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Investigation Prosperities Of Brick Mixes with Chemically Depolymerized Waste polyethylene terephthalate Aggregates

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Abstract

In order to create environmentally friendly products, this article focuses on reducing plastic waste by recycling polyethylene terephalate (PET) bottles (Green materials). Depolymerized polyethylene terephthalate (DPET) is created by combining PET with ethylene glycol and magnesium oxide (MgO) at a moderate temperature until the mixture reaches 179 oC (ethylene glycol's boiling point) for 40 to 50 minutes. This process first breaks down the polymer into a monomer. Second, bitumen is combined with plastic (either PET or DPET) to create modified bitumen (MB), then modified bitumen is mixed with sand, silica and gravel in order to produce friendly and sustainable construction materials . Bricks have been produced from mixing the modified bitumen with percentage (10-20)% ,sand in percentage (50-60) % and gravel in percentage (30)%. The characterization was carried out for the bricks in two steps : The first was to examine the modified bitumen to determine the best ratio that could be used in the mixture. The hardness test showed the best ratio of modified bitumen in percentages (60% of bitumen and 40% of PET or DPET) percentage is due to the formation of a functional group between bitumen and plastic which has appeared with FTIR characterization .

Secondly, the compressibility of the mixture was fully examined and the results showed the best compressive strength in 20% of modified bitumen with PET and 18% of modified bitumen with DPET. The compressive strength value is 7MPA and 6.9 MPA respectively. Finally , the recent results are compared with the previous research, and the results showed a reduction in the cost as a result of the use of waste materials and an increase in compression value.

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1. Introduction

The enormous output of plastic presents a significant global challenge for waste management. Due to population growth, there is more solid trash than ever before. Polymer waste makes up a sizable component of all municipal solid waste[1]. Plastic is now being burned and deposited all over the world. They release a lot of poisonous and harmful gases[2]. On the use of recycled light-weight aggregates made from construction debris [3]. Recycling is the process of reusing discarded materials to create new products in order to conserve resources [4]. For instance, daily usage of plastic garbage is rising quickly. According to a 2012 report by global industry analysts, plastic use would increase to 297.5 million tons by 2015 from the anticipated 260 million tons in 2008[5]. Plastic items must be recycled and repurposed because their excessive use is exacerbating the pollution issue [3] [6].Ecological buildings are one of the main ways to strengthen the energy efficiency mentality. The construction of ecological buildings uses environmentally friendly building materials that are also effective insulators to reduce heat loss from the structure [7]. One of the most significant and popular waterproof materials is polyethylene terephthalate (PET), which has a high performance to price ratio and exceptional qualities like high durability, superior mechanical and electrical capabilities, and low production costs. Because of this, it is frequently used in packaging, fabrics, and other things[8][9][10][11] .

Plastics are another material that is frequently used in brick construction in addition to the components described above. The most efficient way to reduce plastic waste, conserve raw materials, and improve the quality of bricks is to use thermoplastic waste in their production[12][13]. Because of their light weight, low cost, low density, good stability and durability, ease of molding, good impact resistance, and mechanical qualities, plastics are favored over other materials[14][15].

One issue is the possibility that plastic in building materials, particularly bricks, would weaken their compressive strength (CS). Empirical data allayes this worry, nevertheless, as the CS of bricks and plastic-embedded concrete are still relatively high[16]. A 17% reduction in CS of concrete containing 10% plastic was noted by Siddique et al. (2008) [17]. Physical parameters show that the CS is larger the smaller the plastic granules are [18]. However, there is minimal difference in CS among all plastic varieties. In other words, adding waste plastic increases energy efficiency and decreases the density of building materials while not reducing CS [19]. Although it appears to still be in the early stages, numerous studies have created various approaches for repurposing waste plastics, particularly in brick combinations. [20]. The management of sustainable waste plastic material can result from the usage of large amounts of recycled plastic in environmentally beneficial products like bricks. Although the results of various research have offered optimism, this technology has not been adopted in applications at the commercial level. Thus, more study is required to enhance the final goods' qualities and raise the proportion of plastic in bricks. On the other hand, using strong and inexpensive materials might sometimes be problematic; for example, ordinary brick typically uses a lot of heat and generates a lot of CO_2 in the bolt [21]. Studies like (Aneke and Awuzie, 2018; Aneke and Celumusa, 2021) have published on the partial as well as the whole conversion of rubbish to eco-friendly construction material to help with the search for environmentally friendly building materials.[22][23].

This project's objective was to do bibliographical study on the subject of recycling plastic waste into building materials, particularly polyethylene terephthalate (PET). Using the terms sustainable development, circular economy, life-cycle assessment, plastic waste, environmental effect, building materials, PET waste, and civil engineering as selection criteria, papers and literature that make up this review were located in Scopus, Science Direct, and Web of Science. The creative utilization of plastic trash in buildings is the main contribution to this work. Other evaluations of the uses for plastic trash are, however, accessible. By enabling studies on the long-term reaction to the use of these wastes rather than merely on immediate responses, this may help demonstrate the true worth of recycling plastic in construction materials, particularly in light of its rising use.

