المجلة العراقية
لبحوث السوق وحماية المستهلك

المجلد (10) العدد (2)
لسنة 2018

EFFECT OF PLASTIC WASTES AS LOW COST MATERIAL ON SOME PROPERTIES OF UNSATURATED POLYESTER.

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تاريخ استلام البحث: 2018/1/18 تاريخ قبول النشر: 2018/2/28

ABSTRACT:

In this study, plastic wastes named (PET and PVC) were used to prepare polymer matrix composite (PMC) which can be used in different applications. Composite materials were prepared by mixing unsaturated polyester resin (UP) with plastic wastes, two types of plastic waste were used in this work included polyethylene-terephthalate (PET) and Polyvinyl chloride (PVC) with various weight fractions (0, 5,10,15, 20 and 25%) added as a filler in flakes form. In this work, some of the tests that were carried out included (tensile, bending, and compressive strength) as mechanical tests, in addition to (thermal conductivity and water absorption) as physical tests. The values of tensile, compressive strength and Young's modulus of UP increased after the reinforcement with PVC or PET. Thermal insulation of the composites is significantly higher than that of pure UP. Although the values of water absorption for composite are higher than pure UP due to the existence of the interface between matrix and filler material. Also, the low cost of plastic wastes recycling encourage preserving the environment.

Keywords: Plastic Waste, polymer matrix composite (PMCs), Polyethylene-terephthalate (PET), Polyvinyl chloride (PVC).

تأثير المخلفات البلاستيكية كمادة واطئة الكلفة على بعض خصائص البولي استر غير المشبع.

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الخلاصة:

في هذه الدراسة تم استخدام مخلفات بلاستيكية نوع (PVC و PET) لتحضير مادة متراكبة ذات اساس بوليمري (PMC) التي يمكن استخدامها في عدة تطبيقات. و تم تحضير المادة المتراكبة عن طريق خلط البولي استر غير المشبع مع المخلفات البلاستيكية بنوعيها و التي كانت بنسب وزنية مختلفة (0، 5، 10، 20 و 25%) والتي اضيفت على شكل رقائق. وكانت الاختبارات التي تم اجراؤها في هذا البحث هي (اختبار الشد، الانحناء والانضغاطية) كإختبارات ميكانيكية، في حين تم ايضا اجراء اختبارات (التوصيل الحراري و امتصاصية المياه) كإختبارات فيزيائية. قيم الشد والانضغاط ومعامل يونك للـUP والتي ازدادت بعد تدعيمها بالـ(PVC و PET). العزل الحراري للمادة المتراكبة وازداد بشكل ملحوظ بعد مقارنة بالـUP النقي. وأرتفعت ايضا القيم الامتصاصية للمياه بسبب وجود السطح البيني بين المادة الاساس والمادة المدعم بها. ان هذا البحث يسهم في الحث على اعادة تدوير المواد البلاستيكية حفاظا على البيئة وبتكلفة قليلة.

الكلمات المفتاحية: مادة متراكبة ذات اساس بوليمري (PMCs)، بولي ايثيلين تريفثالات (PET)، بولي فينيل كلوريد (PVC).

INTRODUCTION:

Waste is now a universal problem. Plastics are made from petroleum which considered as finite resources, and huge progress have been done in plastic wastes recycling technologies. Mechanical recycling methods to make plastic products and feedstock recycling methods that use plastic as a raw material in the chemical industry have been widely adopted, and awareness has also grown recently of the importance of thermal recycling as a means of using plastics as an energy source to conserve petroleum resources, (**Richard *et al.*, 2009**).

The plastics of all types consumed every year are growing in a phenomenal way. The service industries, manufacturing processes and municipal solid wastes (MSW) generate abundant of waste plastic materials. The growing consciousness about the environment has extremely participated the attentions correlated to the disposal of plastic wastes. It is believed that the management of solid waste is the major environmental concerns on earth. Because of limited space on landfills and increasing costs of plastics, utilization of waste plastics has become an attractive alternative for disposal, (**Ahmed *et al.*, 2017**).

The largest amount of plastics is found in packaging and containers (i.e. bottles, packaging, cups etc.) The world yearly consumes of plastic materials raised from almost 5 million tons in the 1950's to about 100 million tons in 2001, (**Gaelle, 2015** ; **European Commission DG ENV, 2011**).

However, plastic waste might cause unfavorable externalities like ecological damage or greenhouse gas emissions. It is generally non-biodegradable which means that it remains in form of wastes for a very long time in the environment; it can impact danger for both environment and human health; in some cases, recycling and reusing may be hard. There is a mounting body of evidence which indicates that substantial quantities of plastic waste are now polluting marine and other, habitats. The widespread presence of these materials has resulted in numerous accounts of wildlife becoming entangled in plastic, leading to injury or impaired movement, in some cases resulting in death. Concerns have been raised regarding the effects of plastic ingestion as there is some evidence to indicate that toxic chemicals from plastics can accumulate, in living organisms and throughout nutrient chains. There is also some public health concerns arising from the use of plastics treated with chemicals, (**Subba *et al*., 2014** ; **Jacqueline *et al.*, 2017**).

