Pharmacogn J. 2024; 16(2): 307-311
A Multifaceted Journal in the field of Natural Products and Pharmacognosy
www.phcogj.com

Original Article

Composite Construction Tiles Manufactured from PET and Other Waste Plastics Reinforced with Polycarbonate and Study their Mechanical Properties

Adam W. Ahmed, Fawzi H. Jabrail*

Adam W. Ahmed, Fawzi H. Jabrail*

Department of Chemistry, College of Science, University of Mosul, Mosul, IRAQ.

Correspondence

Fawzi H. Jabrail

Department of Chemistry, College of Science, University of Mosul, Mosul, IRAQ.

E-mail: fawzijabrail@uomosul.edu.iq

History

- Submission Date: 16-01-2024;
- Review completed: 09-03-2024;
- Accepted Date: 20-03-2024.

DOI : 10.5530/pj.2024.16.46

Article Available online

http://www.phcogj.com/v16/i2

ABSTRACT

Direct recycling of plastic waste without chemical conversion used mechanical shredding with thermal press is the main purpose of this research for manufacturing of building tiles. Seven types of plastic waste have been used in the manufacture of tile includes, PET, PVC, PS, PP, LDPE, HDPE, and PC. In stainless steel mold 250g of different weight percentages of grinded plastic waste have been packed, heated for 30min at ~170°C and then pressed inside piston give pressure of 5ton/in^2 equal to (44.2MPa) and for 5min. The produced tile was cooled gradually inside its mold till reached 5^{o}C. Different mechanical test for the manufacture tiles were done, where the best result was found for specimen3 plastic mixture, where shows compression strength 17.0MPa for square tile form, tile 17.4 MPa for circular tile form, which means the tile form play an important role in its strength. Similarly, the tensile strength and elongation% tests were also be the highest for specimen3 with values equal 3.4MPa and 2.0%, respectively. The Rockwell hardness of the tile shows HRR=95 where large numbers correspond to harder material. Finally the Charpy impact test shows the specimen2 has the highest impact energy 2.421kg.m and toughness 2.968kg.m/cm^2. All previous mechanical values clear the manufactured plastic tiles are suitable as building materials.

Keywords: Composite tiles, Plastic waste, Compressive strength, Tensile, Strength, Rockwell hardness and Charpy impact test.

INTRODUCTION

The plastic polymers play a significant role in daily life, where they widely used in industry; household; construction; and automotive etc.[1,2] and had replaced successfully many conventional products and materials. Mostly, after being used these end-of-life plastics are be thrown into the environment and these non-biodegradable chemicals will a cumulative solid pollution which cause hazards effects and quandary for disposing.[3] Mainly, four strategies are depend for the disposal and recycling of plastic,[4] mechanical recycling,[5] Chemical recycling,[6] change to fuel,[7] and use as construction materials.[8] The mechanical recycling calls for either direct reuse of waste plastics especially if not contaminate where a new products will form without loss of properties, or grinded and melting into granules and her with some loss of their molecular weights.[9] Mechanical recycling need high-quality purification and separation of waste, and necessarily cause destroy of the properties of the recycled plastics, and limits their applications. Whereas, chemical recycling methods could be possible to convert plastic waste materials into compounds of low molecular weights usually in the form of liquids or gases, can be used as raw materials suitable for the production of plastics and new other products.[10,11] Pyrolysis of plastic waste is possible for production of fuel,[12] or by incineration of energetic plastics can create heat use for heat building or as power used for different technological processes.[13] Finally, solid plastic waste can be used as construction materials, since concrete is the most popular construction materials used in the world, the opportunity for waste plastics as substituent of concrete components is wide and possible. Plastic is considered one of those potential consumed materials can be include in concrete and mortar, and there are three likely ways. In the first one waste plastic is depolymerized and produce polymer concrete and mortar from resins.[14] In the second one the waste plastic used as binder, where melted with sand and clay.[15] In the third one, the waste plastic is used as fibers, particles or pellets, as a replacement of aggregate either fine or coarse particles[8] Plastic aggregate (PA) commonly used for building materials.[16] The plastic aggregate (PA) are depend to replace course aggregates and fine aggregates. Generally, the PA has lower bulk density than limestone, granite or basalt; therefore lightweight concrete will be prepared. While plastic fiber (PF) are used building materials as reinforcement to the concrete which can replace steel fiber and improve mechanical and even the strength durability.[17] In present research, different plastics and fiber aggregates includes PET, PVA, PS, PP, HDPE, LDPE and PC, where mixed with different percentages and subjected to certain conditions of heat and pressure for manufacturing of plastic tiles. Different mechanical testing techniques were applied on the plastic tiles and studying their stand the strain from construction engineering view.

