

Research Article

Mechanical Properties of Plastic Sand Brick Containing Plastic Waste

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Received 6 December 2021; Revised 29 January 2022; Accepted 16 February 2022; Published 12 March 2022

Academic Editor: Piotr Smarzewski

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The use of plastic has grown extensively in recent years all over the world. It is inexpensive and easily available and can be moulded into any shape. However, plastic is nonbiodegradable; it causes pollution and create difficulties in managing even for a wealthy nation. The purpose of this study was to investigate the environment-friendly potential use of plastic and demonstrate usefulness of plastic sand bricks as alternative structural elements, replacing standard clay brick. The physical and mechanical properties of plastic sand bricks were studied in different plastic sand ratios of 1 : 3, 1 : 4, and 1 : 5 by their weight, using plastic as a binder. Moreover, the thermal resistance test, split tensile strength test, penetration test, and Fourier transform infrared spectroscopy were performed. The study concluded that the strength of plastic sand brick depends upon the uniformity of the mixture and increases when the ratio of sand and plastic in the mixture is increased to 1 : 4 from 1 : 3. Any increase or decrease in the ratio 1 : 4 is found to reduce the strength. All the bricks in any of the ratios showed zero water absorption and nil efflorescence.

1. Introduction

Plastic, a petrochemical derivative introduced in 1907, is a life-changing resource. It is made up of a variety of synthetic or semisynthetic organic compounds with a high molecular mass, as well as other malleable substances that can be moulded into solid things. They are manufactured by polymerizing or polycondensing natural materials such as cellulose, coal, natural gas, salt, crude oil, minerals, and plants. It is a versatile material that can be used in several different ways. In terms of weight, durability, flexibility, variety, and cost, plastic has proven to have a great advantage over other materials such as wood, natural fibers like cotton and wool, rubber, and paper. Made on a large scale, it is the cheapest material available on the market [1]. However, the same qualities that make it useful have contributed to global waste challenge [2]. It is a material that people do not utilize correctly [3, 4].

Every year, more than 380 million tons of plastic are produced worldwide. As of 2017, over 100 million tons of

polyethylene resins are produced annually, accounting for 34% of the total plastics market [5]. Every year, countries around the world discard millions of tons of plastic waste. Just 16% of plastic waste is recycled to make new plastics, while 40% is sent to landfills and 25% to incineration and 19% is dumped [6]. The amount of plastic garbage produced is constantly increasing, posing serious environmental danger [7]. Because plastic is made up of large toxic pollutants, it has the potential to harm the ecosystem by polluting the air, water, and land [8]. Plastic pollution is the most pervasive concern harming the marine environment, land, and atmosphere. It also puts ocean health, food safety and quality, human health, coastal tourism, and climate change at risk. Plastic contributes to global warming as well. When plastic garbage is burned, carbon dioxide is released into the atmosphere, increasing carbon emissions. Plastic trash degrades the visual value of tourist attractions, resulting in lower tourism-related revenues and significant economic expenditures associated with site cleaning and upkeep [9].

Finding ways to manage plastic waste is daunting even for wealthy nations [10]. Better holistic solid waste management systems and recycling are two simple and effective ways to manage solid waste. Alternatively, attempts have been made to incorporate waste in the production of bricks. These bricks will eventually be able to improve plastic management while also fostering long-term development. The use of plastic sand bricks can be beneficial and would help to reduce waste. As a result, using plastic bricks promotes both sustainable development and environment protection [11].

Researches have studied how plastic waste may be combined with other raw materials to make plastic sand bricks. Wahid et al. [12] used the proportion 9:9:4 with a water-cement ratio of 2 to produce sand bricks. Bhushaiah et al. [13] mixed 0.992 kg cement, 4.04 kg fly ash, and 3.24 kg of fine aggregate; the fine aggregate is replaced by 5% to 20% finely crushed plastic waste. Wahab et al. [14] replaced fine aggregate with finely crushed sand by 100% while maintaining a mix ratio of 1:6 (cement: fine aggregate) and water-cement ratio 0.34 and compared the result with standard sand bricks made with a mix ratio of 1:4 and water-cement ratio 0.35. The first two researchers concluded that, at 5% and 15% of plastic, compressive strength was the highest which are 11.618 N/mm² and 20 N/mm², respectively. The third study found that the brick's compressive strength was 5.56 N/mm², which was greater than Malaysia's 5.2 N/mm² standards.

