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An investigation of manufacturing technique and characterization of low-density polyethylene waste base bricks

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ABSTRACT

Plastic waste is accumulated in recent years, causing environmental problems, particularly in developing nations. Recycling this waste as building materials is considered as a feasible solution to the environmental issue, but it is also a feasible solution to the issue of building economic design. This research aims to study the possibility of using plastic waste in the manufacture of unconventional bricks that are light in weight, environmentally friendly, inexpensive, and as an alternative to traditional bricks made from fossilized clays for use in the construction industries. In this paper, we use the remnants of medical syringes made of low-density polyethylene and two types of additives were added sawdust and sand in different proportions. The melting and moulding process was used in manufacturing. Testing has been conducted to identify hardness, density, water absorption, compressive strength and also to determine morphology properties by FTIR and SEM. The results showed that bricks made of plastic and sawdust gave a high compressive strength of 66Mpa at 20% of sawdust higher than bricks made of plastic and sand with a value of 61Mpa at 60% of sand. In both cases, they gave a higher compressive strength than ordinary bricks, as well as a very low absorption rate. The density was very low, especially with sawdust, where the highest value was 0.8985 g/cm^{3}of pure polymer, and for sand, it was 1.4321 g/cm^3 at 60% of sand and it gave good hardness values. The FTIR results showed that there is no chemical reaction, but only a physical reaction between the polymer and the additives, and through SEM, it was observed that there is homogeneity between the polymer and the additives. As a result, the study presents a new line of investigation into the sustainable recycling of the circular economy of waste thermoplastics.

Selection and peer-review under responsibility of the scientific committee of the International Conference on Recent Advances in Mechanical Engineering and Nanomaterials

1. Introduction

Polymer production was always accompanied by the problem of repurposing them after they've been used. Slower progress in the area of recycling has created a massive issue: each year, tens of millions of tons of old polymeric materials have been wasted. It has a negative impact on the environment and, as a result, on society [1].

Food, bottles, and covers, bottles, and packaging are all common plastic products. The breakdown of plastic is a major issue. Plastic is composed up of non-biodegradable polymer compounds. This implies that when plastic is buried, it will not disintegrate. As a result of its non-biodegradability, waste plastic disposal is a major issue worldwide, and researchers have discovered that plastic products may survive for 4,500 years without degrading. Plastic, while being an incredibly valuable material, which is flexible, strong, and stiff, becomes trash after use, polluting the air and soil [2,3]. As a consequence, these waste plastics will be put to good use. From agriculture to industry, it is now difficult for any essential sector to function effectively without the use of plastic. As a result, although we cannot prohibit the use of plastic, we believe that the reuse of plastic trash in house building and industry is the most practical use [4]. Recycling is the act of converting old (waste) resources into new goods in order to avoid the waste of potentially valuable materials. The growing popularity of utilizing environmentally friendly, low-cost, and lightweight construction materials in the construction industry has necessitated research into how this may be accomplished while still meeting the material criteria outlined in the standards. A recycling process is utilized to preserve the environment and to make use of plastic [5]. Use of

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Table 1
Some characteristics tested for additives.

Additives	Apparent density (g/cm^3)	Aperture size (μm)
Sand	1.3775	≤600
Sawdust	0.7260	≤600

plastic waste in the manufacture of bricks is an excellent way to address the issue of waste storage while also lowering the cost of construction materials [5]. Manjarekar and colleagues investigated the use of plastic wastes in foundry sand bricks. The compressive strengths of brick is higher than that of a regular bricks, and the bricks did not break after falling from a height of 1 m. Additionally, this brick absorbs less water than traditional brick [6]. Physical properties of Waste-Plastic Bricks and Development of Materials for Pothole Filling were investigated by Kedare et al. Because this Brick is constructed of plastic, no impact from oil, salts, or acids has been seen. It has a lower water absorption rate. It can also resist compressive forces of 11.82 Mpa. [7]. Use of limited polyethylene water sachets to create plastic bound sand blocks was investigated by Larbi Jnr, et al. Waste LDPE water sachets were melted and combined with sand to create LDPE-bonded sand blocks in this study. When generated under ideal processing conditions, LDPE-bonded sand is indeed a robust, tough material with compressive strengths up to 27 MPa [8]. The Use of Low-Density Polyethylene Wastes in the Production of Paver Bricks had been investigated by Reddy et al. The compressive strengths of the plastic paver bricks seem to be higher than that of traditional bricks, according to the findings. There are many benefits to adopting this plastic paver brick, including lower brick costs than traditional bricks that is cost effective [9]. Mondal M. K. investigated the characteristics of plastic bricks made from polycarbonates, polystyrenes, and blended polymers, as well as fly ashes, sand, and regular cement. The bricks produced have a strong heat resistance as well as a compressive strengths of around 17 MPa [10]. Nursyamsi et al. conducted an experimental research on waste plastic bricks by varying the quantities of sand and plastic and testing compressive, water absorption, efflorescence, resistant against fire, and hard-

Fig. 1. a) LDPE waste material, b) Melting of low density polyethylene in a closed furnace, c) Filler (sand or sawdust) sieved and required amount measured, d) Homogeneous mixing of molten LDPE with the filler, e) Pour the sample into the mould and leave to harden; and f) The sample removed from the mould to produce a brick sample.

Table 2
Compressive strength test results.