2. Materials and Test Methods:

2.1 Materials and sample preparation:

Before starting to explain the materials used and the way they are prepared, the figure (1) shows the progress of the paper and the method of work:

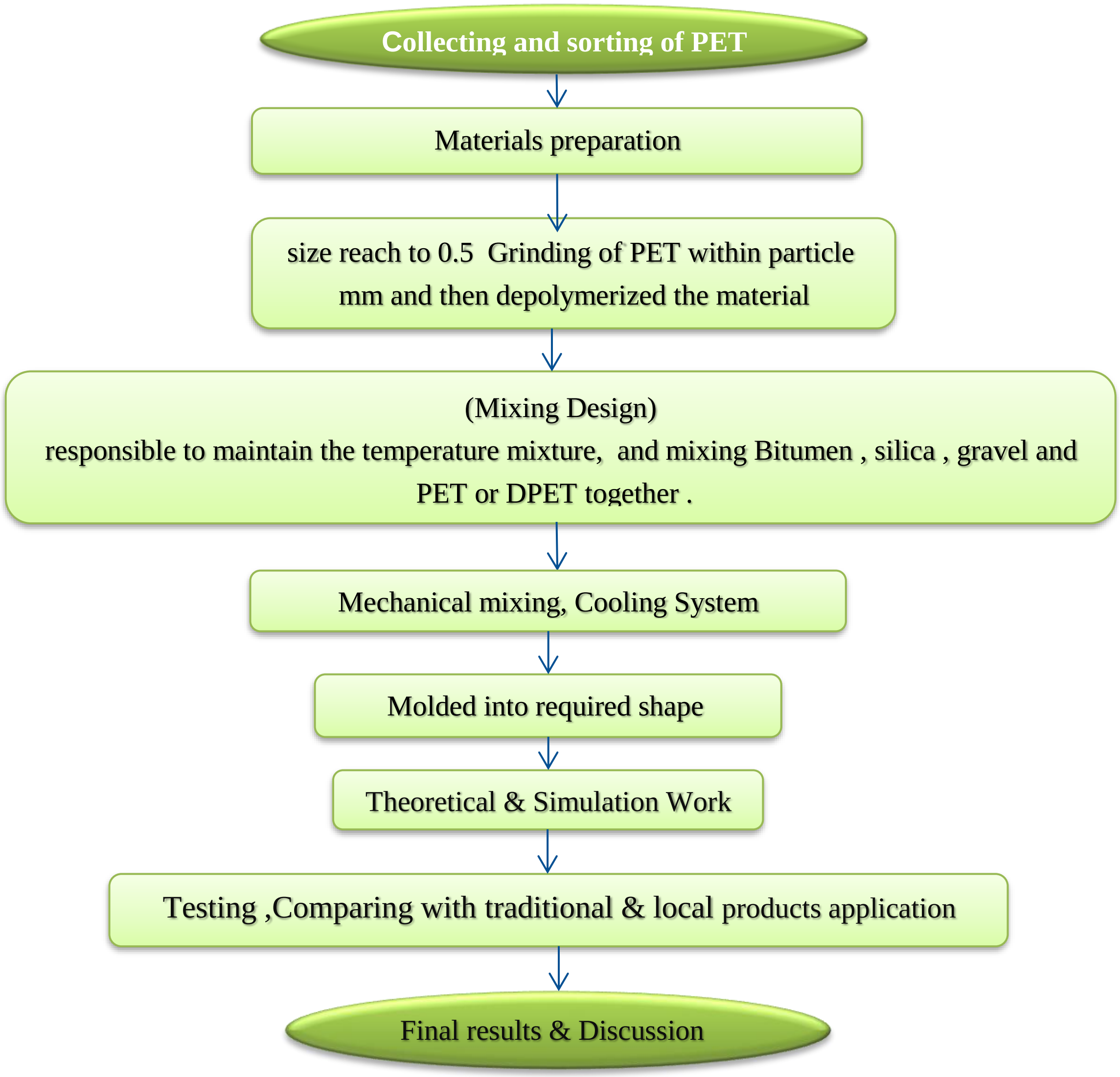

Figure 1: The flow chart show procedure of work.

2.1.1. Polyethylene terephthalates

PET bottles are collected from landfills, dusted off, cut into the required sizes, cleaned again, and finally ground into powder. based on the figure (2). The 0.5mm sieve was used to filter the chopped waste material.

Figure 2 : PET powder

2.1.2. Depolymerized polyethylene terephthalates preparation (DPET)

PET powder is chemical recycling or de polymerization, where the plastic is broken down into monomers, or is the treatment of polyester terephthalate (PET) waste with a chemical reaction (Nano MgO as catalyst and ethylene glycol as solvent) in bubble column reactors. Every (100) gram of PET was mixed with (100) mL of ethylene glycol and about 0.01 gram of MgO for every 100 gram of ethylene glycol [24]. By using moderate heat, it reaches 179 ºC (boiling point of ethylene glycol) for 40-50 min to produce chemical precursors (monomers) [25][26] .DPET then it is ground into powder as shown in Figure (3) .