MATERIALS AND METHODS

Materials: Different types of industrial plastics and fibers after being used by the society are collected from various sources for small local factories, shredded and grinded into small particles of almost

Cite this article: Ahmed AW, Jabrail FH. Composite Construction Tiles Manufactured from PET and Other Waste Plastics Reinforced with Polycarbonate and Study their Mechanical Properties. Pharmacogn J. 2024;16(2): 307-311.

1.5mm size. The waste plastics includes poly(ethylene terephthalate) (PET), poly(vinyl chloride) (PVA), polystyrene (PS), polypropylene (PP), high density polyethylene HDPE, Low density polyethylene LDPE, and polycarbonate (PC). Special molds with different forms for casting the plastic tiles and manual piston of 25ton/in^2 were used.

Manufacturing of the Plastic Tiles: Different weight percentages of waste plastic were mixed before packing inside casting molds, one has square form of 15cm x 15cm with 2.0cm depth and the second has circular form of 176.8 cm^2 circle area and 2.0cm depth. Both are made of stainless steel and having closed cover. The molds are greased with engine oil before packing with plastics for easy removal of the pressed tile.

Total mixture weight of plastic waste 250g was packing inside the mold where the mixture prepared with different weight percentages of the plastic waste Table1. The final composite of the mixture was fixed for each sample and the molds were closed and start heated for 30min at ~ 170°C. The molds were sequentially transferred to the piston and pressed to pressure of 5 ton/in^2 equal to (77.2 MPa) and for 5min. The casted plastic tile then was cooled gradually to 5°C, and de-molded at room temperature. The manufactured tiles were evaluated by different mechanical tests.

Mechanical Tests of the Tiles

Compression Strength Test: It is a force applied to the tested sample to both top and bottom until it is deformed or fractured. The compression strength can be calculated according to the following formula;

$$\text{Compression strength} = \frac{\text{Maximum load}}{\text{Original cross} - \text{sectional area}} \quad \ldots (1)$$

The cold working of the tile also measured which represent a process in which the tested plastic is shaped at accepted low temperature and as follows;

$$\text{Cold Working (Cw\%)} = \frac{A_o - A_f}{A_o} x100 \quad \ldots (2)$$

where, A_o is the original and A_f is the final circular cross sectional area of the examined rod.

Tensile Strength Test: Ultimate tensile strength represents the maximums stress where the plastic specimen can withstand under stretched or pulled before breaking. Ultimate tensile strength can be measured by tensile tester depending on the following formula;

$$\text{Tensile strength} = \frac{\text{Maximum force}}{\text{Original cross} - \text{sectional area}} \quad \ldots (3)$$

Accordingly, the elongation (%) represents the percentage where the plastic stretches after its original length before break. The elongation (%) is calculated according to the following formula;

$$\text{Elongation (\%)} = \frac{L_f - L_o}{L_o} x100 \quad \ldots (4)$$

where, L_f is final and Lo is the original length of the specimen.

Hardness (Rockwell Hardness) Test: The test depends on indentation hardness of a plastic, where the Rockwell hardness tester used with a steel ball for measuring the depth of penetration done by indenter under a known miner lead. The following formula can be depends for calculation of Rockwell hardness (HR).

$$\text{HR} = N - \left(\frac{d}{D}\right) \ldots (5)$$

where (N) is applied load (kgf); (d) is indentation depth (mm); (D) is the ball diameter, or diamond cone width (mm).

