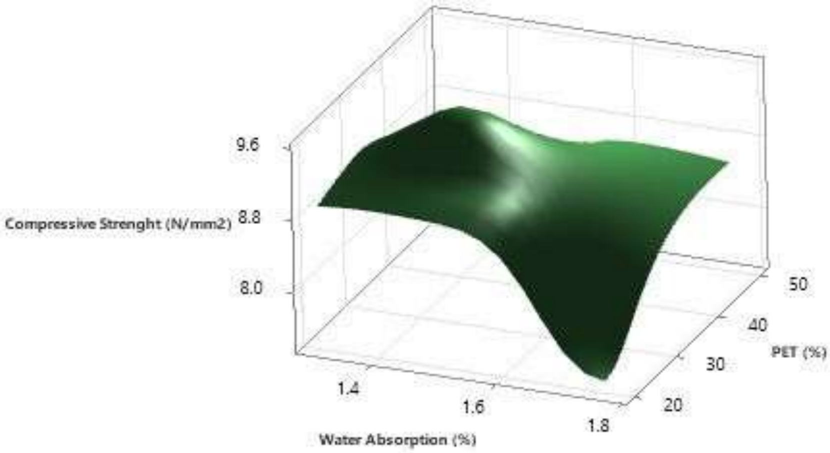


Figure 16: Surface plot of PET as a function of compressive strength and water absorption

Effect of stone dust on compressive strength and water absorption

It can be observed from Figure 17, that the compressive strength of brick increased till 54.6% but beyond this, the compressive strength decreased on increasing the stone dust content. This is because, as shown by SEM analysis, the composite brick contained micro voids and cracks that were created by an excessive amount of stone dust acting as an impurity rather than fine aggregate. On the other hand, increasing the percentage of stone dust had a direct impact on the percentage of water absorption because this stone dust has a water absorption percentage of 1.98%, as determined by experimental research

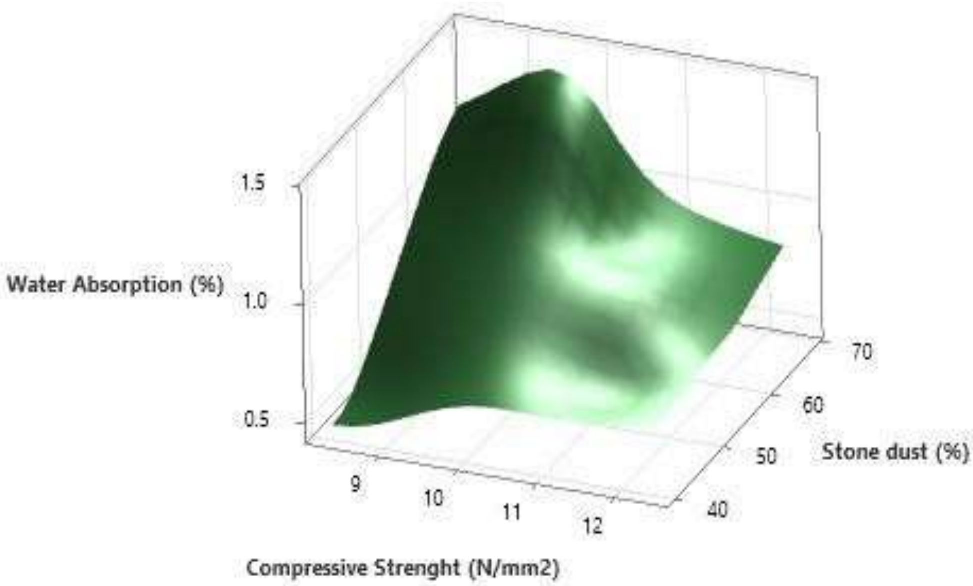


Figure 17: Surface plot of stone dust as function of compressive strength and water absorption.

The optimum dosage of stone dust obtained by response optimization was 54.6% with compressive strength of 12.302 KN/mm2 and water absorption of 0.75% as shown in figure 18.