In other studies, plastic was used as a binder (plastic binder) rather than cement. Gopu Mohan et al. [15] combined sand and thermocol in molten plastic, with plastic percentages of 5%, 15%, 25%, and 35%, respectively, thermocol at 5%, and the rest of the brick being sand. The study concluded that water absorption was null for each sample and compressive strength was highest at 11 N/mm² when the plastic percentage was 25%. Salahuddin and Zambani [7] blended molten plastic with 4.75 mm sand in a 1:4 ratio, resulting in 0.789% water absorption and 9.141 N/mm² compressive strength. Sellakutty and Dinesh [16] used a mix ratio of 1:3, 1:4, and 1:5 in their research and found compressive strengths of 4.78 N/mm², 5.12 N/mm², and 4.92 N/mm² correspondingly. Singhal and Netula [17] mixed molten plastic with stone dust at the proportion of 3:7, concluding zero water absorption and 5.6 N/mm² compressive strength. Chauhan et al. [18] conducted research using a mix ratio of 1:2, 1:3, and 1:4 (plastic: sand) and concluded that water absorption was very less varying from 0.95 to 4.5% and compressive strength was higher than conventional clay brick.

The above studies suggest that utilization of plastic waste has good potential in brick manufacturing. Plastic sand bricks also have certain benefits over traditional bricks, particularly in terms of compressive strength, water absorption, and efflorescence. However, the prior studies have not focused on the specific gravity test of plastic and sand, penetration test and FTIR analysis of plastic, split tensile strength test, and thermal resistant test of the brick sample.

The goal of the present experiment was to investigate the physical and mechanical properties of plastic sand bricks with varying plastic and sand mixes, incorporating all the

mentioned tests. Furthermore, an attempt was made to use plastic waste in the production of plastic sand bricks as a construction material, which would address one of the world's most pressing issues at the moment. Figure 1 shows the study site of this research [19].

2. Materials and Methods

2.1. Plastic. In this research, waste plastic (polyethylene or polythene: IUPAC name polyethylene) collected from nearby garbage, dumping sites, and industrial waste, as well as food containers, was used.

A plastic penetration test was used to measure the consistency of the material [20]. Plastic penetration testing was performed following IS 1203:1958. The penetration value also determines the setting time of molten plastic [21]. Figure 2 shows the penetration testing apparatus which was used in this study.

The specific gravity test was used to determine the material's strength or quality following IS 2720:1980. The specific gravity of plastic was calculated using pycnometer of capacity 1 litre shown in Figure 3. Plastic has a specific gravity of 0.89, according to a specific gravity test of the sample.

In addition, FTIR spectroscopy, which is a technique for detecting organic, polymeric, and inorganic substances, was used for material quality control and contaminant analysis. The FTIR analysis method uses infrared light to scan test materials and assess chemical properties. When infrared radiation is passed through a sample during testing, some of it is absorbed by the sample and the remainder goes through [22]. This provides an absorbance spectra graph, which shows the sample material's unique chemical bonding and molecular structure. The peaks in these absorption spectra signify the components that are present. Functional groupings are indicated by these absorbance peaks (e.g., alkanes, ketones, acid chlorides). Different types of bonds absorb different wavelengths of infrared radiation, and hence different functional groups absorb different wavelengths of infrared radiation [23].

2.2. Sand. In this investigation, well-graded natural river sand that passed through a 4.75 mm sieve was used, and it met all of the criteria for producing plastic sand bricks [24].

The particle size distribution of fine aggregates was determined via sieve analysis. The sieve analysis procedure was carried out by following IS 2386:1963 (Part I). Figure 4 shows the sieving of sand after which the further calculation was done (shown in Table 1).

From Figure 5, $D_{60} = 0.42$, $D_{30} = 0.19$, $D_{10} = 0.088$, where D_{60} , D_{30} , D_{10} are particle size corresponding to 60%, 30%, and 10% finer, respectively.

$$\text{Coefficient of uniformity (Cu)} = \frac{D_{60}}{D_{10}} = 4.77, \quad (1)$$

$$\text{Coefficient of curvature (Cc)} = \frac{D_{30}^2}{D_{60} * D_{10}} = 1.01.$$



FIGURE 1: Plastic waste around Kathmandu Valley, the study site of this research [19].



FIGURE 2: Penetration test.



FIGURE 3: Specific gravity test.



FIGURE 4: Sieving of sand.

The value of the coefficient of curvature (C_c) lied between 1 and 3, and the value of the coefficient of uniformity (C_u) was less than 6.

The specific gravity test, which was used to determine the strength of plastic, was used to test the strength of sand as well. The specific gravity of sand was calculated as 2.67.

2.3. Mix Proportion. To find the suitable ratio of plastic and sand, various mix proportions were made and tested in Universal Testing Machine (UTM) [25]. In this study, the (plastic: sand) proportions (i.e., 1:3, 1:4, and 1:5) were used in manufacturing of plastic sand bricks to get desirable strength and durability by their weight. Table 2 shows the different mix ratio of (plastic: sand) proportions.