Impact (Charpy Impact) Test: The Charpy impact test is represent standardized test of high strain rate. The test can measure the amount of the energy absorbed by a plastic material over fracture. The following formula depends for calculation of impact energy;

$$\text{Impact Energy} = W.L.(\cos\alpha - \cos\beta) \quad \ldots \ldots (6)$$

where (W) is the pendulum weight, (L) is the pendulum length,

is the angle and β: constant. The Charpy impact tester was used for Charpy impact measurement.

$$\text{Toughness} = \frac{\text{Impact energy}}{\text{Area of the sample}} \text{ x } 100 \quad \ldots \ldots (7)$$

RESULTS

Plastics are composite materials used in different areas but the main problem is finding at their end service life. Mainly, because of their non-biodegradability and non-recyclable materials and even their traditional recycling cause harmful pollution and give sometimes dangerous side products, besides they are expensive materials. Therefore, cheap and safe recycling processes are the urgent requirement, and because of the huge quantities of the following waste plastics PET, PVC, PS, PP, LDPE, HDPE, and PC are available in our local markets, which are treated well and grinded into small particles for their own uses. So we decided to manufacture a plastic tiles, the cheap building materials from plastic wastes by transformative process.

Manufacture of Plastic Tiles: Different weight percentages of the following plastic wastes PET, PVC, PS, PP, LDPE, HDPE, and PC Table 1 were depended in manufacturing three specimens arranged with their total used weights 250g which was packaged inside the molds having two forms square and circular for manufacture the plastic tiles.

Mechanical Results of the Manufactured Tiles: The manufactured tiles were mechanically measured using four main mechanical tests in order to evaluate them geometrically in terms of their validity as building materials.

Table 1: The weight percentages of plastic waste in each sample of the manufactured tiles.

Plastic waste	Weight percentage of plastic waste (g)		
	Specimen1	Specimen2	Specimen3
PET	40, 16%	100, 40%	35, 140%
PVC	40, 16%	20, 8%	35, 14%
PS	40, 16%	20, 8%	13.5, 14%
PP	30, 12%	20, 8%	35, 14%
HDPE	30, 12%	20, 8%	25, 10%
LDPE	30, 12%	20, 8%	25, 10%
PC	40, 16%	50, 20%	60, 24%
Total weight, %	250, 100%	250, 100%	250, 100%

Table 2: Compression strength (CS) and cold work (%) data of different prepared tiles.

Specimen No.	Square tile form		Circular tile form	
	CS (N/mm^2)	CW (%)	CS (N/mm^2)	CW (%)
Specimen1	16.5	4.6	16.9	4.4
Specimen2	15.0	5.4	15.5	5.1
Specimen3	17.0	2.9	17.4	2.7

Compression Strength Test: The universal testing machine of compression strength used to measure the compression strength and the cold working % of the manufactured tiles and the results which recorded by the machine and calculated according to the Eq.(1 and 2) are listed in Table 2.

Tensile Strength and Elongation Test: The Tensile tester was used for getting data about tensile strength and elongation % of the tested specimens, then the data was entered into Eq.(3 and 4) for calculation the tensile strength and elongation% Table 3.

Hardness (Rockwell Hardness) Test: Rockwell hardness tester was used for measuring the hardness of the prepared specimens, and the collected results were entered in Eq.5 and the Rockwell hardness of the tiles.

Impact (Charpy Impact) Test: The Charpy impact tester was used for measuring impact energy and toughness, and the collected results were applied in Eq.(6 and 7) and the calculated Charpy energy and toughness values of the manufactured tiles were listed in Table 5.

Table 3: Tensile strength and elongation (%) data of different prepared tiles.

Specimen No.	Square tile form		Circular tile form	
	Tensile strength (MPa)	Elongation (%)	Tensile strength (MPa)	Elongation (%)
Specimen1	2.0	1.19	2.3	1.05
Specimen2	1.9	1.9	2.0	1.7
Specimen3	3.0	2.2	3.4	2.0

Table 4: The Rockwell hardness (HRR) data of the prepared tiles.

Specimen No.	Square tile form	Circular tile form
	Rockwell hardness (HRR)	Rockwell hardness (HRR)
Specimen1	95	95
Specimen2	80	80
Specimen3	95	95

Table 5: Impact energy and toughness data of the prepared tiles.