Maja *et al.* (2008) investigated the mechanical recycling process of PET wastes consisted of some materials that needed to be taken care of. The procedure of compression moulding was chosen and mechanical properties were tested. Application of such materials was few because it was not uniform cross section and poor mechanical properties, furthermore research would be homogenized of the mixture, also using extrusion moulding instead of compression or by adding new material (e.g. polypropylene or polyethylene) to the mixture. Also it could be used in wide range of applications such as coasters, plant pots, stadiums seats, pencils stands and documents.

Djoko (2016) showed new implementation and packaging design of quality enhancement of plastic waste supporting the existence of material value conservation in real world. Huge implementations of design for recycling are required to maximize benefit of material value. When the advantages of materials are revealed and consumed through material value conservation, we will get more value from it in our life and decreasing the environmental issues.

This study aims to recycle the plastic waste to produce a new composite material with improved properties and can be used in different applications for example (precast, partitions, thermal and acoustic insulators).

EXPERIMENTAL WORK

Materials:

Three types of materials were used to prepare composite materials. The matrix is unsaturated polyester resin while the reinforcements included Polyethlene-trephthalate (PET) and polyvinyl chloride (PVC) respectively. Unsaturated polyester (UP) was used, supplied by Saudi Industrial Resins Limited Company (SIR) while Polyethlene-trephthalate (PET) was obtained from water bottles waste while Polyvinyl chloride (PVC) was achieved from sheet wastes. The density of Polyester resin is 1.37g/cm^3 while (PET) is 1.38 g/cm^3 and PVC is 1.35 g/cm^3. These types of wastes were used as reinforcement after the shredding process in flakes form.

Samples Preparation:

Composites were manufactured from unsaturated polyester resin with 2% of hardener then mixed homogenously with the flakes PET and PVC respectively after washing the waste and shredding it. Mould was made from glass with dimensions of (25*25*2.5) cm to prepare the casts. The outsides of mould were surrounded with silicon to prevent the leakage of resin from it. The reinforcements (PET and PVC) were cut in flakes form with thickness of (200) micron and approximate dimensions (0.8*0.4) mm. The composites were prepared with different weight fractions (5, 10, 15, 20 and 25 wt. %) of filler (PET or PVC) flakes. After mixing all the constituents for each type together the cast was put in the mould containing lubricant material to release inner sides of the composite easily and left them for 1 day in room temperature to complete the curing process. After fully solidification composites samples were cut according to ASTM and ISO specifications. After the cast being rejected from the mould, it was placed in oven (50 ˚C) for two hours in order to fully curation.

TEST PROCEDURE

Tensile Test:

The tensile test type “Larye Technologyco LTD” with model WDW_50 manufactured by Chinese company due to (ASTM D-638) Fig. (1). with (165 mm) length and (10mm) thickness in (Department of Applied Sciences/University of Technology).

Bending Test (3- Point test):

Bending machine type “PHYWE” made in Germany which used to calculate Young’s modulus of samples that were reinforced with recycled plastics as in Fig.(2), masses were added gradually and the deflection were calculated through the gauge , The Young's modulus was calculated from this equation: **(Mallick, 2014)**

$$E = \frac{MgL^3}{48Is} \text{ MPa……. (1)}$$

M: mass (gm)
g: 9.8 m/s^2
L: the distance between two supports (mm)
S: the deflection (mm)
I: geometrical bending moment (mm^4)

$$I = \frac{bd^3}{12} \text{ mm}^4\text{…….. (2)}$$

Compression Test:

Compression test carried out according to (ASTM D-695) using compression machine Type “Leybold Harris/ Germany”. The samples dimensions are (20 mm length, 10mm thickness and 10mm width) as in Fig.(3). The values of ultimate compressive strength (UCS) were determined from the (stress – strain) under compression load. This value represents the maximum stress at which the fracture of sample was happened.

Thermal Conductivity Test:

Lee’s disc device which was manufactured by England Company to determine the coefficient of thermal conductivity of Samples according to (ASTM D-7340) were cut in circular shape in order to test them as shown in Fig. (4)

The equation is: **(Mohapatra *et al.*, 2014)**

$IV = \pi r^{1}2\ e(T_1A + T_1B$) + 2 Tre[(T_A +T_B) + $d_bT_B + d_cT_c$] …….. (3)

Where:

(e): represents the amount of heat (heat energy) through unit area per second. (I) is the current value through the electrical circuit. (V) is the applied voltage For calculating the coefficient of thermal conductivity (K), the following equation is used: **(Mohapatra *et al.*, 2014)**

$^{F}((T_1B - T_1A)/d_1s)$ = e[$T_1A + 2/r\ \ (d_1A + (\ 1/4\ \ ds)\ )^{T_{A}+\frac{1}{2r}\mathbf{ds}}\ T_1B]$ …….. (4)

Where r: radius of sample (mm).