LDPE wt. %	Snad wt. %	Max load (kN)	Compressive strength (MPa)
90	10	693.4	57.591
80	20	678.0	56.312
70	30	719.2	59.734
60	40	734.9	61.038
50	50	753.6	61.244
40	60	737.9	61.287

Table 3
Compressive strength test results.

LDPE wt. %	Sawdust wt. %	Max load (kN)	Compressive strength (MPa)
90	10	703.7	58.45
80	20	805.4	66.89
70	30	753.5	62.58
60	40	595.3	49.44
50	50	204.3	16.97

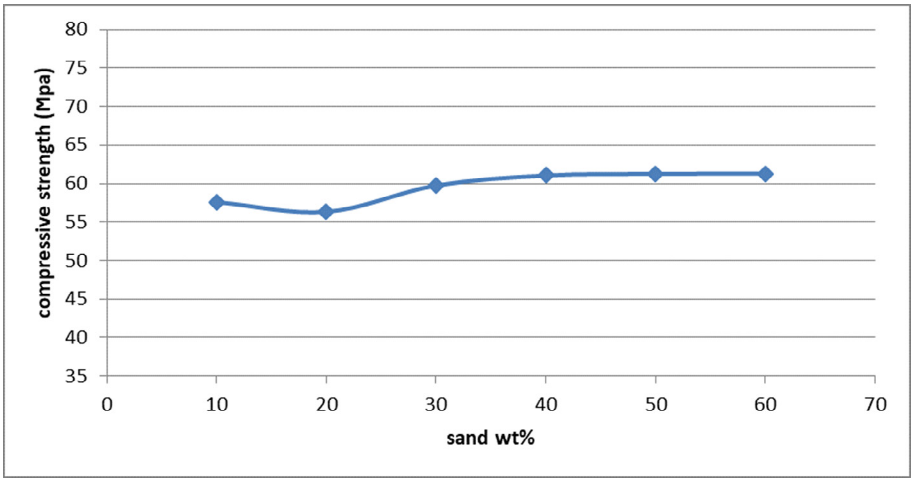


Fig. 2. The effect of adding sand on compressive strength of bricks.

ness. It was proposed that instead of river sand, fly ashes or quarry dusts might be used to cut costs even more [11]. Kumar et al also looked at plastic bricks made from different mixes of fly ashes, sludge lime, gypsum, fine aggregates, and high-density polyethylene wastes plastic bottles. The amount of plastic in the specimens ranged from 5 to 20 percent, and it was discovered that as the percentage of plastic increases, the compressive strengths drops [12].

This study using plastic waste from a medical syringe factory, which is the syringe piston made of low-density polyethylene (LDPE), and this plastic will be combined with sawdust once and with sand again and in different proportions. Then, the bricks will be tested to investigate compressive strengths, water absorption, density, hardness, and FTIR and SEM testing.

Table 4
Water absorption test results.

LDPE wt. %	Sand wt. %	Water absorption wt. %	LDPE wt. %
100	0	0	100
90	10	0.92	90
80	20	0.76	80
70	30	0.71	70
60	40	0.65	60
50	50	0.52	50
40	60	0.50	40

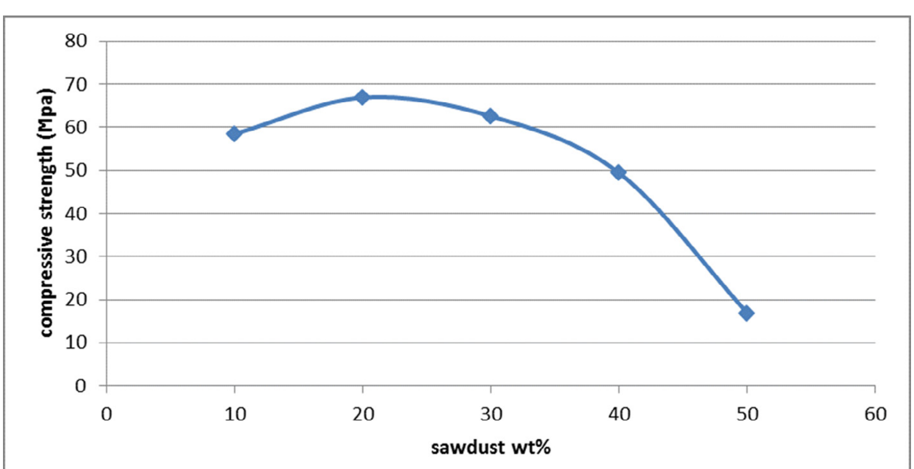


Fig. 3. The effect of adding sawdust on the compressive strength of bricks.

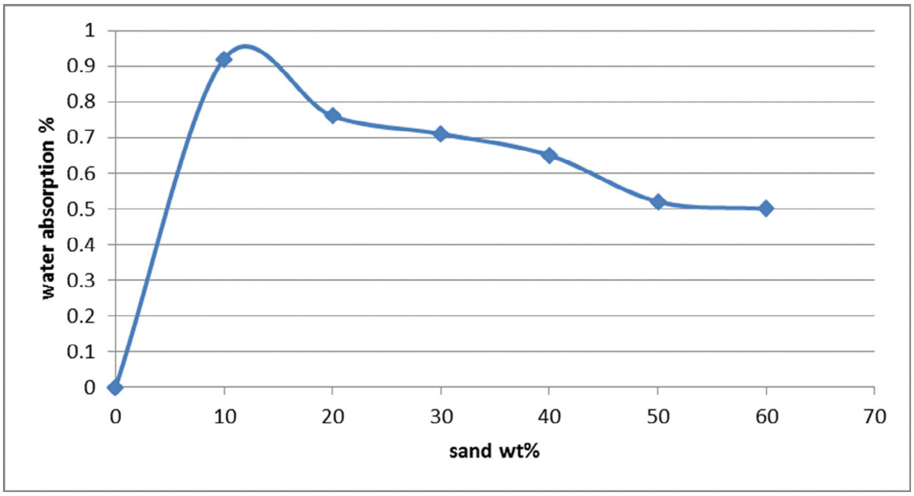


Fig. 4. The effect of adding sand on water absorption of bricks.