Specimen No.	Square tile form		Circular tile form	
	Impact energy (Kg.m)	Toughness (Kg.m/cm^2)	Impact energy (Kg.m)	Toughness (Kg.m/cm^2)
Specimen1	1.955	2.443	2.122	2.671
Specimen2	2.187	2.734	2.421	2.968
Specimen3	1.703	2.129	1. 845	2.438

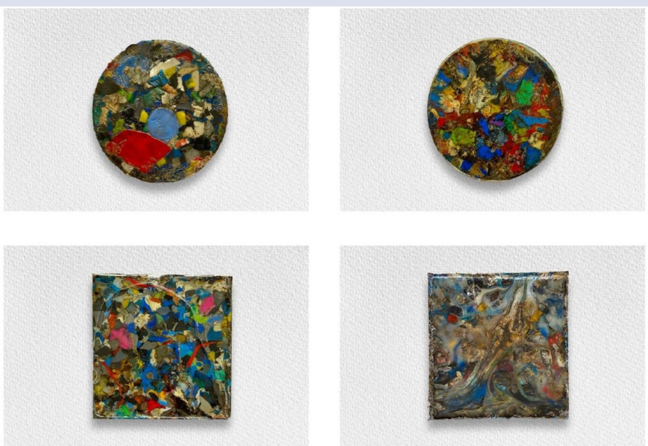


Figure 1: Circular and square manufactured plastic tiles

DISCUSSION

Controlling the specifications of the prepared tile need three stages that must the tile passes through, which are necessary for the tile mixture obtaining a homogenous result, beside the produced tile get mechanic properties includes flexibility, resistance, malleability and hardness.

The plastic waste materials used for manufacturing of tiles are polycarbonate (PC) mixed with the PET, PVC, PS, PP, LDPE and HDPE plastic which are soft materials. In general, the materials need first for shredding into small pieces and then grinding for reduction of particle size and their diameter must be near or smaller than 1.5mm and composed by a percentage including all the present polymers in the original mixture. Accordingly, the process need fair distribution of all percentages of participating polymers especially those which are working as binder, in order to confirm the final mechanical properties of the tiles such as hardness and resistance.[27]

The manufactured tiles need to obtain the suitable density of the material through fair distribution of its particles. This is done by suppressing between the material particles because the thermal compression will enhance the contact of the solid particles with the binder and diminish the nucleation of the material. Pressure is important to interact with in this stage. And because we have different materials in the mixture so the process required different points of resistance, so pressure could generate enough stress important to the deformation of different kinds of materials, but it must not miss the distribution of the binder otherwise it could generate Porosities which influence the internal may resistance of the mixture.[27] For this stage molds need pressure exposure between 50 KPa - 150 KPa distributed along the total material, for obtaining a solid tile that will not break and have no porosities. If this stage has done well the particles will agglutinate and finally forming agglomerate.

To achieve the union of particles it is necessary to take the material on its liquid stage where it is able to fill the voids between the other particles and in this way could create an internal support network. The plastic waste mixture was heated inside the molds before pressing by the piston that was at ~170°C, and then decreasing temperature after pressing process which must be gradual and under controlled up to 5°C. It is prefer to cool the tiles inside their molds.[27]

Three specimens with different plastic weight percentages Table1 were manufactured in two casting molds square and circular forms Figure5. The types of plastic waste used and their average weights are shows in Table1. Where PET, PVC, PS, PP, LDPE, HDPE, and PC are the main plastics used with total weight 250g packing inside the mold. Poly(ethylene terephthalate) (PET) was the main difference factor in weight percentage between all used specimens because of its role as binder,[18] in addition to its high strength, low-water-absorption and eco-friend polymer.[19] The second polymer used also as a main difference factor was the polycarbonate (PC) where PC can provide high strength and heat resistant properties to the products.[20] The differences in weight percentages of plastic waste mixtures were also shows progressive increase in Charpy impact of tiles as the polycarbonate percentage increase in the plastic mixture.[21] Poly(vinyl chloride) (PVC) was added to the plastic waste mixture almost with same weights in the three specimens, where PVC could increase the tensile strength and give higher thermal stability to the mixture.[22] Similarly, polypropylene (PP) present in the three specimens almost with same weights which could add good mechanical properties, water stability, and a caustic property to the mixture. In addition, PP could enhance the reinforcement of the tiles, leads to increase the impact resistances, tensile strength and flexural properties.[23,24] Low density polyethylene (LDPE) also added to the mixture where it is suitable for the tiles as anti-friction material, mechanically it is suitable in cutting and finishing of the tiles, and LDPE is suitable for marine applications due to its tendency to floats on water.[25] Whereas, the high density polyethylene (HDPE) offer high degree of crystallinity for the plastic mixture, high resistance for corrosion and smooth interior surface for the tiles.[26]