Figure 3: Depolymerized polyethylene terephthalates

2.1.3. Bitumen

Bitumen used throughout this work was brought from ministry of Mining industries within properties

- Density 1.04 gm. /cm³.
- Grade 40-50
- ASTM D-947

2.1.4. Silica Sand

Sand used throughout this work was brought from the Ministry of Mining Industries. The sand has a white color within particle size ≤ 10 mm.

2.2 Method of preparation and mixing

2.2.1. Mixing Process:

Earlier , we prepared modified bitumen ,where two types of modified bitumen is produce :
First : Bitumen is mixed with PET
Second : Bitumen is mixed DPET
Mixing in percentage (10%-20%-30%-40%-50%) to produce modified bitumen.
Modified bitumen mixed with sand and gravel (particle size is 0.5cm) in order to produce a brick , the mixture details are shown in table (1).

Table1 : The mixing design

Materials	PET or DPET with Bitumen (modified bitumen)	Sand	Gravel
Percentage	10-20 %	50-60%	30%

2.2.2. *Heating mixing design*

The consisting of three parts is shown in figure (4) of systems that maintain from material volatile and these part are:

- **Heater :** which is responsible for heating
- **A mechanical mixer** : for high viscous materials is responsible for mixing bitumen with PET or DPET and metal oxides.
- **The cooling system**: is tap water for cooling, which is used for consolidation of volatile material and preventing evaporation.

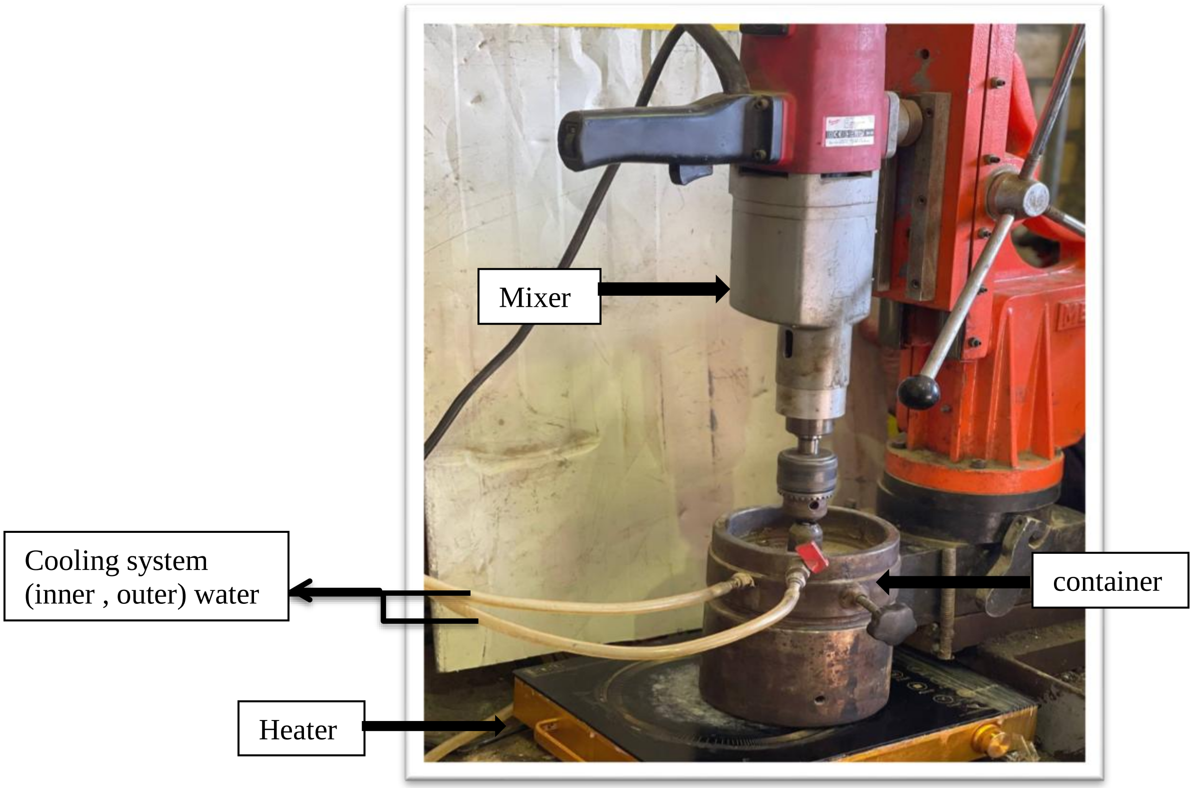

Figure 4: mixing design

Mixing process consist several rule is explain below :

- The time for heating is : 2 hours.
- 1 hour for mixing with continuous heating
- For modified bitumen, the total bitumen percentage is added to 60%, and 40% represents the percentage of DPET:

• As illustrated in figure 5, the sample for testing will be prepared in accordance with ASTM C67-05:

Figure 5 : The mold according ASTM C67-05

Following the mixing process, the samples are chilled in a mold for 15 minutes, and then they are removed from the mold in the form seen in Figure (6):

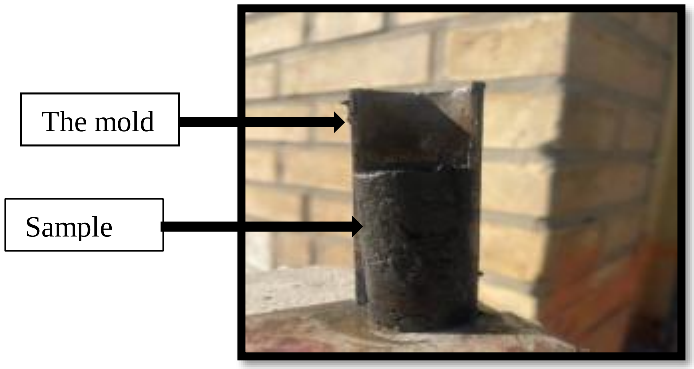

Figure 6 :sample after being taken out from the mold

For homogeneous samples and less gaps within the samples, the sample is heated until it reaches 100 oC, then a compressive load of roughly 2000 kN is applied. The compact procedure uses the apparatus seen in Figure 7, where the sample size is C67 ASTM and the mold measures 2.5 cm in width by 10 cm in depth.

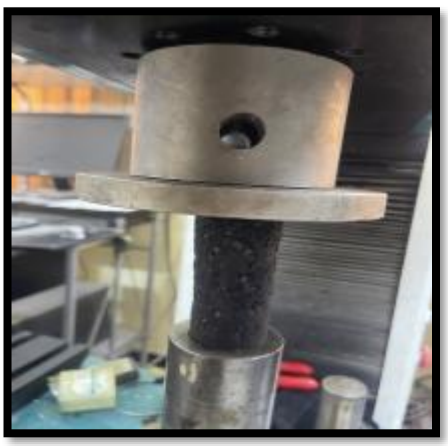

Figure 7 :sample during compact in the mold

3. Result and Discussion

The number of specimens prepared for permeability computation was 22, and the permeability test results for all mixtures (once PET and others with DPET) were reported.

3.1 Hardness for Modified Bitumen

The hardness test is typically applied to 20 samples, ten of which are made from PET with bitumen addition and the others from DPET.

The hardness result is generally shown in Figure (8) for the modification of bitumen within PET. When compared to bitumen without any addition, the best result was obtained with the addition of 40% PET, which is generally equal to 70 HRC. while figure (9) demonstrates how adding depolymerized polyethylene terephthalate improved the hardness of bitumen. The total hardness is approximately 68.8 at 40 %. The increase in hardness is due to the formation of functional groups between particles of plastic and bitumen, as shown in the FTIR test.

As the amount of polymer waste increases, penetration falls. The oil/asphalting ratio (O/A) of bitumen oils decreases as PET polymers adsorb them and create a distinct dispersion phase, which raises viscosity and an erosion of penetration [27]. In addition to, modified bitumen becomes stiff and can absorb the energy [28].

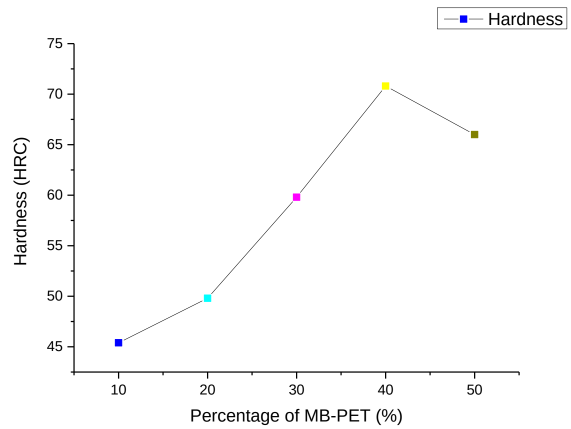

Figure 8 : Hardness for modified bitumen with PET

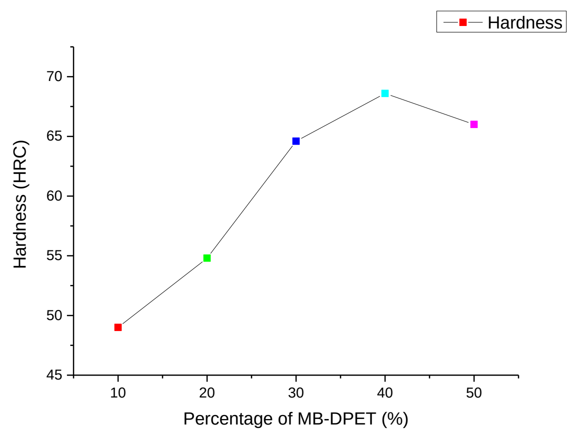

Figure 9 : Hardness for modified bitumen with DPET

3.2 FTIR Characterization

Pure PET in figure (10) At 729 cm1, there is complete aromatic (-C-H) wagging. The peak related to aromatic (-C-H) out of the plane's winding was observed at 877 cm1. The (-O-C-C) underwent asymmetric stretching at 1094 cm1 and was partitioned.