2.4. Procedure of Casting Plastic Sand Brick

2.4.1. Batching of Plastic. The plastic collected from nearby garbage was batched. To ensure there was no water content in the sample taken after classifying the types of plastic, water in the collected material was removed through oven drying at a temperature ranging from 20 C to 25 C, and any other garbage was removed through hand segregation. The components for the preparation of the plastic sand bricks were then measured.

2.4.2. Melting. The plastic waste was melted after batching, with 8 kg melted plastic in 2 minutes at temperatures ranging from 105 C to 115 C.

2.4.3. Mixing. After melting the plastic at temperatures ranging from 105 C to 115 C, river sand was added. The hot molten plastic and river sand were continuously mixed until the mixture became homogeneous, uniform in color, and consistent. During this technique, the hand mixing method was used.

2.4.4. Moulding. In the moulding process, the prepared mixture was poured into the mould and pressed down with a tamping rod. The tampering rod applied pressure to ensure that the mixture filled the mould appropriately. Oil was applied to the walls of the mould before filling it so that the bricks would be readily removed at the end. After 6 h, the brick was taken from the mould. Figure 6 shows the mould prepared for the casting of bricks.

3. Study on Physical and Mechanical Properties of Plastic Sand Bricks

3.1. Water Absorption Test. The purpose of the water absorption test on brick was to measure how much moisture the brick absorbed when exposed to dampness. The technique followed was as per IS 1077:1992.

The brick specimen was initially dried in an oven at a temperature between 40°C to 45°C until it reached a constant mass. After allowing the heated specimen to cool to room temperature, it was weighed and its mass was recorded

TABLE 1: Sieve analysis of sand.

Sl. No.	Sieve size (mm)	Weight retained (gm), W1	% Weight retained (W1 * 100/1000)	Cumulative % weight retained (x)	% Finer (100-x)
1.	4.75	0	0	0	100
2.	2.36	40	4	4	96
3.	1.18	85	8.5	12.5	87.5
4.	0.6	180	18	30.5	69.5
5.	0.075	675	67.5	98	2

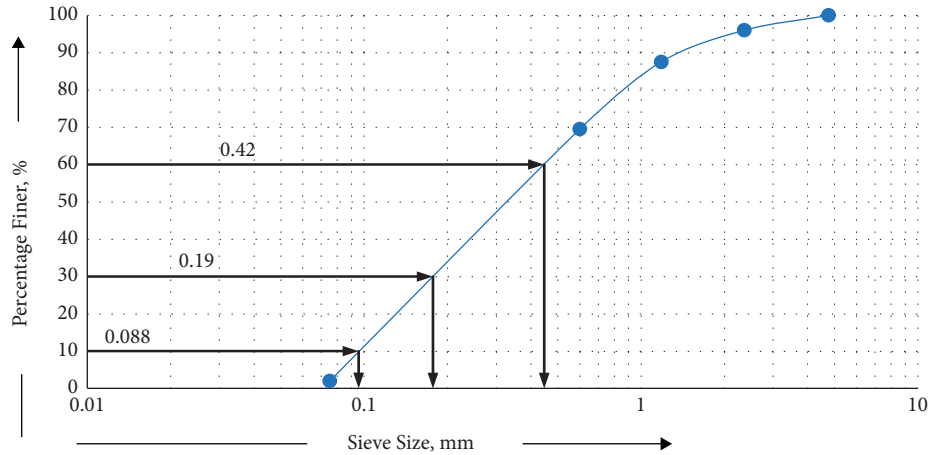


FIGURE 5: Semilog graph.

TABLE 2: Mix ratio.

Sl. No.	Sample ratio (plastic: sand)	Percentage of plastic (%)	Percentage of sand (%)
1.	1 : 3	25	75
2.	1 : 4	20	80
3.	1 : 5	16.67	83.33



FIGURE 6: Mould prepared for the casting of bricks.



FIGURE 7: Water absorption test.

(M_1). The specimen was then immersed in water for 24 h (shown in Figure 7) at the temperature of 27°C. To eliminate the traces of water, the brick specimen was removed from the water and wiped with a clean cloth. Finally, the specimen was reweighed and its mass recorded as (M_2). Then, the water absorption of the specimen was calculated as follows:

$$\text{Water Absorption (W)} = \frac{M_2 - M_1}{M_1} * 100\%. \quad (2)$$

3.2. *Hardness Test.* The hardness test determines the resistance of the bricks to scratch. The brick is scraped with a sharp tool (steel rod) for this test, and if no impression is left, the brick is considered hard. In this test, nail scratch did not affect bricks of all ratios, implying that the bricks were tough.

3.3. *Thermal Resistance Test.* Plastic is highly susceptible to fire but in this study, the presence of sand imparted insulation.