Parameters

Response	Goal	Lower	Target	Upper	Weight	Importance
Water Absorption (%)	Minimum	–	0.475	1.451	1	1
Compressive Strength (N/mm^2)	Maximum	8.206	12.302	–	1	1

Solution

Solution	Stone Dust (%)	Water Absorption (%) Fit	Compressive Strength (N/mm^2) Fit	Composite Desirability
1	54.6	0.738	12.302	0.859274

Figure 6.36: Results of optimum dose of stone dust.

Effect of glass powder on compressive strength and water absorption

It can be observed from Figure 19, that the compressive strength of brick increased till 12.2% but beyond this, the compressive strength decreased on increasing the glass powder content. This is because glass powder filled the voids and cracks present within the composite brick but when all the voids and cracks were filled the glass powder in excess amount start acting as impurity instead of filler material which was clearly visual in SEM analysis. On the other hand, increasing the percentage of glass powder decreased the water absorption of composite brick as glass powder had 0% water absorption, as determined by experimental research.

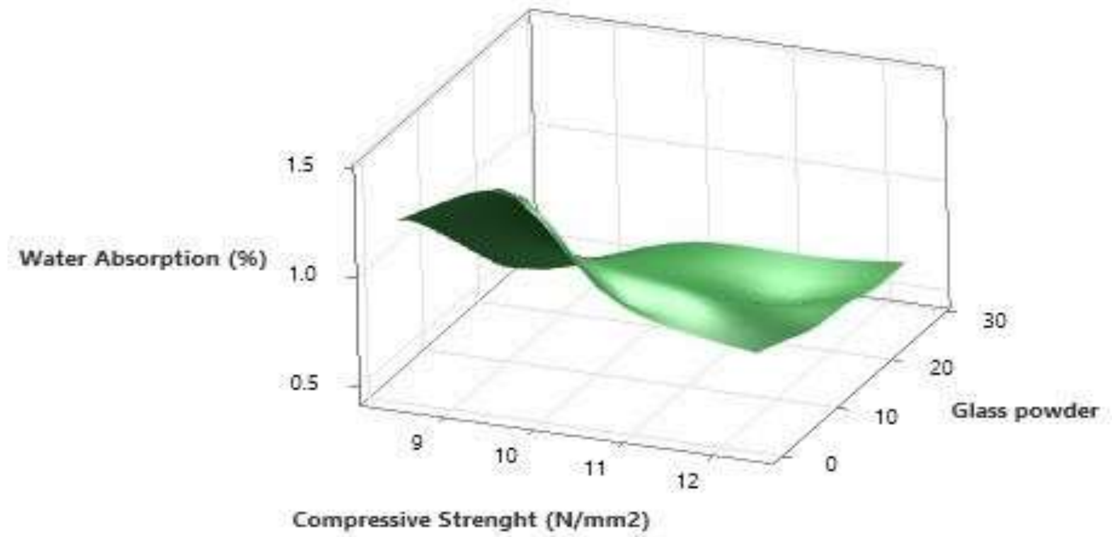


Figure 19: Surface plot of glass powder as function of compressive strength and water absorption.

The optimum percentage of glass powder obtained by response optimization was 12.2% with compressive strength of 12.302 KN/mm^2 and water absorption of 0.742% as shown in figure 20

Parameters

Response	Goal	Lower	Target	Upper	Weight	Importance
Water Absorption (%)	Minimum	–	0.475	1.451	1	1
Compressive Strength (N/mm²)	Maximum	8.206	12.302	–	1	1

Solution

Solution	Glass Powder (%)	Water Absorption (%) Fit	Compressive Strength (N/mm²) Fit	Composite Desirability
1	12.2	0.742	12.302	0.856481

Figure 6.38: Results of optimum dose of glass powder.

TESTING ON CONVENTIONAL BRICKS

Compressive Strength Test

Compressive strength test was performed following IS 3495:1992 (Part I). Each brick sample was tested using five specimens, and the strength was calculated by averaging the results of these five specimens. Conventional brick was found to have an average compressive strength of 10.68 N/mm^2. According to IS 3495:1992 (Part I), the conventional brick was classified as first-class brick.