Table 5
Water absorption test results.

LDPE wt. %	Sawdust wt. %	Water absorption %	LDPE wt. %
100	0	0	100
90	10	0.99	90
80	20	1.80	80
70	30	2.02	70
60	40	7.03	60
50	50	21.05	50

Table 6
The results were obtained from the density test.

LDPE wt. %	Sand wt. %	Density (g/cm^3)	LDPE wt. %
100	0	o.8985	100
90	10	0.9449	90
80	20	1.0411	80
70	30	1.1350	70
60	40	1.2254	60
50	50	1.4208	50
40	60	1.4321	40

2. Methodology

2.1. Materials

The low-density polyethylene material used from the medical syringe factory, which is a syringe piston has a density (0.8985 g/cm^3). There are two types of fillers in this study which are sand and sawdust, which are added to low-density polyethylene (LDPE) in different ratios. Table 1 demonstrates some of the characteristics of the additives.

2.2. Plastic batching

Batching is the process of measuring ingredients for brick production. Following the collecting of materials and the removal of any additional trash from the selected materials, the weights of the selected materials are determined as indicated in Fig. 1(a). Fillers are sieved through a 600 μm sieve before being utilized to make bricks, as illustrated in Fig. 1. (c). for bricks, various amounts of plastic wastes with fillers are used. Fig. 1 depicts the whole process of making plastic bricks.

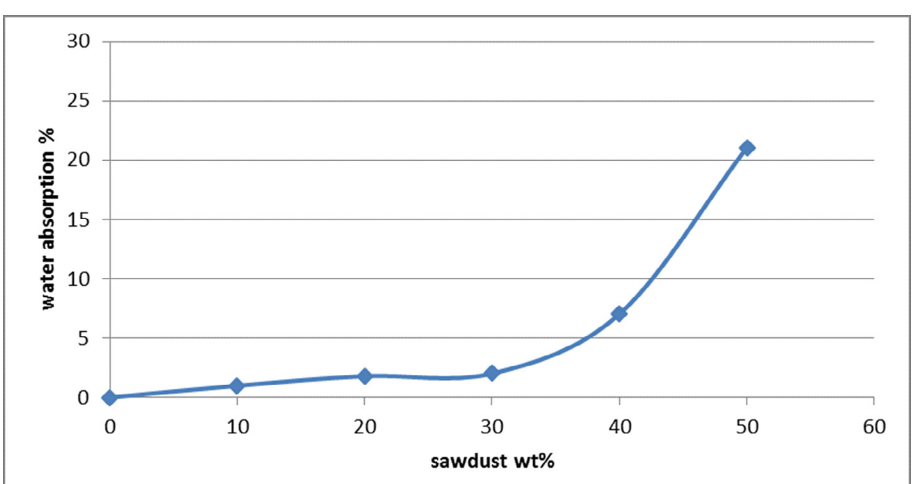


Fig. 5. The effect of adding sawdust on water absorption of bricks.

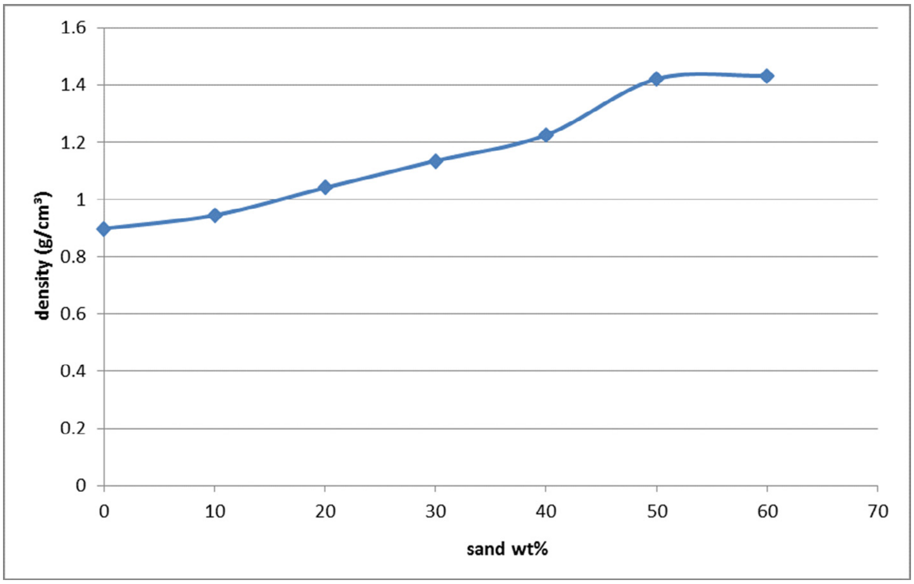


Fig. 6. The effect of adding sand on the density of bricks.