Constant heat was regulated to the sample placed in a mould (diameter 6.135 cm and 3.513 cm depth) using a heat regulator in the flashpoint testing machine and the temperature observed in the thermometer was noted. Figure 8 shows the conduction of thermal resistance test in the laboratory.

3.4. Efflorescence Test. An efflorescence test on brick was done to find out if there were any alkalis present. The technique was followed as per IS 3495 : 1992.

No efflorescence was observed on the surface of the bricks.

3.5. Compressive Strength Test. Compressive strength test on bricks was carried out to determine the load-carrying capacity of bricks under compression with the help of a compression testing machine [26]. The test was performed in a UTM, which applied an axial load of 14 N/mm^2 (140 kg/cm^2) per minute until the brick broke [27] as shown in Figure 9. The procedure was carried out following IS 3495 : 1992 (Part I). Figure 10 shows the casted plastic sand bricks before the test was performed.

3.6. Split Tensile Strength Test. Split tensile strength test is a method of determining tensile strength using a cylinder with a split across the vertical diameter [28].

To conduct the split tensile test, a load was applied continuously without shock at a rate ranging from 0.7 to 1.4 MPa/min (1.2 to 2.4 MPa/min) until the cylinder broke. The procedure for split tensile strength testing was followed as per IS 5816 : 1999 [16]. Figure 11 shows the split tensile test strength testing of plastic sand bricks.

The splitting tensile strength of the specimens is calculated by the following equation:

$$T = \frac{2 * P}{\pi * L * D} \quad (3)$$

where T = splitting tensile strength (MPa). P = the maximum applied load indicated by the machine at failure (N). D = diameter of cylinder (mm). L = length of cylinder (mm).

4. Results and Discussion

4.1. Compressive Strength. Table 3 shows 28 days of compressive strength of plastic sand bricks.

The representation of the compressive strength of plastic sand brick in (N/mm^2) is shown in Table 3. As shown in the table, the compressive strength of bricks went on increasing with a decrease in the percentage of plastic up to 20% but beyond this, the compressive strength decreased on decreasing the amount of plastic. This may be because the quantity of plastic in the brick increases noticeably when the ratio is greater than 1 : 3. This causes the bricks to be more susceptible to heat, thus causing shrinkage and brittleness. If the ratio of plastic and sand is chosen to less than 1 : 4, the molten plastic and sand fail to bind properly, hence reducing the strength of the brick.



FIGURE 8: Thermal resistance test.



FIGURE 9: Compressive strength test.



FIGURE 10: Casted bricks.

The finding of this study compared with the strength of locally available conventional brick shows relatively better strength of plastic sand bricks. Table 4 shows the compressive strength of locally available conventional brick. These bricks were bought from the local market and the test was performed in the Universal Testing Machine (UTM).

The average compressive strength of plastic sand brick of ratio 1 : 3 was found to be 9.72 N/mm^2 , of 1 : 4 to be 12.28 N/mm^2 , and of 1 : 5 to be 3.39 N/mm^2 . This decrease in strength may be due to the reduction in bonding between plastic and



FIGURE 11: Split tensile test of plastic sand bricks.

TABLE 3: Compressive strength test on different ratios of plastic and sand.

Sl. No.	Sample (plastic: sand)	Applied load (KN)	Contact area (mm ²)	Compressive strength (N/mm ²)	Average compressive strength (N/mm ²)
1	1:3	152.80	16500	9.26	9.72
		155.90		9.45	
		172.70		10.46	
		205.00		12.42	
2	1:4	201.00	16500	12.18	12.28
		202.00		12.24	
3	1:5	55.00	16500	3.34	3.39
		59.00		3.56	
		54.00		3.27	

TABLE 4: Compressive strength test results on locally available conventional brick.

Sl. No.	Applied load (KN)	Contact area (mm ²)	Compressive strength (N/mm ²)	Average compressive strength (N/mm ²)
1	92.50	16500	5.6	5.1
2	74.25		4.5	
3	85.60		5.2	

sand as the amount of sand increased substantially compared to the quantity of plastic.

The test performed on the locally available conventional bricks showed an average compressive strength of 5.1 N/mm² which was lesser than the average compressive strength of plastic sand bricks of ratio 1:3 and 1:4 whereas it was greater than the compressive strength of plastic sand bricks of ratio 1:5.

The finding of the present study differs from the observation of Salahuddin et al. [7] in which the compressive strength of plastic sand brick of ratio 1:4 using 4.75 mm sand was observed to be 9.141 N/mm² and that using 600 μ m sand was found to be 7.468 N/mm². However, the present study resembles another study by Sellakutty et al. [16] that showed a compressive strength of 4.65, 4.78, 5.12, 4.92, and 3.17 for the plastic sand bricks of ratios 1:2, 1:3, 1:4, 1:5, and 1:6, respectively. In addition, compressive strength of 5.6 N/mm² was obtained in the research carried out by Singhal et al. [17] for plastic sand bricks of ratio 3:7.