T: temperature of the three discs A, B and C (^{o}C).

$\mathbf{d}_A$: Thickness of disk A (mm).

$\mathbf{d}_B$: Thickness of disk B (mm).

$\mathbf{d}_C$: Thickness of disk C (mm).

Water Absorption Test:

Water absorption is use to determine the diffusivity of water through the specimens with dimensions of (10mm length, 10mm width and 10mm height) as in Fig. (5) after being immersed in water for more than 5 months and the weight was weekly measured (except for the first week where it was measured daily) and compared to the weight of the same sample before immersing.

The equations are, **(W.W.Wright, 1981), (Dewimille *et al.*, 1983)**

Weight Gain % = $\frac{\text{weight of wet specimen} - \text{weight of dry specimen}}{\text{weight of dry specimen}}$ ……………… (5)

Diffusivity = π $\left({kt}/{4Mm}\right)^{2}$ ……… (6)

k: is the slope of straight line of the curves

t: is the thickness of the specimen (mm)

Mm: is the apparent maximum water content

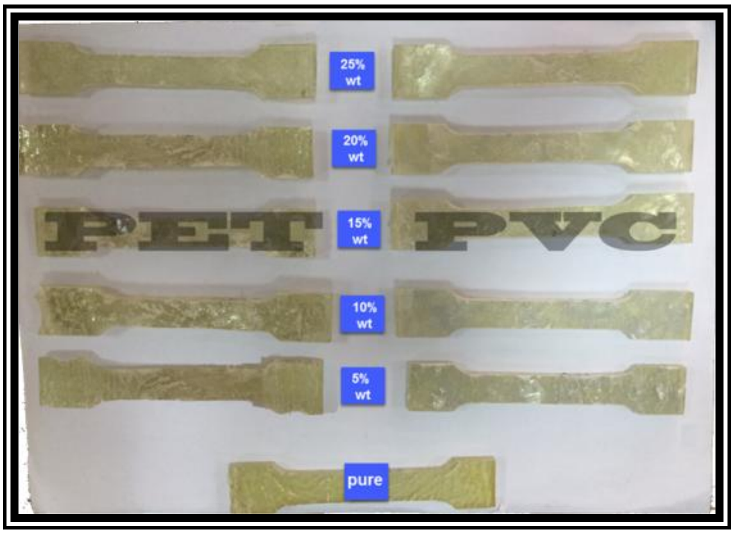

Fig. 1: Tensile test specimens.

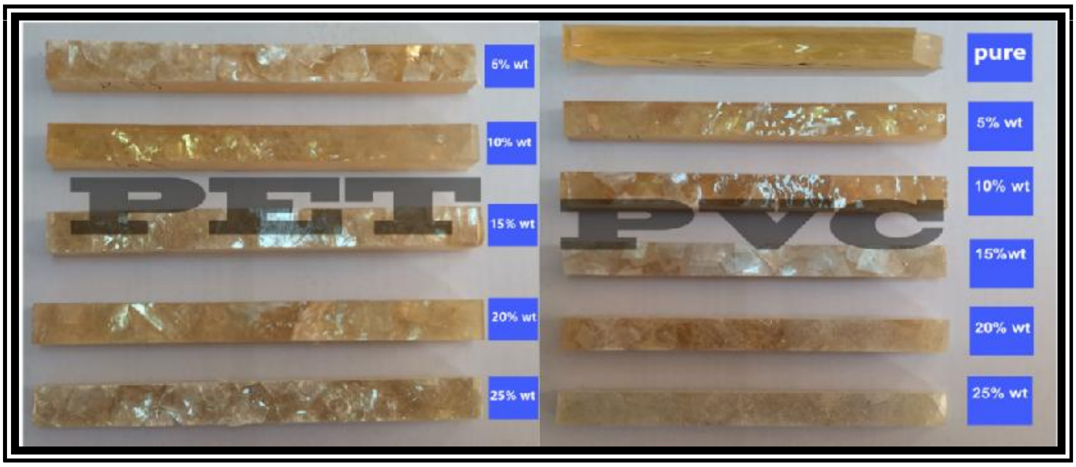

Fig. 2: Bending test specimens.

Fig. 3: Compression test specimens.