Table 7
Density test results.

LDPE wt. %	Sawdust wt. %	Density (g/cm^3)
100	0	0.8985
90	10	0.8662
80	20	0.8526
70	30	0.8545
60	40	0.8183
50	50	0.7065

Table 8
Hardness test results.

LDPE wt. %	Sand wt. %	Hardness
100	0	60.1
90	10	60.36
80	20	61.8
70	30	64.5
60	40	69.03
50	50	70.06
40	60	70.46

2.3. Melting and moulding

After batching, the plastic wastes were transported to be melted, and the plastic syringe pistons were all thrown into one container. To avoid hazardous gases being discharged into the atmosphere, they would indeed be carried out in a closed tank. These will be cooked at a temp of 170–190 degree centigrade for 60–90 min.

The mixing process was carried out by hand. Plastic pieces are put to the melting container until the proportions needed reached, as illustrated in Fig. 1. (b). Filler is a material that is added to a plastic composition. The filler is applied to the container when the temperature of the melted plastic in the containers reaches approximately 170–190 degree centigrade. The filler and molten plastic are blended together to ensure that they are properly connected. As a result, the mixing procedure should not take too long.

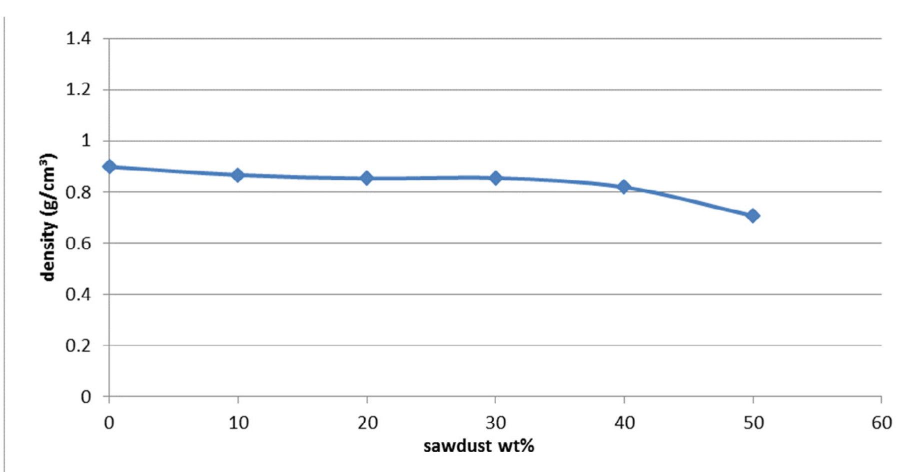


Fig. 7. The effect of adding sawdust on density of bricks.

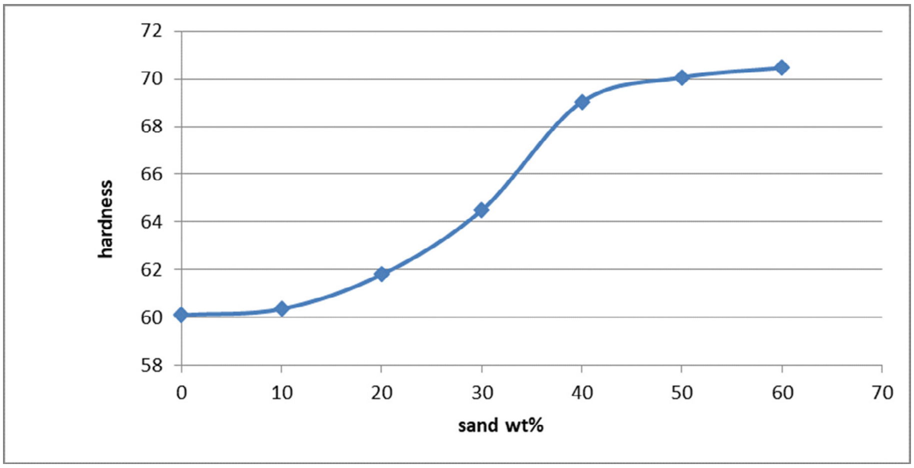


Fig. 8. Shows the effect of adding sand on hardness of bricks.

Table 9
Hardness test results.

LDPE wt. %	Sawdust wt. %	Hardness
100	0	60.1
90	10	59.86
80	20	58.76
70	30	58.13
60	40	55.94
50	50	44.8

As the plastic pieces melt, they begin to bind with the filler particles, resulting in the brick-making combination illustrated in Fig. 1. (d). The produced mixture is then poured into a steel mould, in this case utilizing the brick sizes (14.5x8.5x3 cm) as indicated in Fig. 1 for the moulding process (e). The pressure used is contact pressure, which ensures that the mixture fills the mould correctly. Then it's allowed to cool in the air, but before filling the mould, rub oil on the inside walls to make it easier to remove the bricks afterwards. The application of oil to the inside surfaces of the mould is required since this brick will not come out easily after solidification, and removing the mould will need some pressure, which will wear the edges of the brick. As a result, adequate oiling is required prior to filling the mould with the mixture. Remove the brick from the mould after 4–6 h. After moulding, the test specimens were allowed to dry for 24 h, as illustrated in Fig. 1. (f).

2.4. Tests conducted on plastic bricks

2.4.1. Compressive strength

In this test, we adopted Iraqi Standard Specifications No. 25 of 1988 (IQS 25 – 1988). The compressibility of all samples were measured by a compression device.