4.2. Water Absorption and Efflorescence. The water absorption of plastic sand bricks and locally bought bricks is shown in the tables below (Table 5 and Table 6).

The water absorption of bricks made in all proportions was 0% of their dry weight, and the bricks showed no efflorescence. Plastic repels water molecules and leaves no room for water to flow around. As a result of the reduced voids within the brick, there was no water absorption in plastic sand bricks.

Table 6 shows water absorption of locally bought clay bricks.

The water absorption of locally available conventional bricks was found to be 3.5%, 2.6%, and 2.9% for first-class brick.

The present study reiterates the water absorption and efflorescence result observed by Singhal et al. [17]; they found no water absorption and no efflorescence. However, the present study contradicts the study of Salahuddin et al. [7], which showed 0.789% water absorption of plastic sand

TABLE 5: Water absorption test result on the different ratios of plastic and sand.

Sl. No.	Proportion (plastic: sand)	Number of brick sample	Water absorbed (%)
1.	1 : 3	3	0.0
2.	1 : 4	3	0.0
3.	1 : 5	3	0.0

TABLE 6: Water absorption test result on locally available conventional brick bought from a local market.

Sl. No.	Class of brick sample	Water absorbed (%)
1.	1 st	3.5
2.		2.6
3.		2.9

TABLE 7: Thermal resistance test on different ratios of plastic and sand.

Sl. No.	Sample (plastic: sand)	Melting point (Degree Celsius)	Average temperature (Degree Celsius)
1	1 : 3	110°C	110°C
2		115°C	
3		105°C	
4	1 : 4	149°C	149°C
5		148°C	
6		150°C	
6	1 : 5	181°C	181.33°C
7		183°C	
8		180°C	

bricks of ratio 1:4 using 4.75 mm sand and 3.060% absorption by the bricks made with 600 μ m sand. Sellakutty et al. [16] found the value of water absorption to be 1.082% and very little presence of efflorescence.

4.3. Thermal Resistance. The thermal resistance of plastic sand brick with the corresponding ratios is given in Table 7.

Thermal resistance test results showed that the resistance capacity of bricks increased with an increase in the amount of sand; i.e., the plastic sand brick of 1:5 ratio performed best in thermal resistance, withstanding the temperature of 181.3°C. There was no change in the structural properties of the plastic sand brick of ratios 1:3, 1:4, and 1:5 up to the temperature of 110°C, 149°C, and 180°C, respectively. This result, understandably, can be due to the higher thermal resistance of the sand.

The current study confirms the thermal resistance capabilities of bricks, as found in a previous study by Sellakutty et al. [16]; plastic sand bricks withstand a temperature of 180°C.

4.4. Penetration. The results of a penetration test on a plastic sample are shown in the table below (Table 8). The sample was made of plastic only, and the test was used to assess how long it took for the melted plastic to set.

With the increase in time of observation, the penetration value decreased. First, complete penetration was detected till the 10th minute, whereas the plastic sample revealed nil penetration by the 40th minute. Plastic took 40 minutes to settle completely. This is owing to the quality of the plastic (Low-Density Polyethylene) employed in the test, which has a melting temperature of 105°C to 115°C and settles faster as

a result of the lower melting point, resulting in a shorter settling period.

During the test, the plastic exhibited shrinking qualities. After the plastic sample was set, it was discovered that the sample's height was reduced by 5 mm. In addition, after 25 minutes, the exterior borders of the plastic sample exhibited no penetration while the center area still had penetration. This demonstrates that the outer layer of plastic hardens faster than the inner layer. As a result, there was nonuniformity in the plastic throughout the setting process.

4.5. Split Tensile. The split tensile strength of plastic sand bricks is shown in the table below (Table 9).

The average split tensile strength of the samples was found to be 737.486 MPa, 804.53 MPa, and 654.25 MPa for plastic sand ratio of 1:3, 1:4, and 1:5, respectively.

The split tensile strength of bricks increased when the percentage of plastics was reduced by up to 20%, but as the percentage (%) of plastics was reduced further, the split tensile strength dropped. Because the amount of sand used was notably more than the amount of plastic used, this loss of strength was caused by a reduction in the bonding between plastic and sand.

4.6. FTIR Analysis. The graphical representation of the FTIR analysis of Low-Density Polyethylene (plastic sample) is shown in Figures 12 and 13, and the apparatus used in this analysis is shown in Figure 14 (Annex).

As shown in the figure, the characteristic PE absorbance bands were located at 2920 cm^{-1} , 1520 cm^{-1} , and 760 cm^{-1} .

The current study findings are comparable to those of D'amelia et al. [29], who observed PE absorbance bands at

TABLE 8: Penetration test results of plastic.