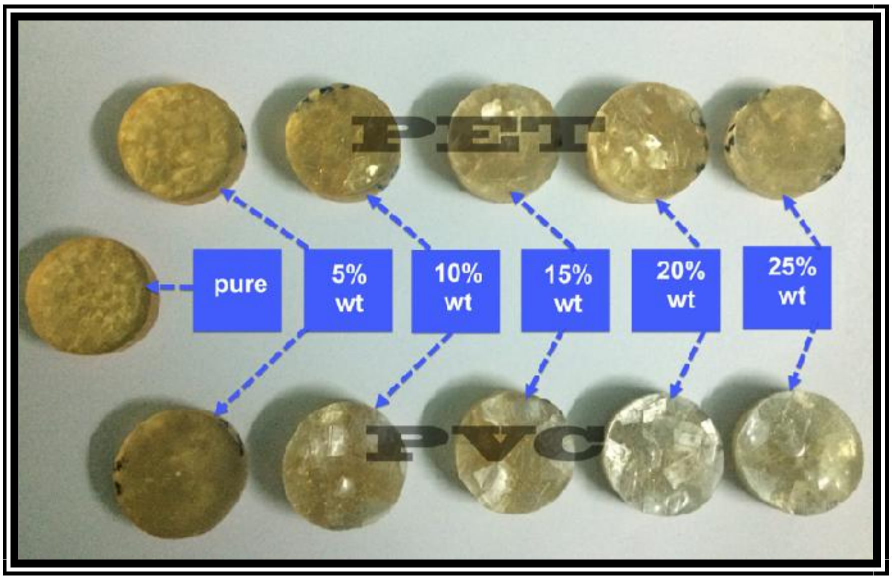

Fig. 4: Thermal conductivity test specimens.

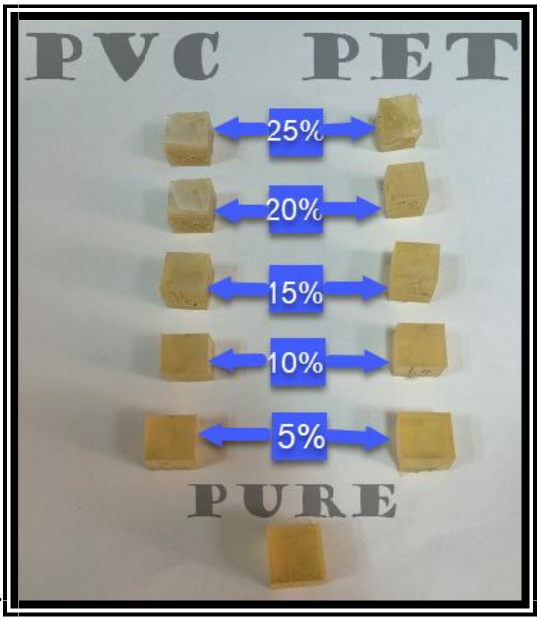

Fig. 5: Water absorption test specimens.

RESULTS AND DISCUSSION

Tensile Test:

Tensile test mean sample or object fitted between two grips then pulled out slowly till the sample breaks (Fig. 6) Demonstrates the relationship between the ultimate tensile strength (UTS) and weight ratio of the added wastes. It can be noticed that the values of UTS increased with increasing the weight fraction of waste because plastic wastes act as reinforcing phase within the composite and sustain the larger amount of applied force on the material. Also, it was found that PET /UP gave the higher values of UTS compared to PVC /UP. This behavior is due to PET has UTS higher than PVC. The increment ratio of UTS of the composites under work was (15%) compared the pure UP. (Table, 1) lists the values of UTS for these composites.

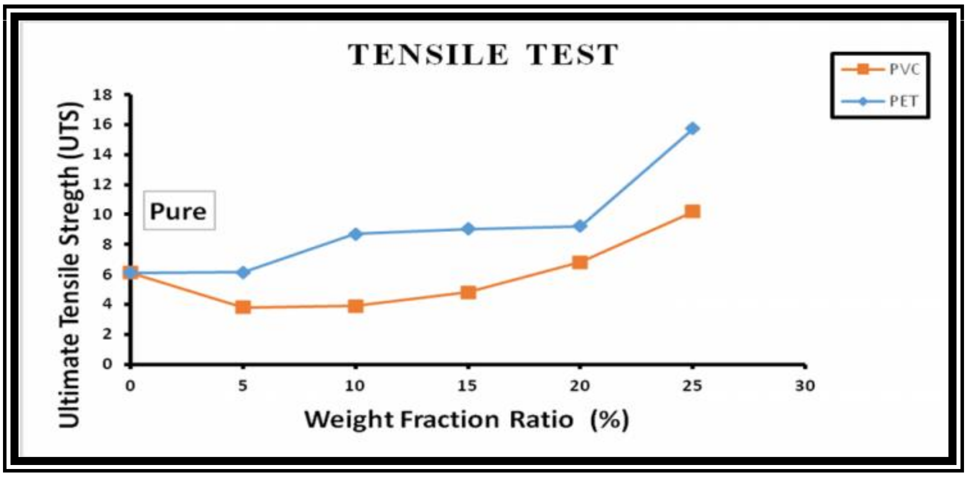

Fig. 6: Effect of weight ratio of the added waste on the UTS for PVC /UP and PET/UP composites.