2.4.2. Water absorption

In this examination, we adopted Iraqi Standard Specifications No. 25of 1988 (IQS 25–1988).

As the method of work is to dry the examination model in a drying oven at a temperature of (100 ± 10) until its weight is stabilized, then it is cooled to room temperature and weighed and let it be the dry weight (w1).

The dry model is immersed in pure water at a temperature of (15–30)C for 24 h, then it is lifted and dries the surface with a piece of cloth and weighed within 3 min of taking it out of the water and let the weight be (w2)

Water absorption in % by:

$$w_t = \frac{w_1 - w_2}{w_1} \times 100 \quad (1)$$

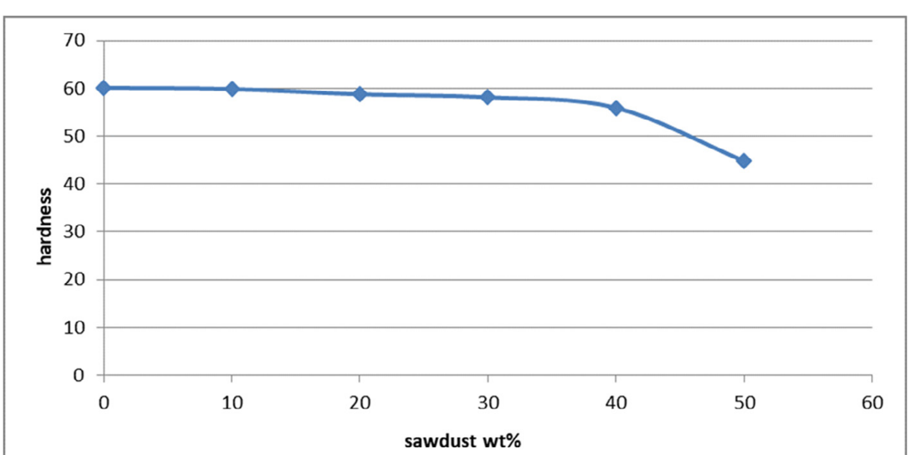


Fig. 9. The effect of adding sawdust on hardness of bricks.

Table 10
The absorption bands of IR spectrum characteristic of LDPE and composites.

Type of bond	LDPE standred[16]	LDPE exp.	LDPE/sand	LDPE/sawdust
CH2 stretching	29182851	2924.09,2954.952839.22	2924.09,2954.952839.22	2924.09,2954.952839.22
CH2 bending	14681373	1458.181373.32	1427.32	1458.181373.32

2.4.3. Density test

The ASTM 792 high precision density tester, model GP-120 S, manufactured in Matsu Haku, China, has a digital accuracy of 0.0001 g/cm3 as one of its requirements. The GP-120 S instrument was used to measure the density of the sample in liquid density mode. The sample is weighed in air before being immersed in distilled water at 23 degree centigrade utilizing a sinker and wire to keep it fully buried as needed.

2.4.4. Hardness test

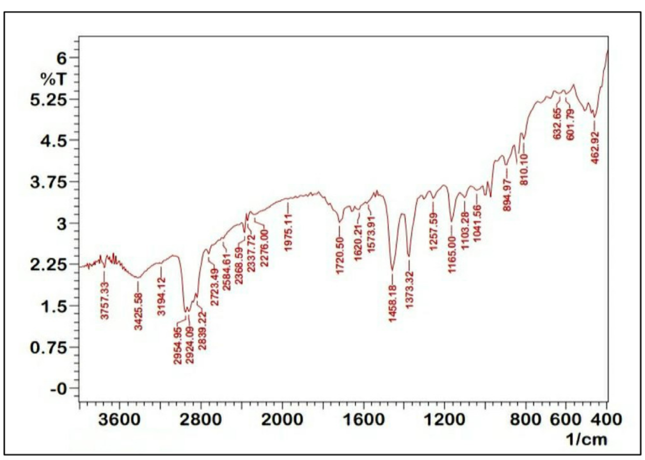
Shore D hardness device model (TH 210 FJ) made in Germany.

2.4.5. Fourier transform infrared spectroscopy analysis (FTIR)

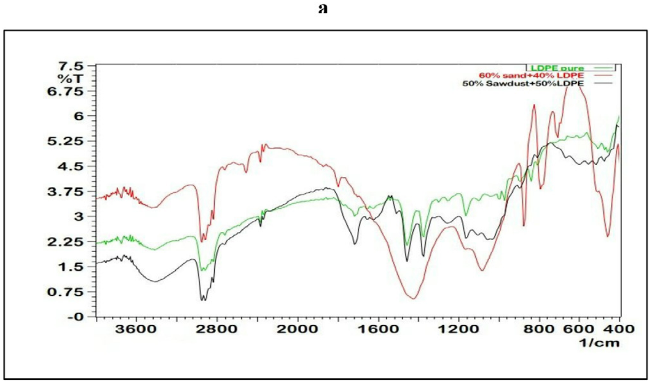
The FTIR analysis equipment Type (IR Affinity-1) developed in Japan is used to characterize extremely complex mixes using the Fourier transform infrared spectra method (Kyoto Japan).