Sl. No.	Time (minutes)	Penetration (mm)		
		Initial	Final	Difference
1	10	0	386	386
2	12	0	377	377
3	14	0	280	280
4	16	0	250	250
5	18	0	210	210
6	20	0	155	155
7	22	0	135	135
8	24	0	89	89
9	26	0	53	53
10	28	0	32	32
11	30	0	27	27
12	32	0	19	19
13	34	0	15	15
14	36	0	9	9
15	38	0	5	5
16	40	0	0	0

TABLE 9: Split tensile strength test results of plastic sand bricks.

Sl. No.	Plastic: sand	Applied load (Kg)	Applied load (P) in KN	Split tensile strength (T) = $2 * p/\pi * L * D$	Mean value
1.		5200	50.96	721.3	
2.	1 : 3	5400	52.92	749.05	737.486
3.		5350	52.43	742.11	
4.		5800	56.84	804.53	
5.	1 : 4	5900	57.82	818.4	804.53
6.		5700	55.86	790.66	
7.		4600	45.08	638.07	
8.	1 : 5	4850	47.53	672.75	654.25
9.		4700	46.06	651.95	

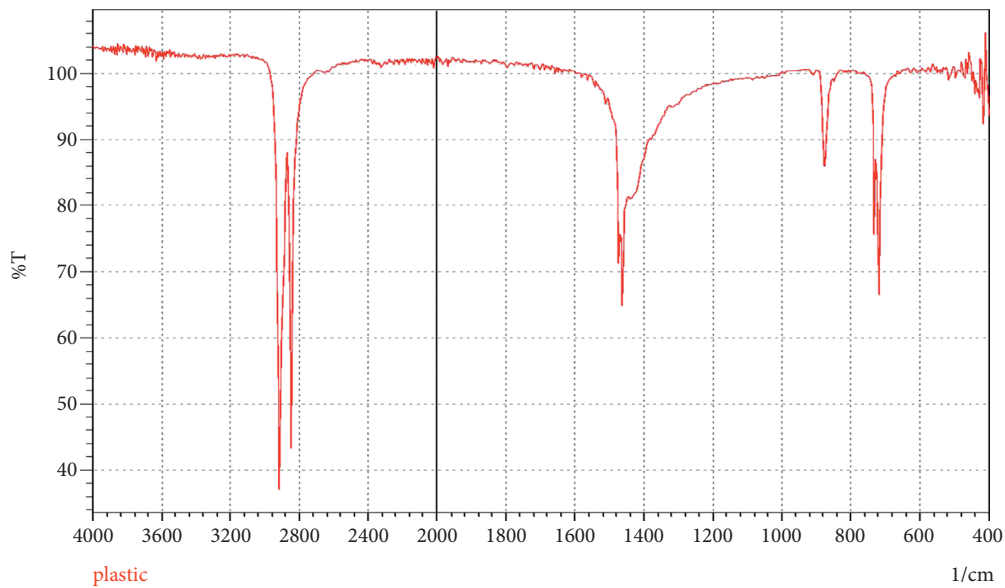


FIGURE 12: FTIR spectrum of Low-Density Polyethylene (Sample 1).

