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Tensile characterization of polymer composite reinforced with gravel particles (GP)

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خصائص الشد لمتراكب بوليمري مدعم بدقائق الحصى

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المستخلص

تم في هذا البحث تحضير مواد متراكبة ذات اساس بوليمري بطريقة الصب اليدوي (Hand lay-up) وقد حضرت المواد المتراكبة من راتنج البولي استر غير المشبع كمادة اساس مدعمة بدقائق الحصى ذات الحجم الحبيبي (121.74 nm) كمجموعة اولى من العينات (نوع I) ومجموعة ثانية (نوع II) من العينات مدعمة بدقائق الحصى ذات الحجم الحبيبي (100.16 nm) .

تضمن البحث دراسة تاثير الكسر الوزني المختار %(0,10,20,30,40) لدقائق الحصى على خصائص المواد المتراكبة المحضرة ، وقد تم اجراء اختبار الشد لهذه المتراكبات .

اظهرت نتائج البحث ان قيمة متانة الشد تزداد مع زيادة الكسر الوزني لدقائق االحصى ولكلا عينات المجموعتين كما وبينت النتائج ان قيم متانة الشد هي اعلى للمواد المتراكبة المدعمة بدقائق الحصى نوع II عن قيم نظيراتها المدعمة بدقائق الحصى نوع I. حيث بينت النتائج ان قيمة متانة الشد للبولي استر قد ازدادت عند نسبة الإضافة 10% وكانت 25.45 MPa لدقائق الحصى النوع I ولكنها تناقصت عند نسب الإضافة 20%, 30%, 40% .كذلك بينت النتائج ان قيم متانة الشد للبولي استر قد تناقصت عند اضافة دقائق الحصى من النوع II عند نسب الاضافة 10%,20%, 30% ولكنها ازدادت عند نسبة الاضافة 40%. كذلك بينت النتائج ان قيم معامل يونك للبولي استر قد ازدادت عند نسب الاضافة 10%, 30%, 40% ولكلا النوعين من دقائق الحصى.

Abstract

The work focuses on the preparation of polymer matrix composite materials prepared from the unsaturated polyester resin UPE as a matrix reinforced by gravel particles with particle size (121.74 nm) as first group type-I GPI of samples and the second group type-II GPII of samples reinforced by gravel particles with particle size (100.16 nm) . This work includes studying the effect of selected weight fractions (0%, 10%, 20%, 30%, and 40%) of gravel particles on the properties of the prepared composite materials, tensile test were done.

The results of the present work showed that the values of tensile strength of pure UPE (24.66MPa) was increasing by additional of GPI at weight percentage 10% and however, it gained 25.45 MPa, but decreased at weight percentage (20%, 30%, and 40%) (21.21, 20.98 and 23.87 MPa) respectively. Also the results showed the tensile strength of pure UPE had decreased by additional of GPII at weight percentage (10%, 20%, and 30%) (19.67, 23.31 and 23.12 MPa) respectively, but increasing at weight percentage 40% and gained 27.84MPa. Beside the result shows that the values of tensile strength for composite materials reinforced by GPII is higher than values reinforced by GPI.

Also the results showed the Young Modulus of pure UPE increased with the addition of 10 %, 30% and 40 % of two types GPI and GPII fillers. Where the samples of UPE \ GPI composites have a highest value of Young's Modulus at ratio percent 40% as compared with other composites samples.

Keywords: Gravel Particles, Unsaturated Polyester Resin, and Composite Materials.

Introduction

Many of our technologies require materials with unusual combinations of properties that cannot be met by the conventional metal alloys, ceramics, and polymeric materials. This is especially true for materials that are needed for aerospace, underwater and transportation application. For example, air craft engineers are increasingly searching for structural materials that have low densities, strong, stiff, abrasion and impact resistant, and are not easily corroded [1].

Generally speaking, a composite is considered to be any multiphase material that exhibits a significant proportion of the properties of both constituent phases such that a better combination of properties is realized.

The constituent phases must be chemically dissimilar and separated by a distinct interface.