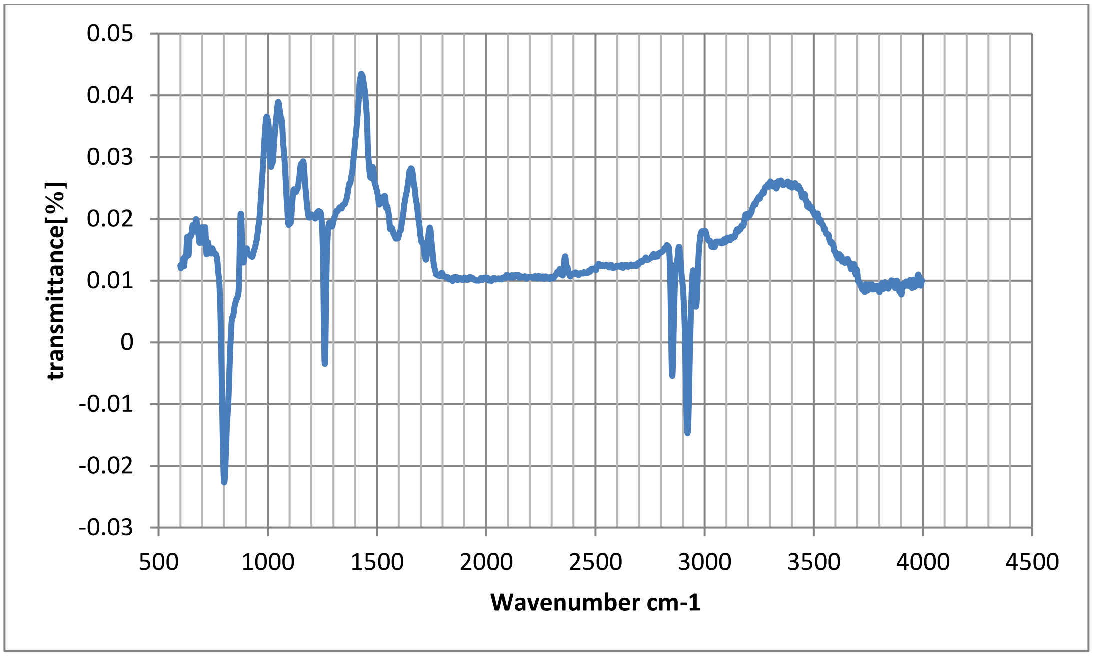

Figure 10: pure PET

Figure (11), "FTIR Characterization of DPET," Peaks were seen for the aromatic C-C stretching at 1504 cm-1, the aromatic C-C stretching at 1455 cm-1, and the asymmetric stretching of -C-H at 2962 and 2879 cm-1 (bending of C-H). At 1409 cm-1 and 1379 cm-1, peaks associated with the deformation of (-C-H alkanes) were visible. The usage of the bubble column reactor was a great method for PET degradation, as this figure showed an alkyl-CH band at 294 cm-1, a C = O stretching band at 1720 cm-1, an OH band at 3421 cm-1, and an aryl group stretching band at 1504 cm-1. [29] .