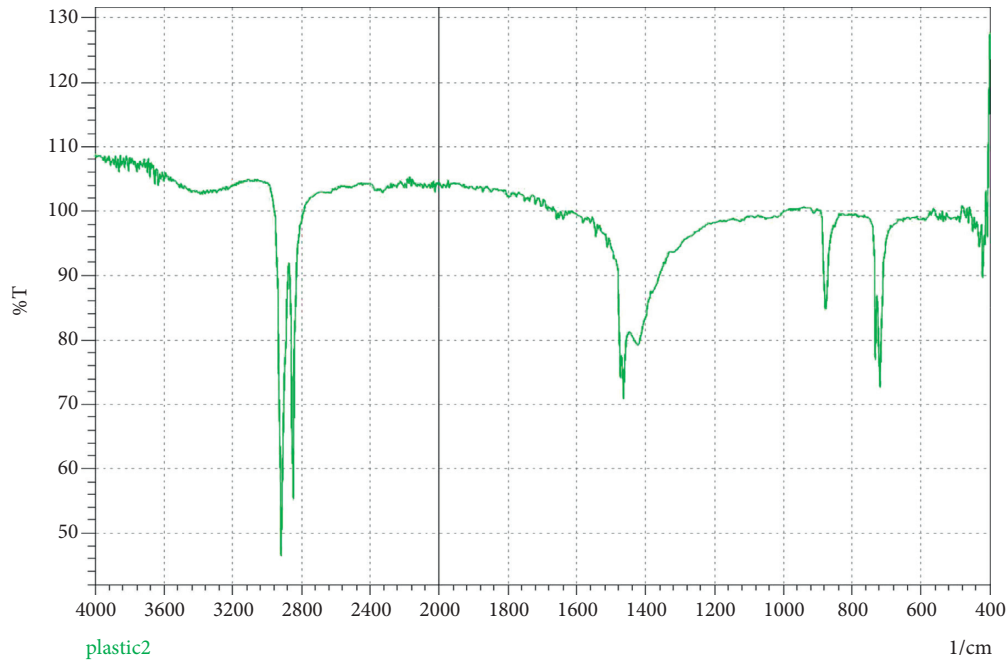


FIGURE 13: FTIR spectrum of Low-Density Polyethylene (Sample 2).



FIGURE 14: FTIR testing apparatus.

2914 cm^{-1} , 2847 cm^{-1} , 1470 cm^{-1} (blue shaded peak), and 718 cm^{-1} . With a small variance, the results obtained in this investigation are identical to that of D'amelia et al. [29].

5. Conclusion

Based on the experimental study of plastic sand brick, it is concluded that the proportions of plastic and sand, as well as the uniformity of mixture, impact the compressive and split tensile strength of plastic sand brick. Such bricks qualify to pass water absorption at 0% and nil efflorescence, and bricks with higher sand content exhibit higher thermal resistance. The compressive and split tensile strength increases with a reduction in the percentage of plastic from 25% to 20%. However, further reducing the amount of plastic results in decreasing the compressive and split tensile strength of brick but the thermal resistance of bricks increases with a decrease in the amount of plastic. From the results of compressive strength and tensile test, it is concluded that both compressive and split tensile strength are the highest for plastic

sand bricks of ratio 1:4. Plastic sand brick, on the other hand, has the considerable drawback of being unable to tolerate high temperatures.

Data Availability

All the data used in this study “Mechanical Properties of Plastic Sand Brick Containing Plastic Waste” supports the findings which are cited within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

The authors are grateful to Kathmandu University’s Department of Civil Engineering, as well as the Departments of Pharmacy and Mechanical Engineering, for providing the materials that the authors used during this study. The authors would also like to convey their heartfelt gratitude to Asst. Prof. Khagendra Acharya, Writing Unit Coordinator, who led them, worked with them at all times, and gave them instructions on how to revise this article.

References

- [1] A. Parasnis, V. Barthwal, M. Asodekar, P. Chavan, and P. Joshi, “Introduction to Plastic Pollution,” 2020, https://www.teriin.org/sites/default/files/files/Annexure_B6_%20Braille-Booklet-on-Plastic-Pollution.pdf.
- [2] S. S. Chauhan, J. K. Singh, H. Singh, S. Mavi, V. Singh, and M. I. Khan, “An overview on recycling plastic wastes in bricks,” *Materials Today Proceedings*, vol. 47, pp. 4067–4073, 2021.