Most composites have been created to improve combinations of mechanical characteristics such as stiffness, toughness, and ambient and high – temperature strength. [1]

Composites are usually manufactured in order to provide materials which possess mechanical properties superior to those of the individual constituents. [2]

Aggregate is the component of a composite material that resists compressive stress and provides bulk to the composite material. For efficient filling, aggregate should be much smaller than the finished item, but have a wide variety of sizes. For example, the particles of stone used to make concrete typically include both sand and gravel. [3]

Composites typically use thermoset resins which, begin as liquid polymers and are converted to solids during the molding process. This process, known as cross linking, so that the composite materials have chemical resistance, higher mechanical properties and greater structural durability than thermoplastics. [4]

The aim of this work is to:-

1. Fabrication of UPE / gravel composites.
2. Evaluation of mechanical properties of the composites.
3. Prepare material composite important in industrial applications such as waste water pipes.

Materials and Methods:

(A) Raw materials

The materials used to prepare the composites are unsaturated polyester (UPE) resin type (A-50) with the hardener MEKP and with accelerator cobalt naphthenate (having a symbol SIR SIROPOL) which was supplied from Saudi industrial resin and two different types of fine gravel powder were used in this research as follow:

1- Gravel particles type GPI (take from badra quarry/ Wasit-Iraq) with particles size of (121.74 nm), which measured by AFM test, it used in this work as a filler materials shown in Fig. (1-a) and Fig.(2-a)
2- Gravel particles type GPII (take from Ali Alghrbi quarry / Misan-Iraq) with particles size of (100.16 nm) which measured by AFM test, it used used in this work as a filler materials shown in Fig. (1-b) and Fig.(2-b).

The compositions of these materials are shown in the table (1).

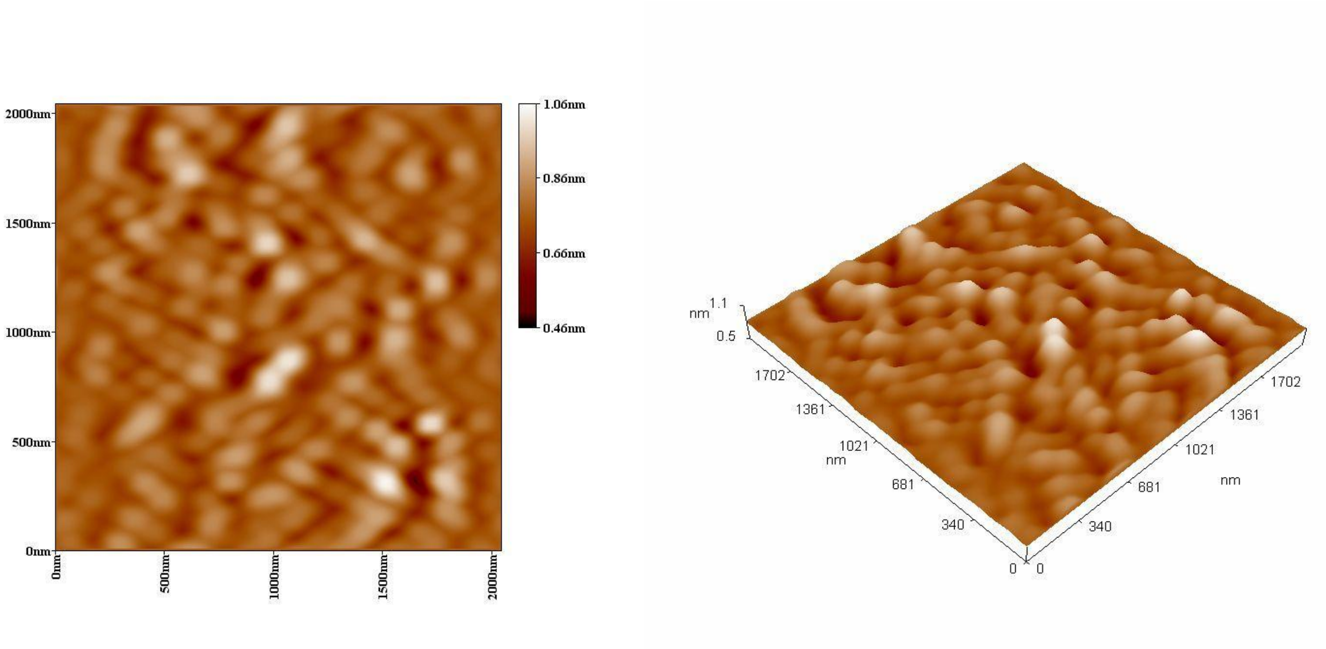
Table (1): Chemical composition for the two types of gravel particles (GPI, GPII)