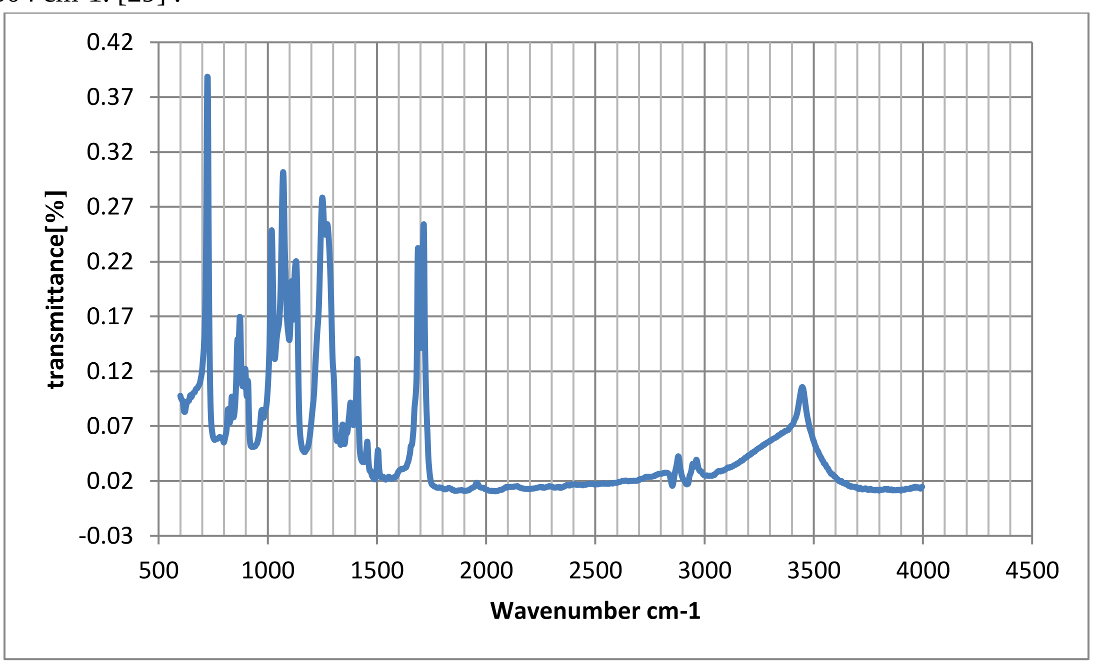

Figure 11: pure DPET

The bitumen modification in figures (13) and (14) shows the alkane C-H chain, which has lignin peaks at 2924 and 2853 cm-1. The height of the CH2 chain is shown to be 1581 cm1. Peaks 1462 and 1376 cm-1 showed CH3 chain. Peak 1019 cm-1 displays the functional groups involved in the ether C-O hydrogen bonding. At a peak of 873 cm-1, the aromatic functional groups are discernible. At a high of 727 cm-1, the meta-aromatic functional groups are discernible. Assuming there was a hydrogen bond there, the ether peak displayed a decline from 1066 to 1019 [30]. Increasing bitumen polarity, bitumen aromaticity, and bitumen molecule size, as well as hardening the brittle bituminous binder [29].