Table 1: Values of ultimate tensile strength (UTS) for composites reinforced with (PVC) or (PET) flakes.

	UTS (MPa)	
wt.%	**PVC**	**PET**
Pure		**6.1**
5	**3.8**	**6.13**
10	**3.9**	**8.7**
15	**4.8**	**9.03**
20	**6.8**	**9.2**
25	**10.2**	**15.74**

Bending Test:

(Fig. 7 and 8) illustrate the relationship (mass-deflection) of each sample under test. It was found that the relation was proportional or semi linear because the material still within the elastic limit. From this curves, the slope was calculated according to Hook's law. (Table, 2) shows the effect of weight fraction of waste on the Young's modulus values (E). It is obvious that PVC/UP composite records higher value of E compared with PET /UP. This is due existence of PVC lead to increase E value where E equal to ~3.25 GPa while E of PET equal to ~2.35GPa.

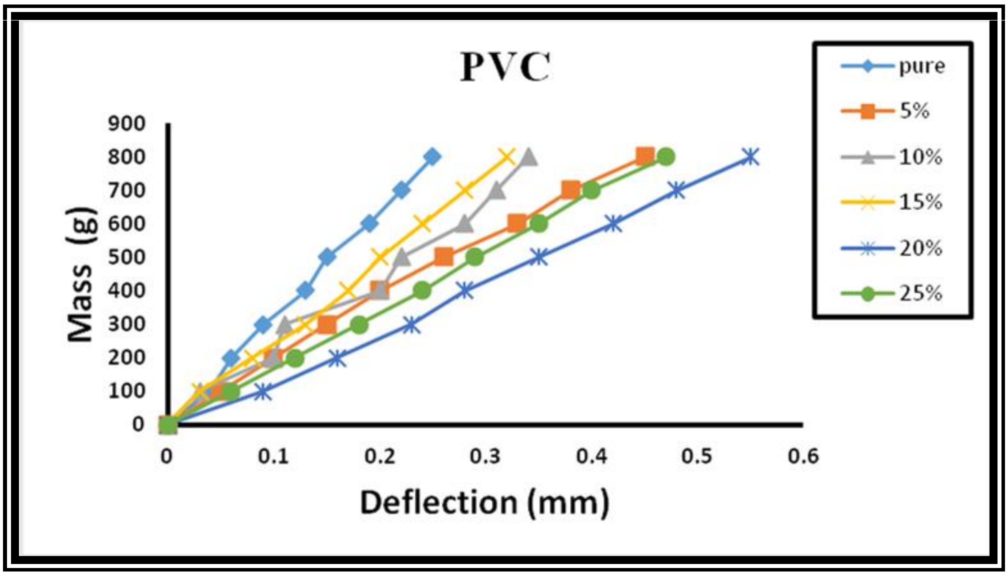

Fig. 7: Mass - Deflection curves for bending test of composite reinforced with (PVC) flakes.

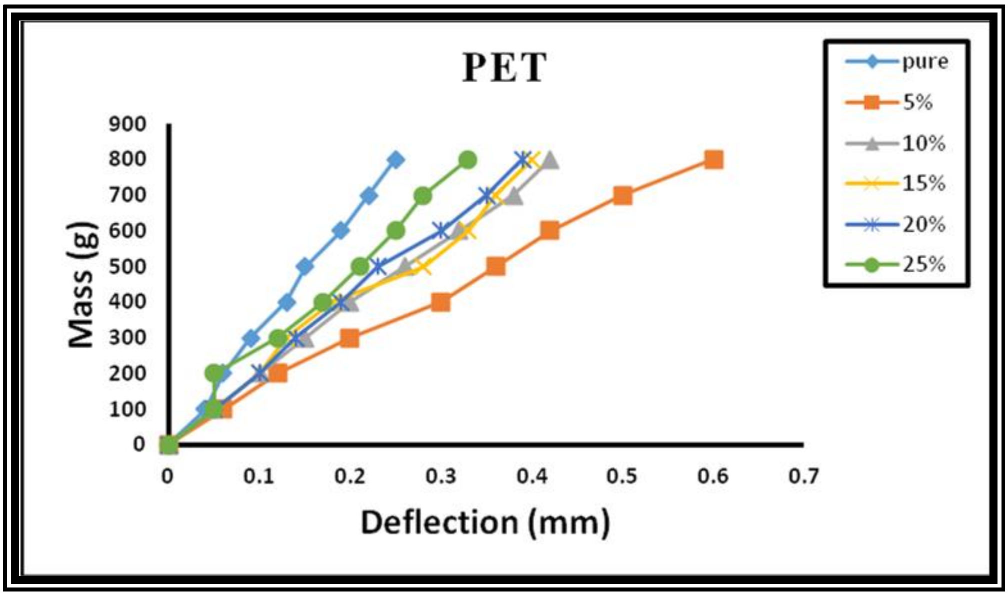

Fig. 8: Mass - Deflection curves for bending test of composite reinforced with (PET) flakes.