Several mechanical tests were measured for the manufacture tiles which are important for fixing their specifications and accordingly it can be determine their construction uses. The compression strength (CS) and cold work CW(%) of the prepared tiles were examined using the machine in Figure1 and the mechanical results Table2 shows the weight percentages of different polymers in the tile mixture beside the tile form have a significant effects on CS and CW(%).

However, changing the percentage of each used plastic waste in the tile mixture could change the mechanical properties of the tile. High percentage of PET(40%) in the tile composite Table 2 will decrease the CS although it is important as binder but investigations discovered higher PET fiber contents will greatly reduce the sample's compressive strength.[18] Whereas, PC% Table2, shows the CS is directly proportional with PC(%) in the tile mixture. The rest plastic wastes (PVC, PS, PP. HDPE and LDPE) their presence is necessary but preferably in equal quantities. The circular form tile shows higher CS values in comparison with a square form tile because it gives more enclosed space (area) for a given distance than a square form. The cold work (%) Table 2, shows low percentages as the PC% increase, and this is ordinary fact where the tile shaped at a fairly low temperature cause decrease in its yield strength and shows ductility.

The tensile strength test of the prepared tiles and their elongation(%) were tested Figure2, and their results Table 3, shows almost similar results to that of compression strength test. Where Specimen3 has shown higher tensile strength may due to the high PC%, but its elongation (%) is higher means has higher ductility in comparison with others specimens and this is due to the high percentages of plastic materials in its mixture although 2% elongation for polymers is not high and within the standard. The circular tile form also shows Table 3, higher tensile strength in comparison with that of square tile form.

The Rockwell hardness of the tiles were tested Figure 3, and the results Table 4 shows both specimen (1 and 3) has same HRR value and higher than specimen 2. The larger Rockwell hardness numbers correspond to harder tile and it is correlates linearly with tensile strength. The tile form shows Table 4 same values both square and circular tile form means both are similar in penetration of indenter in their body because they are made of same materials whereas, the tile form has no effects.

The Charpy impact test of the examined tiles were tested Figure 4 and the results in Table 5, shows the absorbed energy in fracture is maximum for specimen 2 and minimum for specimen 3. These results are consistent with the hardness, tensile strength and Compression energy values. The circular tile form shows Table 5, less absorb energy than the square tile form.

CONCLUSION

Recycling of plastic wastes into building materials was the goal of this work. Where seven types of plastic that are considered to be the most widely produced and used polymers in the world namely PET, PVC, PS, PP, LDPE, HDPE, and PC were treated mechanically in order to turn it into a building material with good specifications. The manufacture tiles show high compression strength and low cold work% around 17.4MPa and 2.7% respectively. This is because first some of the added plastic works as binders and others as fibers, and second the heat and press of the plastic will bring the solid particles together and then contact the binder which decreases the nucleation of the materials. Whereas, the applied pressure could remove air between the particles and prevent the formation of porosity. Similarly, the higher tensile strength 3.0MPa and low elongation 2.0%, means the tile has ability to withstand stress or load before breaking and has sufficient ductility. The Rockwell hardness of the manufactured tile was high number which means harder and there is a linear correlation between the tensile strength and Rockwell hardness. Finally, the Charpy impact test shows the specimen2 has high Charpy impact energy 2.421kg.m, and roughness 2.968kg.m/cm^2, means the manufactured tile has high ability to absorb energy before fracturing. The high toughness means the tile has higher strength and good ductility. Finally our manufactured plastic tiles are suitable to be use in various construction works.