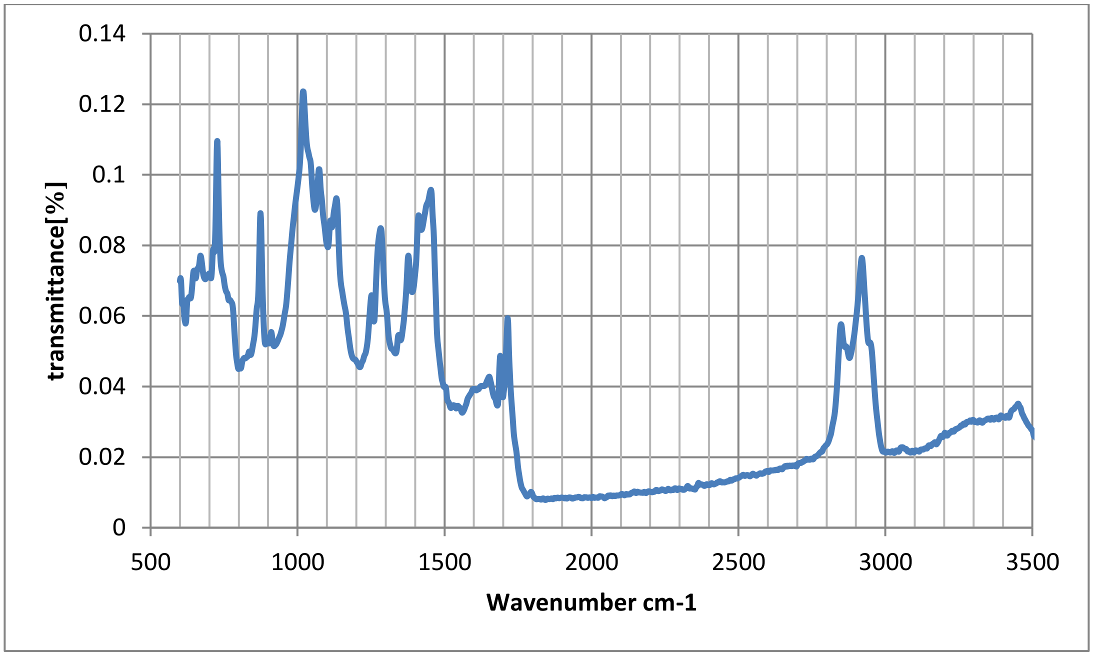

Figure 12 : pure Bitumen

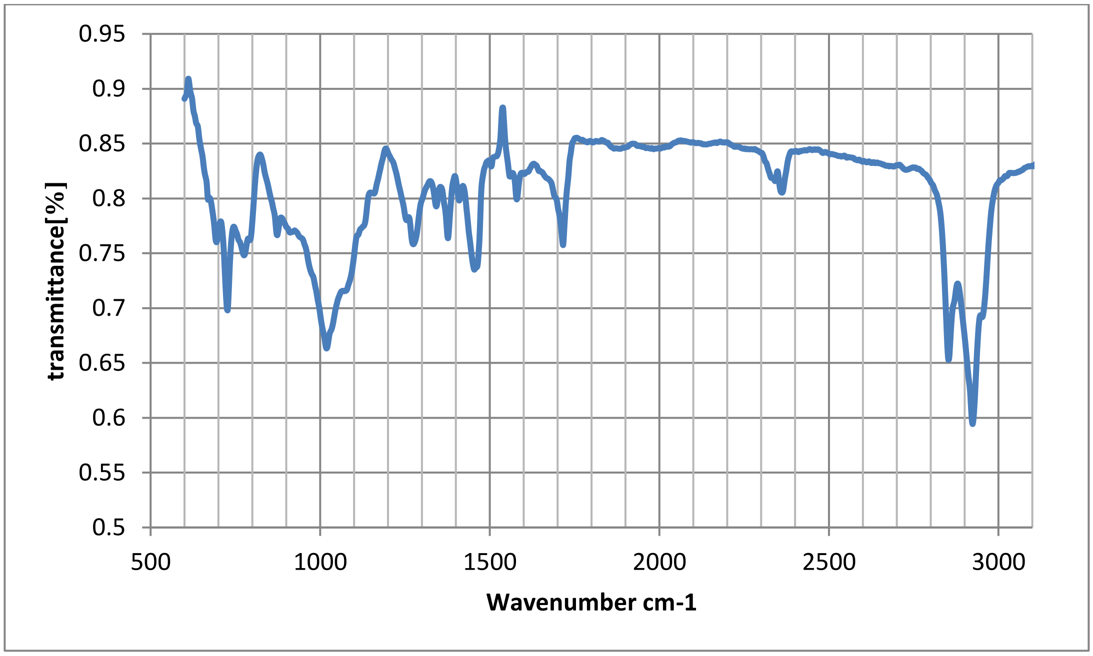

Figure 13: bitumen with PET

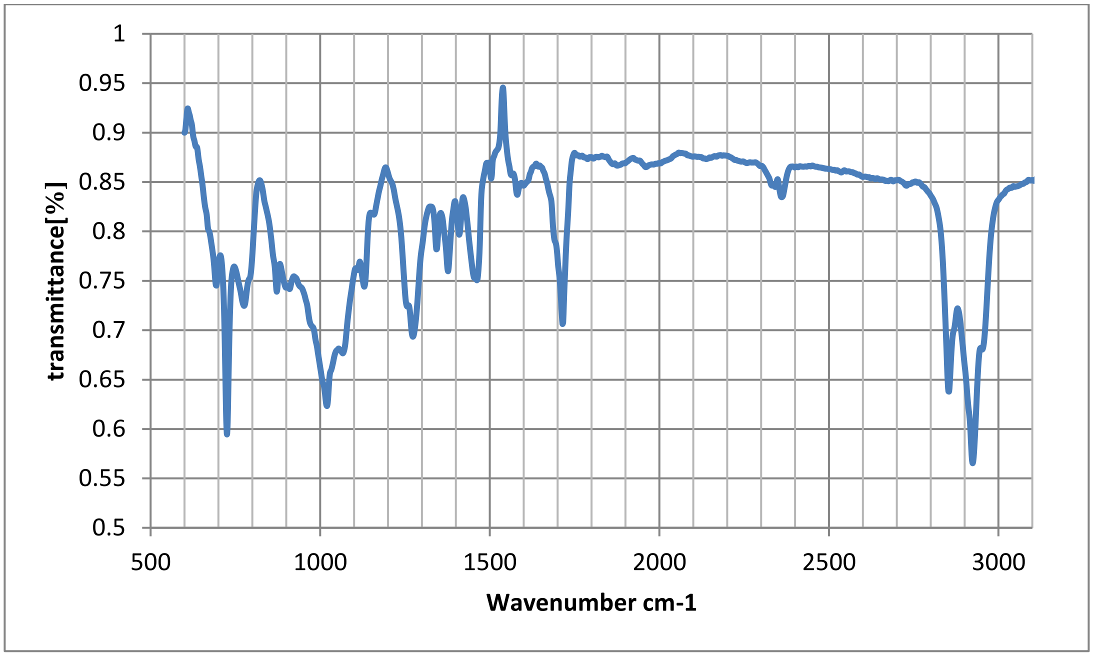

Figure 14: bitumen with DPET

3.3 Compact characteristic

As indicated in Figure 15 below, a load is given to the sample to the point of failure in order to evaluate compressive strength, at which point data is entered in the computer:

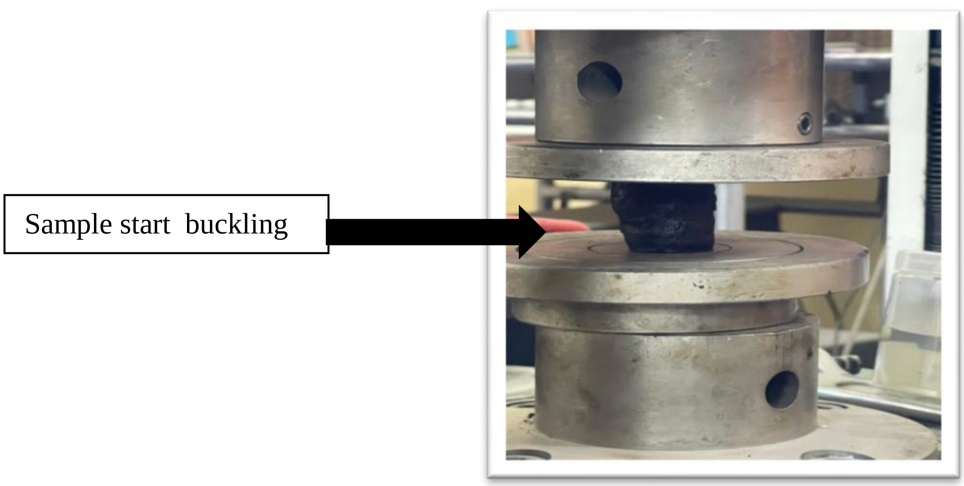

Figure15: sample during compression process

Figure 16 depicts the maximum compressive strength for modified bitumen with PET, which is roughly 13 Mpa at a 20% modification percentage. Figure 17 depicts the maximum compressive strength with the addition of DPET, which is 12.9 Mpa at an 18% modification percentage and decreases in percentages 19% and 20%. The increase in compressive strength is due to the formation of functional groups between bitumen and both DPET and PET [8]. The compressive strength is high compared with traditional clay [31]. We can conclude that Compressive strength increased as the percentage of waste plastic added rose[32]. The reason is due to what was mentioned in the hardness test, in that increasing the addition of plastic waste will lead to an increase in hardness and penetration resistance, because the polymer will reduce the viscosity of bitumen, in addition to absorbing part of the energy, which may be compressive [28]. During the work and from the conclusions of the experiments, the reason for the decrease in the compressibility of DPET compared to pet can be attributed to the fact that DPET is the formation of joint aggregates with bitumen, and since DPET is considered a fragile material and less solid than pet, so the compressibility is less than PET, and this is also the reason for the fact that the compressibility begins to decrease when increasing Quantity.

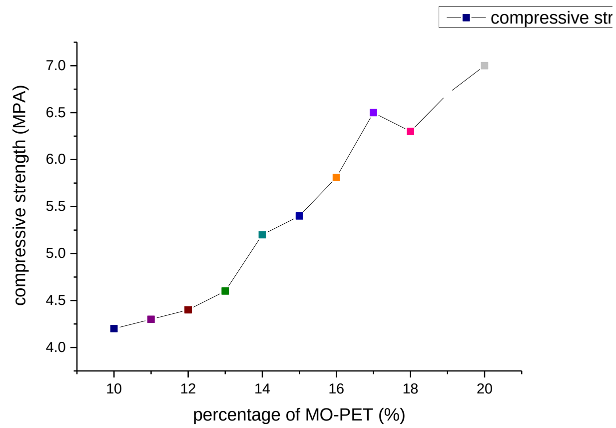

Figure 16: compressive strength for modified bitumen with PET

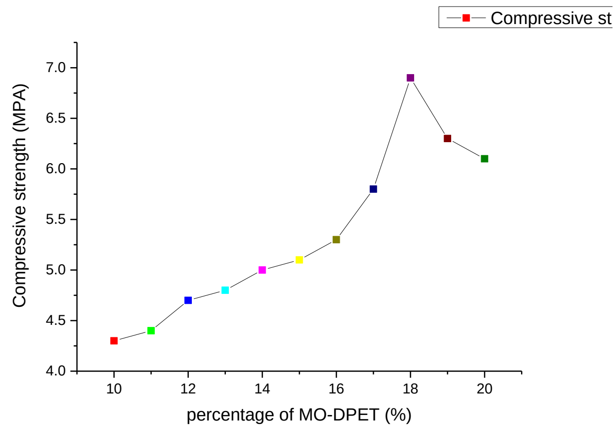

Figure 17: compressive strength for modified bitumen with DPET

4. The Economic Feasibility of This Study:

1- In this study, we do not need high temperatures and special kilns, as in the preparation of ordinary bricks, where the temperatures reach 1000, but on the contrary, the required temperature in preparing this type of brick is low, not exceeding 200 according to the work done.
2- When compared to regular bricks, the preparation time does not exceed three hours. It takes 24 to 48 hours to prepare.
3- The materials that were used in the research are materials of waste origin, and their recycling is environmentally friendly and sustainable, while the manufacture of ordinary bricks is a distortion of the environment and requires quarries and sums from the government to prepare the materials.

5. Conclusion

The results that follow are only applicable to the testing procedures and materials used:

1. Reduce plastic waste through recycling.
2. The best value for modified bitumen that is used in mixing is 40% from PET or DPET and 60% from bitumen.
3. The oil/asphalting ratio (O/A) of bitumen oils decreases as PET polymers adsorb them and create a distinct dispersion phase.
4. The hardness result for modified bitumen is more clearly identified within FTIR characterization due to the formation of the functional group (-OH).
5. The best compressive strength is achieved at 18% of DPET mixing and 20% of PET mixing.
6. An rise in plastic trash production may result in an increase in its market value.
7. As compared with traditional bricks and according to C67 ASTM, this new mixture of bricks has greater compressive strength than traditional bricks.

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