Table 2: Comparison between Young's modulus (E) for both composites.

	Young's modulus E(MPa)	
wt.%	PVC MPa	PET MPa
pure	**2284**	
5	**2703**	**2583**
10	**2666**	**2472**
15	**2017**	**2096**
20	**1962**	**1799**
25	**2427**	**1585**

Compressive Strength Test:

(Fig. 9 and 10) show the stress-strain curves of the two composites under work. It can be noticed that ultimate compressive strength of UP remarkably increased after reinforcing with PVC and PET because the (PVC and PET) have higher compressive strength then of the matrix material UP. (Table, 3) lists the values of ultimate compressive strength in compare to pure UP.

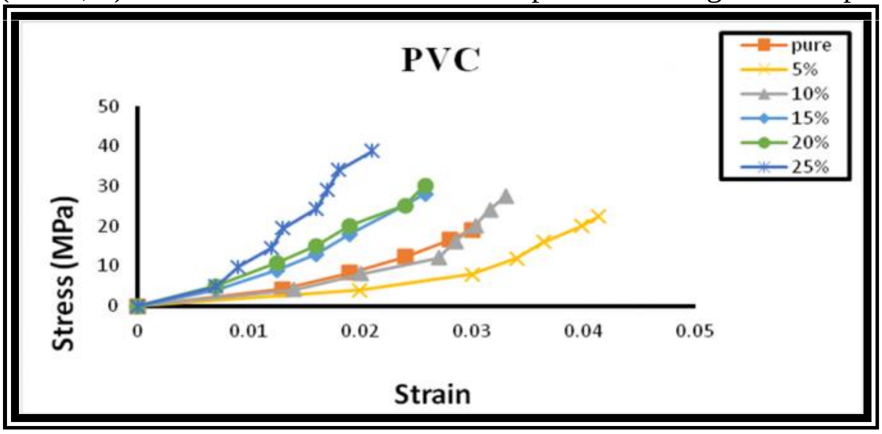

Fig. 9: Stress- strain curves of PVC /UP composite under compression load.

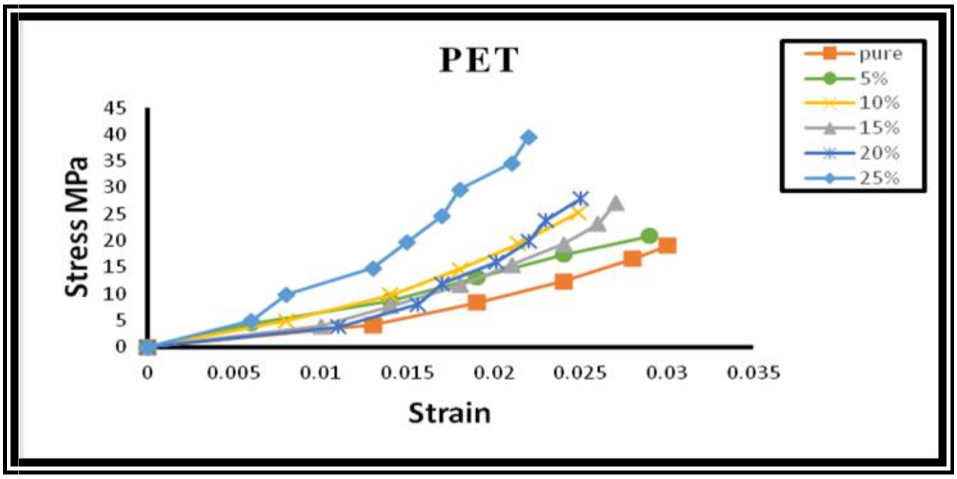

Fig. 10: Stress- strain curves of PET /UP composite under compression load.

Table 3: Values of ultimate compressive strength for composites reinforced with (PVC) or (PET) flakes.

	UCS (MPa)	
wt.%	**PVC**	**PET**
pure	**19.01**	
5	**22.302**	**20.868**
10	**25.151**	**25.305**
15	**28**	**27.026**
20	**30.228**	**27.81**
25	**38.86**	**39.509**

Thermal Conductivity Test:

(Fig. 11) illustrates the values of thermal conductivity of both types of composites under study. It is clear that the two types of wastes led to decrease these values. This means, it makes the composite further thermal insulation compared with pure UP because (PVC and PET) are much higher in thermal insulation than the UP. Although the little difference between the two composite, PET gave higher insulation compared to PVC.