ACKNOWLEDGMENT

The authors are grateful to the College of Science/University of Mosul for providing the facilities to carry out this work.

REFERENCES

1. Alighiri D, Yasin MN, Rohmawati B, Drastisianti A. Processing of recycled waste PET (polyethylene terephthalate) plastics bottle into for the lightweight and reinforcement bricks. J Phys Conf Ser. 2019;1321(2):022023.
2. Soni A, Das PK, Yusuf M, Kamyab H, Chelliapan S. Development of sand-plastic composites as floor tiles using silica sand and recycled thermoplastics: a sustainable approach for cleaner production. Sci Rep. 2022;12(1):18921.
3. Chakrabarti S, Adak S, Bandyopadhyay A. Composite tiles from waste plastics and fly-ash: modelling the influence of composition on mechanical and physical properties. IJMatEI. 2022;13(1):43-57.
4. Vollmer I, Jenks MJ, Roelands MC, White RJ, Van Harmelen T, De Wild P, *et al*. Beyond mechanical recycling: Giving new life to plastic waste. Angew Chem Int Ed Engl. 2020;59(36):15402-23.
5. Schyns ZO, Shaver MP. Mechanical recycling of packaging plastics: A review. Macromol Rapid Commun. 2021;42(3):2000415.
6. Rahimi A, García JM. Chemical recycling of waste plastics for new materials production. Nat Rev Chem. 2017;1(6):0046.
7. Fahim I, Mohsen O, ElKayaly D. Production of fuel from plastic waste: A feasible business. Polymers. 2021;13(6):915.
8. Mercante I, Alejandrino C, Ojeda JP, Chini J, Maroto C, Fajardo N. Mortar and concrete composites with recycled plastic: A review. Sci Tech Materials. 2018;30:69-79.
9. Zefirov VV, Elmanovich IV, Stakhanov AI, Pavlov AA, Stakhanova SV, Kharitonova EP, *et al*. A new look at the chemical recycling of polypropylene: Thermal oxidative destruction in aqueous oxygen-enriched medium. Polymers. 2022;14(4):744.
10. Ragaert K, Delva L, Van Geem K. Mechanical and chemical recycling of solid plastic waste. Waste management. 2017;69:24-58.
11. Jiang J, Shi K, Zhang X, Yu K, Zhang H, He J, *et al*. From plastic waste to wealth using chemical recycling: A review.J Environ Chem Eng. 2022;10(1):106867.
12. Wong SL, Ngadi N, Abdullah TA, Inuwa IM. Current state and future prospects of plastic waste as source of fuel: A review. Renew Sustain Energy Revi. 2015;50:1167-80.
13. Al-Salem SM, Lettieri P, Baeyens J. The valorization of plastic solid waste (PSW) by primary to quaternary routes: From re-use to energy and chemicals.PECS. 2010;36(1):103-29.
14. Mahdi F, Abbas H, Khan AA. Strength characteristics of polymer mortar and concrete using different compositions of resins derived from post-consumer PET bottles. Construction and Building Materials. 2010;24(1):25-36.
15. Ge Z, Sun R, Zhang K, Gao Z, Li P. Physical and mechanical properties of mortar using waste Polyethylene Terephthalate bottles. Construction and Building Materials. 2013;44:81-6.

16. Gu L, Ozbakkaloglu T. Use of recycled plastics in concrete: A critical review. Waste Management. 2016;51:19-42.

17. Yin S, Tuladhar R, Shi F, Combe M, Collister T, Sivakugan N. Use of macro plastic fibres in concrete: A review. Construction and Building Materials. 2015;93:180-8.

18. Omosebi Taiwo O, Abas NF. Tiles from Recycled Plastic Bottle (Pet) Wastes and POFA: Strength Properties and Durability. Civil Eng Architecture. 2022;10(4):1253-9

19. Omosebi TO, Abass NF. Polymer tiles from polyethylene terephthalate (PET) wastes and fly ash: mechanical properties and durability. F1000Research. 2021;10:1139.

20. Reich MJ, Woern AL, Tanikella NG, Pearce JM. Mechanical properties and applications of recycled polycarbonate particle material extrusion-based additive manufacturing. Materials. 2019;12(10):1642.