Figure 22: Compressive strength test of conventional brick.

Water Absorption Test

Figure 23: Water absorption test of conventional

Efflorescence Test

Figure 24: Efflorescence test of conventional brick.

COMPARISON BETWEEN COMPOSITE AND CONVENTIONAL BRICKS

From Table it can be concluded that the composite bricks are superior than the conventional bricks

Table 6 Comparison between composite and conventional bricks.

Sr. No.	Property			Composite Brick	Conventional Brick
1.	Compressive Strength (N/mm^2)			12.302 N/mm^2	10.68 N/mm^2
2.	Water Absorption (%)			0.742%	11.48%
3.	Efflorescence			Nil	Slight
4.	Hardness			Hard	Hard
5.	Soundness			Ringing Sound	Ringing Sound
6.	Durability Behaviors by acid attack (H2SO4)	Reduction in Compressive Strength	1%	4.765%	14.242%
			3%	7.710%	18.064%
		Weight Change	1%	0.0360%	0.942%
			3%	0.0536%	2.057%
7.	Effect of temperature up to 300°C			No change in shape and Size	No change in shape and Size
8.	Weight (Kg)			2.6-3.2 Kg	3.4 – 3.8 kg

CONCLUSIONS AND FUTRE SCOPE OF WORK

This study investigates the performance analysis of composite brick fabricated from waste plastic (PET), stone dust and glass powder using parameters of compressive strength, water absorption, efflorescence, hardness, soundness, durability behaviour and microstructure analysis. Based on the experimental results and their explanation, the following conclusions can be made from the present study:

1. The optimum dosage of waste plastic (PET), stone dust and glass powder to use as building material for construction was obtained by brick specimen S3, containing 34.00% plastic, 54.6% stone dust and 12.20% glass powder.
2. The highest compressive strength of 12.41 N/mm^2 was achieved by composite brick specimen S3 with peak load of 212.3 KN, which was 15.19% greater than the compressive strength of conventional brick.
3. The water absorption of composite brick specimen S3 was found to be 0.75%, which was 175.48% lower than water absorption of conventional brick.
4. The composite bricks were classified as "Nil" for efflorescence, as plastic does not contain any soluble salts or alkali in it.
5. The composite bricks were categorized as “Hard” and produced a ringing sound when they struck each

other, making them ideal to use as building material for construction.

6. In terms of durability, the composite bricks proved to be more durable than conventional bricks, when subjected to sulfuric acid attack.
7. The composite bricks can easily withstand temperature up to 300°C without undergoing morphological or dimensional changes.
8. The microstructural imagine from SEM analysis revealed that the inclusion of glass powder in the composite brick produced a uniform binding between the plastic and stone dust, with less voids within the brick, leading to higher compressive strength and reducing the water absorption.
9. Composite bricks exhibit different densities and structural efficiencies which was due to presence of micro-voids and cracks present within the brick specimens, as revealed by the SEM analysis.
10. Conventional bricks have a weight range of 3.4 kg to 3.8 kg, while composite bricks range from 2.6 kg to 3.2 kg. This weight difference makes composite bricks lightweight, which reduces labour energy and shipping convenience.
11. Using waste plastic, stone dust and glass powder as raw materials for producing brick masonry is one of the practical ways to recycle tremendous amount of waste; support wildlife preservation and environmental pollution reduction.

FUTURE SCOPE OF WORK

The current study examined the compressive strength, water absorption, efflorescence, hardness, soundness, durability behaviour and microstructural analysis of composite brick fabricated from plastic, stone dust and glass powder. However, there remains some parameters that can be used for conducting future research. The following are the future scope of the research:

- Limited research work is done on the thermal conductivity of composite brick. Thus, further research into the behaviour of composite brick's thermal conductivity may be potential avenue for future research.
- By comparing the carbon dioxide emissions of the burnt clay brick and plastic composite bricks, one can quantify the carbon dioxide embodied in each brick and perform a sustainability analysis.

There are many prospects for the plastic composite brick industry to grow internationally, especially in regions where there is a high demand for construction and plastic waste

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