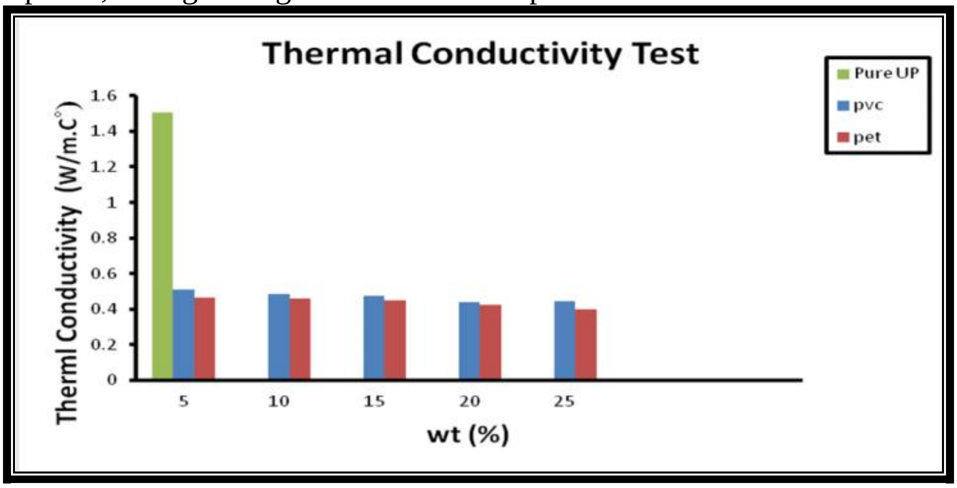

Fig. 11: Effect of weight fraction of added wastes on the thermal conductivity values of each sample under test.

Water Absorption Test:

This test gives primary idea about the ability of material under test to absorb some amounts of water when immersed in it. (Fig. 12 and 13) show the relationships between weight gains with square root of immersion time into water within sealed containers. It was found that water absorption values of the two composites were convergent; the difference between them was little. But if it compared with pure UP, it was obvious that their values are higher. This means that the second phase which added to the UP led to higher value of water absorption due to existence the interfaces between the matrix and interface acting as channels to penetrate little amounts of water inside it. (Table, 4) lists the values of diffusivity for both composites reinforced with PVC or PET. From this table, it is clear that the coefficient of diffusivity for (UP) is slower than its composites.

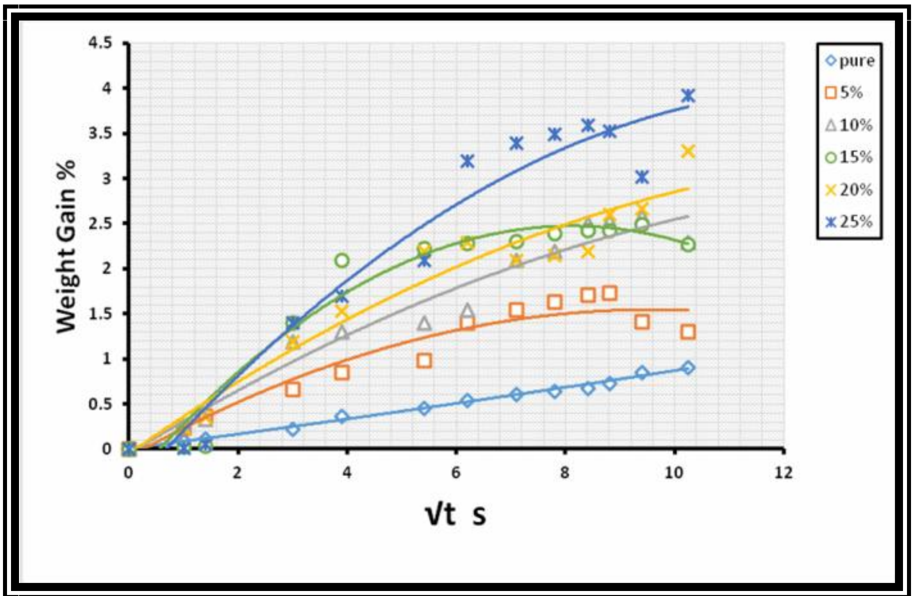

Fig. 12: Weight gain with √t of immersion time into water for PVC/UP composite.