- [3] N. J. Beaumont, M. Aanesen, M. C. Austen et al., "Global ecological, social, and economic impacts of marine plastic," *Marine Pollution Bulletin*, vol. 142, pp. 189–195, 2019.
- [4] S. Rhein and M. Schmid, "Consumers' awareness of plastic packaging: More than just environmental concerns," *Resources, Conservation and Recycling*, vol. 162, Article ID 105063, 2020.
- [5] R. Kumar, M. Kumar, I. Kumar, and D. Srivastava, "A Review on Utilization of Plastic Waste Materials in Bricks Manufacturing Process," *Materials Today: Proceedings*, vol. 46, pp. 6775–6780, 2021.
- [6] K. Latham, "The World's First 'infinite' Plastic," 2021, <https://www.bbc.com/future/article/20210510-how-to-recycle-any-plastic>.
- [7] S. S. Salahuddin and S. S. Zambani, "Utilisation of waste hdpe plastic in manufacturing plastic sand bricks," *International Research Journal of Engineering and Technology*, vol. 70, 2020.
- [8] H. Ritchie and M. Roser, "Plastic Pollution," 2018, <https://ourworldindata.org/plastic-pollution>.
- [9] E. Schmaltz, E. C. Melvin, Z. Diana et al., "Plastic Pollution Solutions: Emerging Technologies to Prevent and Collect marine Plastic Pollution," *Nicholas Institute*, vol. 144, Article ID 106067, 2020.
- [10] P. Singh and V. P. Sharma, "Integrated Plastic Waste Management: Environmental and Improved Health Approaches," *Procedia Environmental Sciences*, vol. 35, pp. 692–700, 2016.
- [11] A. Shakir, S. Naganathan, and K. N. Mustapha, "Development Of Bricks From Waste Material: A review paper," *Australian Journal of basic and applied sciences*, vol. 7, pp. 812–818, 2013.
- [12] S. A. Wahid, S. B. M. Rawi, and N. M. Desa, "Utilization of Plastic Bottle Waste in Sand Bricks," *Applied Scientific Research*, vol. 5, no. 1, pp. 35–44, 2015.
- [13] R. Bhushaiah, S. Mohammad, and S. Rao, "Study Of Plastic Bricks Made from Waste Plastic," *Journal of Engineering and Technology*, vol. 6, no. 4, p. 6, 2019.
- [14] A. A. Wahab, S. M. Rasid, H. Rahim, and M. F. Arshad, "Development of hybrid environmental brick," 2020, https://www.researchgate.net/publication/346013862_Development_of_Hybrid_Environmental_Brick.
- [15] C. M. Gopu, J. Mathew, J. N. Kurian, and J. T. Moolayil, "Fabrication Of Plastic brick Manufacturing Machine and brick Analysis," 2016, https://www.academia.edu/25848874/Fabrication_of_Plastic_Brick_Manufacturing_Machine_and_Brick_Analysis.
- [16] D. Sellakutty and A. Dinesh, "Utilisation of Waste Plastic in Manufacturing of Bricks and Paver Blocks," *International journal of applied engineering research*, vol. 2, no. 4, pp. 364–368, 2016.
- [17] A. Singhal and O. Netula, "Utilization of Plastic Waste in Manufacturing of Plastic Sand Bricks," 2018, https://www.researchgate.net/publication/325870842_UTILIZATION_OF_PLASTIC_WASTE_IN_MANUFACTURING_OF_PLASTIC_SAND_BRICKS.
- [18] S. S. Chauhan, B. Kumar, P. S. Singh, A. Khan, H. Goyal, and S. Goyal, "IOPscience. IOP Conference Series: Materials Science and Engineering," 2019, <https://robots.iopscience.iop.org/article/10.1088/1757-899X/691/1/012083>.
- [19] Q. Liu, J. Xiao, and A. Singh, "Plastic shrinkage and cracking behavior of mortar containing recycled sand from aerated blocks and clay bricks," *Sustainability*, vol. 13, no. 3, p. 1096, 2021.
- [20] *Method of Testing Tar and Bituminous Materials as Per IS 1201 to 1220*, Bureau of indian standards, Chennai, Tamil Nadu, 1978.
- [21] M. Sarker, M. M. Rashid, and M. Molla, "Waste plastic conversion into chemical product like naphtha," 2011, https://www.researchgate.net/publication/267790077_Waste_Plastic_Conversion_into_Chemical_Product_Like_Naphtha.
- [22] P. R. Janissek, J. Gulmine, H. Heise, and L. Akcelrud, "Polyethylene characterization by FTIR," 2002, https://www.academia.edu/26043972/Polyethylene_characterization_by_FTIR.
- [23] I. Mashudi, N. Suardana, I. A. Thanaya, I. W. B. Adnyana, and C. Kencanawati, "Compressive strength and truck run over ability of plastic/sand paving block composites," 2020, <https://www.semanticscholar.org/paper/Compressive-strength-h-and-truck-run-over-ability-of-Mashudi-Suardana/831cbb458427c44279e8227cbd41313970b3f68b>.
- [24] C. H. Sheshachala, K. B. Manjunath, T. H. Dasharatha, H. N. Mahendra, K. R. Sneha, and G. T. Bhavani Keerthi, "Utilization of waste plastic in manufacturing of bricks," *International Journal of Scientific & Engineering Research*, vol. 10, no. 4, 2019.
- [25] H. Rabah, B. Abdelkarim, and S. Guessasma, "Penetration testing and thermal behavior of bitumen 35/50 and modified bitumen 13/40," *The European Physical Journal Applied Physics*, vol. 59, 2012.
- [26] Bureau of Indian Standard, *Methods of Tests of Burnt Clay Building Bricks, IS 3495 (Part 1)*, Bureau of Indian Standard, New Delhi, India, 1992.
- [27] S. Selvaprasanth, "Split tensile strength in concrete. SlideShare," 2017, <https://www.slideshare.net/selvaprasanth549/split-tensile-strength-in-concrete>.
- [28] Bureau of Indian Standard, *Splitting Tensile Strength of Concrete, IS 5816*, Bureau of Indian Standard, New Delhi, India, 1999.
- [29] R. P. D'amelia, S. Gentile, W. F. Nirode, and L. Huang, "Quantitative analysis of copolymers and blends of polyvinyl acetate (PVAC) using Fourier transform infrared spectroscopy (FTIR) and elemental analysis (EA)," 2016, <https://www.semanticscholar.org/paper/Quantitative-Analysis-of-Copolymers-and-Blends-of-D%27amelia-Gentile/60a58a6d636a4744f29849d4449d15986300f59b>.