21. Šenkeřík V, Škrobák A, Fiala T. Influence of mixing recycled polycarbonate to Charpy impact properties at increased temperature. InMATEC Web of Conferences 2018. EDP Sciences.

22. Sultana S, Sarker MK, Islam Z, Islam MS. Comparative Analysis of Compression Molded Products of Recycled Waste Poly (Vinyl Chloride) and Virgin Poly (Vinyl Chloride) Fill Material. J Eng Technol Sci. 2022;54(4).

23. Zhao Y, Pan G, Xu H, Yang Y. Compression-molded composites from waste polypropylene carpets. Polymer Composites. 2018;39(3):595-605.

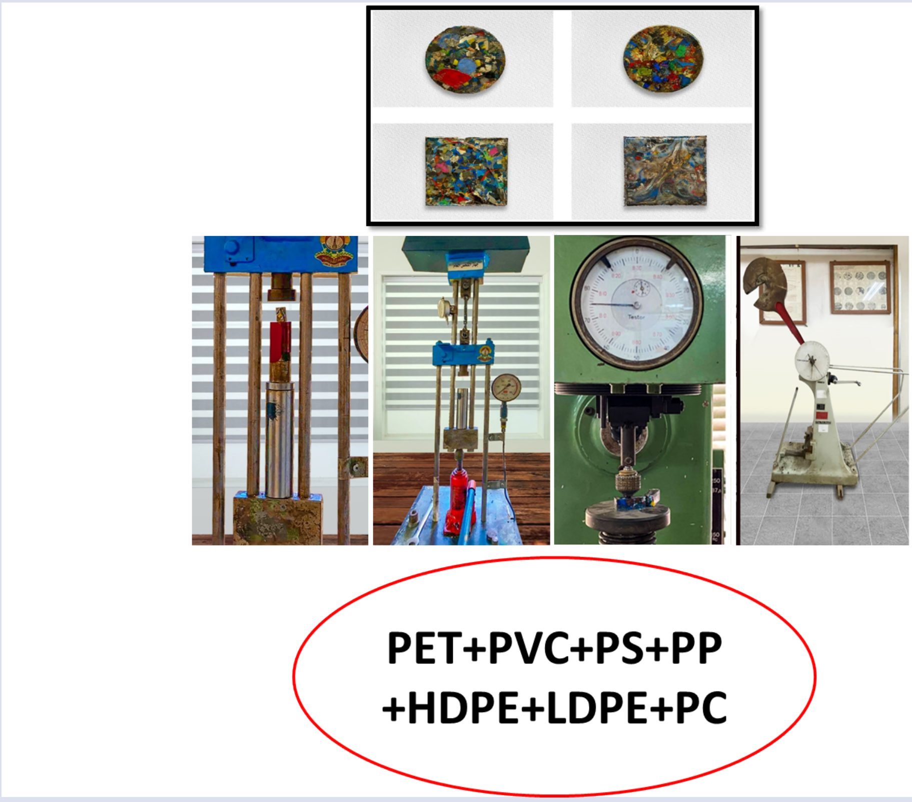
24. Yin S, Tuladhar R, Combe M, Collister T, Jacob M, Shanks R. Mechanical properties of recycled plastic fibres for reinforcing concrete. Fibre Concrete. 2013;1-10.

25. Hardikar A, Borhade O, Wagholikar S, Shivdeo A, Bhikule R. Comparative analysis of tiles made from recyclable LDPE plastic waste. IJERT. 2019;8(02).

26. Raguraman V, Shewale M, Korke P, Asalkar S, Shinde N, Deepasree S, *et al.* Utilization of plastic waste and ProsopisJuliflora Ash in making floor tiles. Materials Today: Proceedings. 2022;49:1658-63.

27. Montaño G, Cisneros JC, Heredia A. Thermal compression process for the recycling of composite materials.IJISET. 2016;3(1):434-7.

GRAPHICAL ABSTRACT



Cite this article: Ahmed AW, Jabrail FH. Composite Construction Tiles Manufactured from PET and Other Waste Plastics Reinforced with Polycarbonate and Study their Mechanical Properties. Pharmacogn J. 2024;16(2): 307-311.