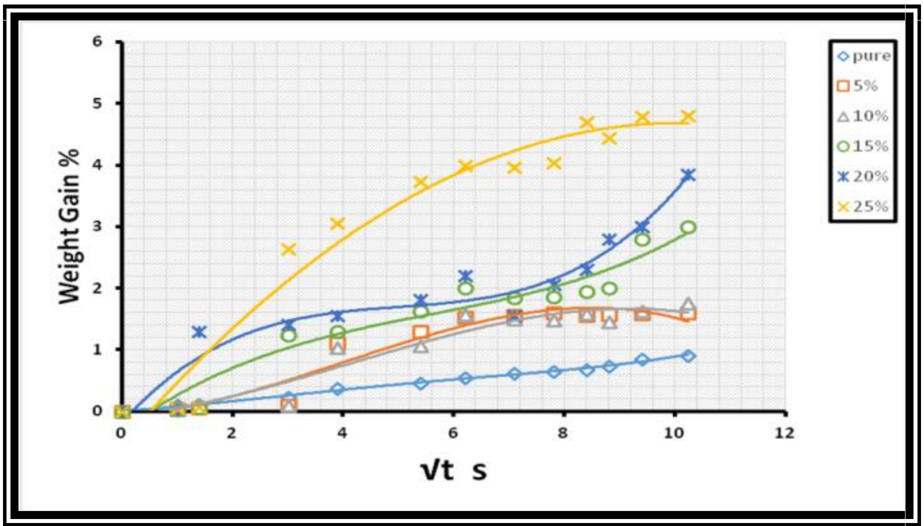

Fig. 13: Weight gain with √t of immersion time into water for PET/UP composite.

Table 4: The diffusivity coefficient (m^2/s) of the composites reinforced with (PVC, PET) flakes.

wt.%	PVC	PET
Pure	$0.12*10^{-12}$	
5	$1.95*10^{-12}$	$1.28*10^{-12}$
10	$2.27*10^{-12}$	$1.88*10^{-12}$
15	$2.51*10^{-12}$	$2.57*10^{-12}$
20	$2.8*10^{-12}$	$2.7*10^{-12}$
25	$2.5*10^{-12}$	$3.22*10^{-12}$

CONCLUSIONS

1. It can be noticed that the values of UTS increased with increasing the weight fraction of waste because of the added waste acting as reinforcing phase, PET/UP gave the higher values of UTS compared to PVC/UP.
2. In bending test, it was found that the relation was proportional or semi linear because the material was still within the elastic limit.
3. It can be noticed that ultimate compressive strength increased of UP after the reinforcement with PVC or PET.
4. In thermal conductivity test, the composite has more thermal insulation compared with pure UP but usually PET gave higher insulation compared to PVC.
5. It was found that water absorption values were convergent to prepared composites, the difference between them were little. But if it was compared with pure UP, it was obvious that their values were higher.

REFERENCES

I. Richard, C. T., Charles, J. M., Frederick, S. V. & Shanna, H. S. (2009). Plastics, the environment and human health: current consensus and future trends. *Philos. Trans. R. Soc. Lond. B. Biol. Sci.*, 364: 2153-2166.

II. Ahmad, F., Razali, A. R. & Rscienceazelan, I. S. M. (2017). Utilization of polyethylene terephthalate (PET) in asphalt pavement: A review. *IOP Publishing Ltd*, 203: 899-1757.

III. Gaelle, G. (2015). Global Plastic Production Rises, *Recycling Lags*. Worldwatch Institute, 1-5.

IV. European Commission DG ENV. (2011). *Plastic Waste in The Environment*, 2011. 07.0307/2009/545281/ETU/G2.

V. Reddy, M. S., Reddy, P. S., Subbaiah, G. V. & Subbaiah, H.,V. (2014). Effect of Plastic Pollution on Environment", Department of Chemistry, S.B.V.R.Aided Degree College. *Journal of Chemical and Pharmaceutical Sciences*, Special Issue, ISSN: 0974-2115.

VI. Jacqueline, E. R. & Emília, W. R. (2017). Recycling in Brasil: Paper and Plastic Supply Chain. *MDPI journal*, 6(3):43-52.

VII. Maja, R., Mladen, Š. & Pilipović A. (2008). *Pet Bottles Recycling Waste-UtilIzation and Properties*. 12th International Research/ Expert Conference, TMT, Turkey, 605-608.

VIII. Djoko, S. G. (2016). *How to Increase Plastic Waste Acceptance for Mechanical Recycling*: An Introduction to Material Value Conservation and its Phenomenon, 705: 362-367.

IX. Mallick, P. K. (2007). *Fibers Reinforced Composites* (3rd ed., PP. 94-99). Taylor & Francis Group, Michigan.

X. Mohapatra, R. Ch., Mishra, A. & Choudhury, B. B. (2014). *Investigations On Thermal Conductivity Of Palm Fiber Reinforced Polyester Composites*, Government College of Engineering, Keonjhar, India, 11(1): 48-52.

XI. Wright, W. W. (1981). The Effect of diffusion of water into epoxy resins and their carbon-fibre reinforced composites. *Composites*, 12(3): 201-205.

XII. Dewimille, B. & Bunsell, A. R. (1983). Accelerated ageing of a glass fibre-reinforced epoxy resin in water. *Composites*, 14(1): 35-40.