2.4.6. Scanning electron microscopy (SEM) Test:

Scanning electrons microscope is utilized powerful techniques that allow the observations and characterizations of the surfaces of both organic and inorganic material, providing important data concerning the morphologies of the sample. The samples were tested using (SEM/ TESCAN/ VEGA II Series).



a



b

Fig. 10. show The FTIR spectrums of plastic bricks. Where a- The FTIR spectrums of pure LDPE sample. b- The FTIR spectrums of plastic bricks compare between pure LDPE and LDPE with two fillers.

3. Results and discussion

3.1. Compressive strength

3.1.1. LDPE with sand

From the results obtained as shown in Table 2 and Fig. 2. It clearly shows that the value of compressive strength increase as the ratio of sand increase and plastic waste decrease (C Gopu Mohan, et al.) [13]. the sample which having a ratio 40% of LDPE and 60% of sand has a higher value of compressive strength that equals 61.287 Mpa. It can be summarized that the increase in plastic content and decrease in sand content has caused the brick to be much flexible, which in turn reduces the compressive strength and also if the content of sand is increased the compressive strength will increase also.

That might be because the adhesion strengths between the sand and polymer has increased. The LDPE seems to function as a binder, encasing the sand grains and achieving maximum compressive strength. The interfacial connection between the sand particles and the LDPE contributes to the compressive strengths of these specimens, which is mostly determined by the sand concentration. The minimum pressure bearing, depending on Iraqi Standard No. 25 from 1988, is 7 pa [14]. The formula may be used to determine the compressive strengths of the brick specimen:

$$\sigma_c = \frac{F_{\max} \times 1000(N)}{A(mm^2)} \quad (2)$$

3.1.2. LDPE with sawdust

From the results obtained as shown in Table 3 and Fig. 3. The results show that the sample, which has a ratio of 80% of LDPE and 20% of sawdust, has the higher value of compressive strength that equals 66.89 MPa, which it illustrates that whenever the ratio of sawdust increased it means it will result in low compressive strength, although at 20% of sawdust, the highest value of the compressive strength was found, which is 66.89 MPa, and this indicates that at this percentage, the best bonding and homogeneity was obtained between the sawdust and the polymer, and also the adhesive strength between them is very good. But when the percentage of sawdust increases, a decrease in the compressive strength is observed, this may be attributed to the decrease in the adhesive strength and bonding between the waste plastic and the sawdust and also perhaps the material (LDPE) is insufficient to encapsulate and bind the sawdust particles, resulting in weak adhesion and thus poor mechanical properties.

3.2. Water absorption

3.2.1. LDPE with sand

The absorption test showed excellent performance of the plastic waste brick. The values range from 0% to 0.92%. Good quality of bricks shall not absorb more than 20% of water according to the Iraqi Standard No. 25 of 1988. The reason for this is that sand enters the polymer pores and closes the pores, and because of the good bonding and homogeneity between the polymer and sand, and the good pressure of the final product leads to the