Type of Gravel	Components %									
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	MnO	Pb_2O_3	Cu_2O
GPI	29.0	0.32	6.96	23.24	1.91	0.44	0.49	0.11	0.018	0.004
GPII	0.96	0.14	2.16	53.67	0.84	0.006	0.006	0.019	0.013	-

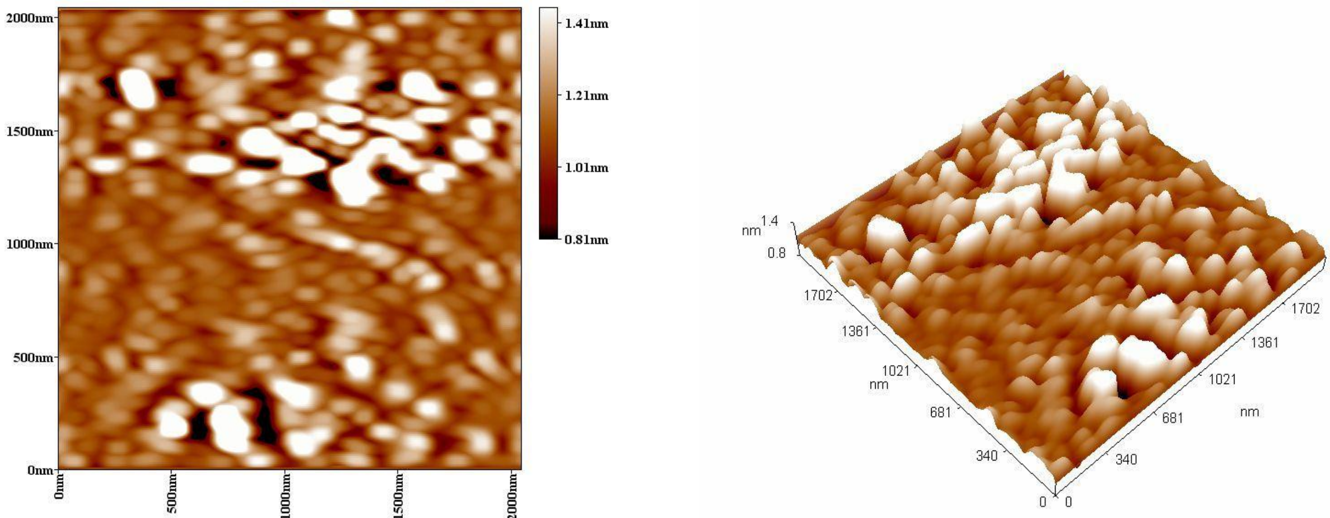

(a) (b)

Figure (1) (a) Photograph shows grave particles GPI.

(b) Photograph shows gravel particles GPII.



(a)



(b)

Figure (2):(a) Scanning probe microscope SPM imager surface roughness analysis of gravel particles GPI

(b)Scanning probe microscope SPM imager surface roughness analysis of gravel particles GPII

(B) Composites preparation

The composites were prepared from unsaturated polyester resin (as a matrix) and the two different types of gravel particles (as a particles fillers) with different weight percentages of 10%,20%,30% and 40% by molding method which can be summarized by the following steps:

1. Determine the weight of gravel particles by using a sensitive balance (four digits).
2. Determine the weight of resin and its hardener.
3. Mix the content thoroughly in a clean disposable container by a fan type stirrer for 15 min. before casting it as sheets (of dimensions 200 mm× 150 mm ×6 mm) by using glass mould.
4. Leave the composite at room temperature about 24 hours and then for post-curing, the sheets were left for 2 hours in an oven at temperature 60˚C.