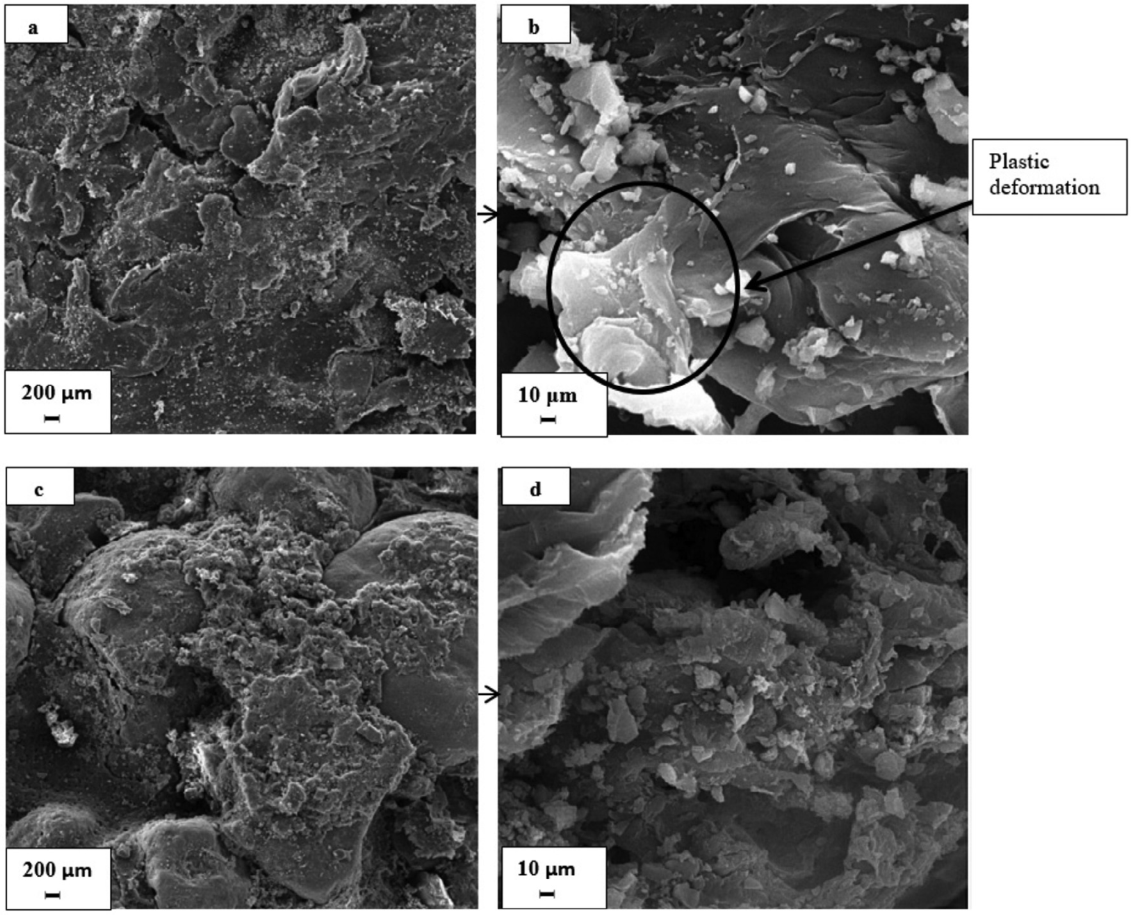


Fig. 11. Scanning electron micrograph of (a), (b) 80% LDPE and 20% sand sample. (c), (d) 40% LDPE and 60% sand sample.

absence of voids, therefore the water absorption rate is very low as shown in Table 4 and Fig. 4. It is also noted that when the percentage of sand increases, the water absorption decreases, and this may be due to the weak bonds in the polymer structure, where when a small percentage of sand is added, it will move away between the chains, but when the percentage of sand increases, it will agglomerate and close the pores between the chains and thus give its absorption low.

3.2.2. LDPE with sawdust

Table 5 and Fig. 5 shows that the higher the percentage of sawdust, the greater the absorption rate, as the highest absorbency rate was at 50% of sawdust. The reason for this is due to the high ability of sawdust to absorb water due to its high porosity. The water absorption increases with increasing sawdust content in the composites (Kamal B. Adhikary, et al. 2007) [15].

3.3. Density test

3.3.1. LDPE with sand

The density of all the samples is shown in Table 6 and Fig. 6. The results revealed that sample 40% of LDPE and 60% of sand, had the highest density of 1.4321 g/cm^3. Sample 90% of LDPE and 10% of sand has the lowest density of o.9449 g/cm^3. The reason is that the density of sand is higher than the density of the base polymer (LDPE), and therefore the greater the percentage of sand addition, the density of the final product increases, according to the rule of the mixtures.

3.3.2. LDPE with sawdust

The density of all the samples is shown in Table 7 and Fig. 7. The results showed that sample 90% of LDPE and 10% of sawdust, had the highest density of 0.8662 g/cm^3. Sample 50% of LDPE and 50% of sawdust had the lowest density of o.7065 g/cm^3. The low density in LDPE sawdust bricks was because of the lightweight of both the LDPE material and sawdust. The more the presence of sawdust in a sample, the lower the density.

3.4. Hardness test

3.4.1. LDPE with sand

From the results obtained as shown in Table 8 and Fig. 8. As the percentage of sand added to plastic waste bricks increases, hardness also goes on increases up to 16%. Hardness is the property of a material that enables it to resist plastic deformation, penetration, indentation, and scratching. A common component of sand is silicon dioxide in the form of quartz, and quartz is known to have high hardness. Thus, when sand is added at high rates, and good spread and interconnection occurs, it will give high hardness.

3.4.2. LDPE with sawdust

From the results of the hardness test as shown in Table 9 and Fig. 9, as the percentage of sawdust added to bricks increases, hardness will decrease. Wood sawdust has high porosity, and therefore the higher the percentage of sawdust, it will increase the porosity of the final product and also weaken the interconnection between the polymer and sawdust. Thus, it decreases hardness, can be easily penetrated, and has rough surface.

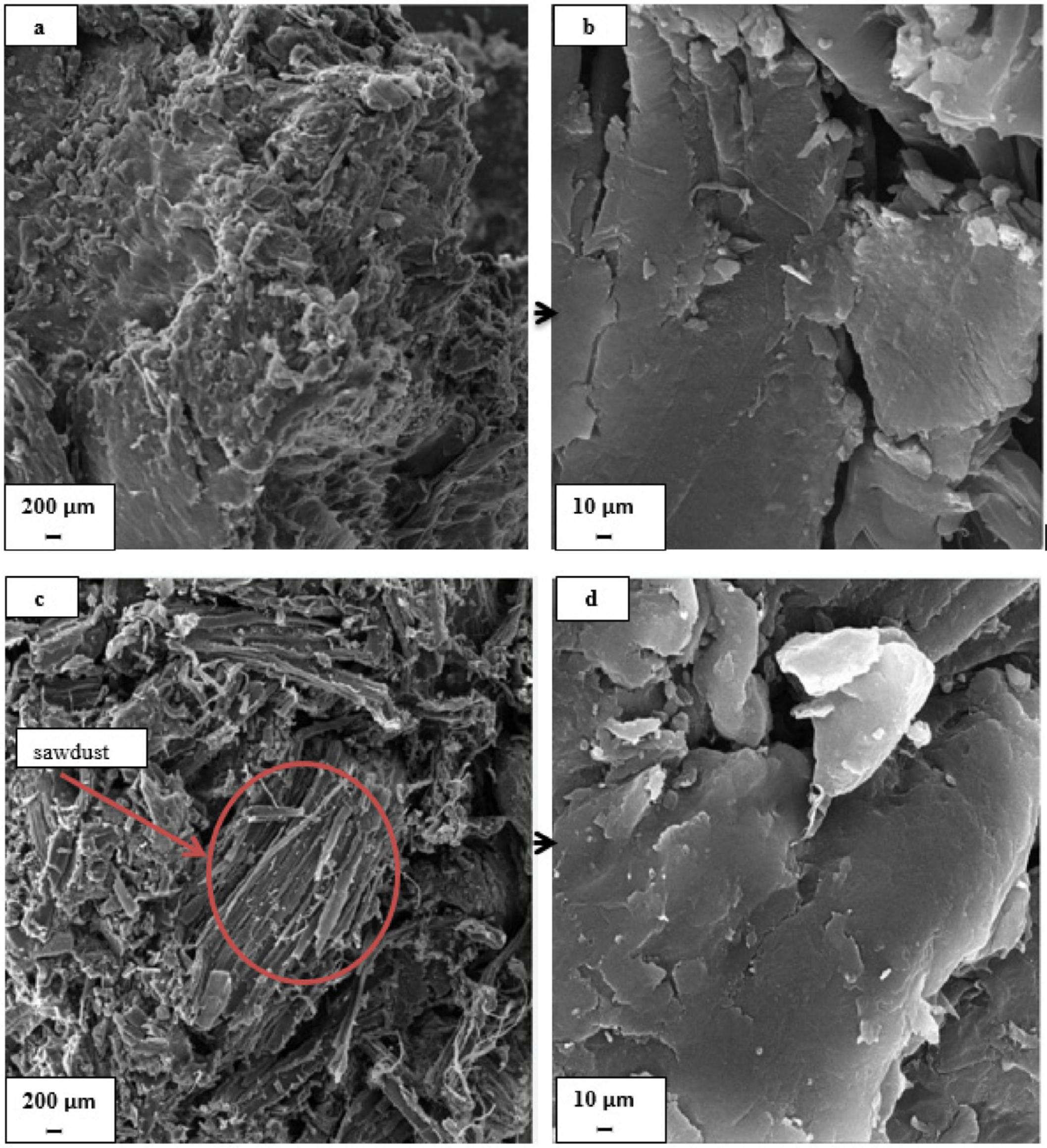


Fig. 12. Scanning electron micrograph of (a), (b) 80% LDPE and 20% sawdust sample. (c), (d) 50% LDPE and 50% sawdust sample.

3.5. Fourier transform infrared spectroscopy analysis (FTIR)

A series of Furrier transform infrared (FTIR) spectra were obtained to detect any chemical interaction in the plastic bricks. Where the highest percentage of sand and sawdust was taken and compared with the pure material (LDPE). It is summarized in Table 10, which is derived from Fig. 10.

FTIR for LDPE shows many bands such as the bands at 2924.09 cm-1, 2954.95 cm-1 and 2839.22 cm-1 for –CH2– stretching, bands at 1458.18 cm-1 and 1373.32 cm-1 for CH2 bending.

Through the examination, it was noted that there is no definitive change in the bricks made of sawdust and LDPE, only a slight change resulting from the physical interaction between the components. While in the bricks made of sand and LDPE, two bonds are broken and a new bond is formed, and this is probably due to the manufacturing process with a high temperature exceeding the melting temperature with the presence of sand (silica), which is conductive compared to sawdust, so it works to concentrate the heat in certain areas and thus this may lead to a break in the bonds in the range (1300–1500) cm-1 and a new bond formed. Thus the FTIR spectrum shows a small effect on the absorption band, which indicate no effect on the primary bond. So no chemical reaction occurred [17].

3.6. Scanning electron microscopy (SEM)

Figs. 11 and 12 show SEM images of the samples. The samples that gave the highest and lowest values in the compressive strength test were taken. In general, through the Fig.s, it is noted that there is homogeneity between the base material (LDPE) and additives and the absence of defects or gaps, which indicates the success of the preparation and mechanical mixing of the composite material.

In Fig. 11.a, b it is clear that by increasing the ratio of sand to polymer (LDPE), the type of fracture changes from plastic deformation to brittle fracture, and this explains the high mechanical properties.

Fig. 12.a, b show the bonding of sawdust with the base polymer (LDPE) is good because the surface wettability of sawdust by the base polymer is high compared to sand, which gives the highest

compressive strength. This may be due to the porous nature of the sawdust and the low interfacial surface tension between the polymer and the sawdust. However, a large increase in the proportion of sawdust significantly reduces the mechanical properties. Perhaps because sawdust has a low density and hence a large volume, the material (LDPE) is insufficient to encapsulate and bind the sawdust particles, resulting in weak adhesion and thus poor mechanical properties, as shown in Fig. 12.c, d.

4. Conclusions

Polymer waste bricks made of plastic waste which in any case would have made contamination, have benefits of cost-effectiveness, asset proficiency, and so on it drives us towards our economical turn of events objective. The bricks made have less porosity and are lightweight with more compressive strength. Further examination may work on the quality and strength of polymer waste bricks.

The outcomes we have shown us that the compressive strength of these bricks is high when contrasted with the customary dirt bricks for similar size and furthermore the heaviness of these bricks are less which thusly will decline the extra weight of the design. The water retention of these bricks is extremely less than 1% also, while in ordinary dirt bricks it is around 15% – 20% of the heaviness of bricks.

CRediT authorship contribution statement

Ahmed Fadhil Hamzah: Superviseror and revised the results and helping in discusion the obtained results. **Rusul Mohammed Alkhafaj:** Validation, Conceptualization, Writing-orginal draft, Writing review and editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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