(C) Samples test cutting

The sheets of the composites are cutting into specimens, by using a circular iron saw, pluses from the samples were removed by using the iron rasp, the samples were polished by using abrasive emery papers of grade 400.The shape and dimension of the samples cut for tensile test according to [ASTM-D638-84] shown at figure 3 and Figure 4.

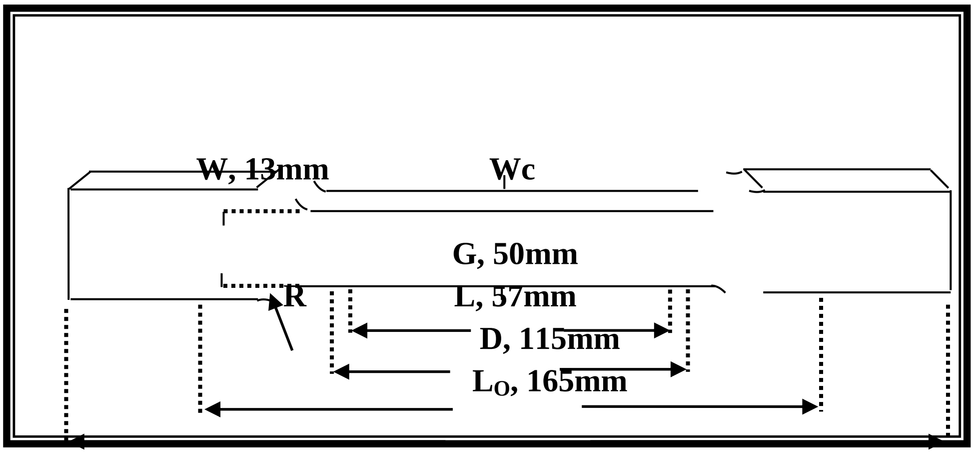
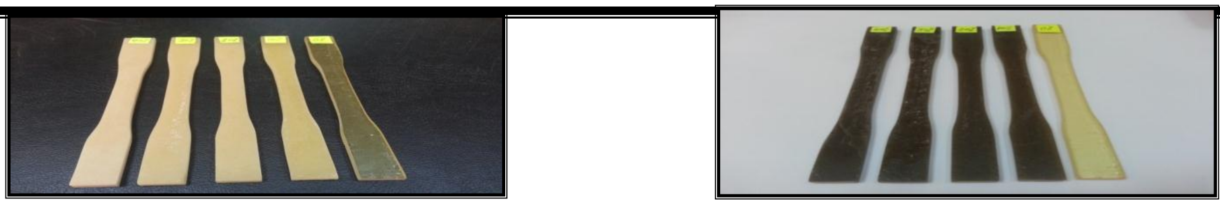


Figure (3): Dimensions of Tensile Test Specimens [ASTM-D638-84].[5]



(a) (b)

Figure 4: Photograph of Tensile Test Specimens before testing.
(a) Pure polyester and polyester/gravel composites GPI samples.
(b) Pure polyester and polyester/gravel composites GPII samples.

Tensile test

Tensile testing is one of the more basic tests to determine stress – strain relationship. A simple uniaxial test consists of slowly pulling a sample of material in tension until it breaks. Test specimens for tensile testing are generally either circular or rectangular with larger ends to facilitate gripping the sample (ASTM D-638 for plastics). Tensile characteristics are the most widely reported mechanical properties of any material. Tensile strength is the maximum load that the sample will carry before breaking under a slowly applied gradually increasing load during a tensile test [6].

The typical testing procedure is to deform or "stretch" the material at a constant speed. The required load that must be applied to achieve this displacement will vary as the test proceeds. A typical set of load-Extension curves are shown in Figures 5-7. During testing, the stress in the sample can be calculated at any time by dividing the load over the cross-sectional area $\sigma = P/A$. The displacement in the sample can be measured at any section where the cross-sectional area is constant and the strain calculated by taking this change in length and dividing it by the original or initial length $\varepsilon = \Delta L/L_0$. Engineering material properties that can be found from simple tensile testing include the elastic modulus (modulus of elasticity or Young's modulus), Poisson's ratio, ultimate tensile strength (tensile strength), yield strength, fracture strength, resilience, toughness, reduction in area, and elongations. These values are typically calculated in tension experimentation and compared to published values [6,7].

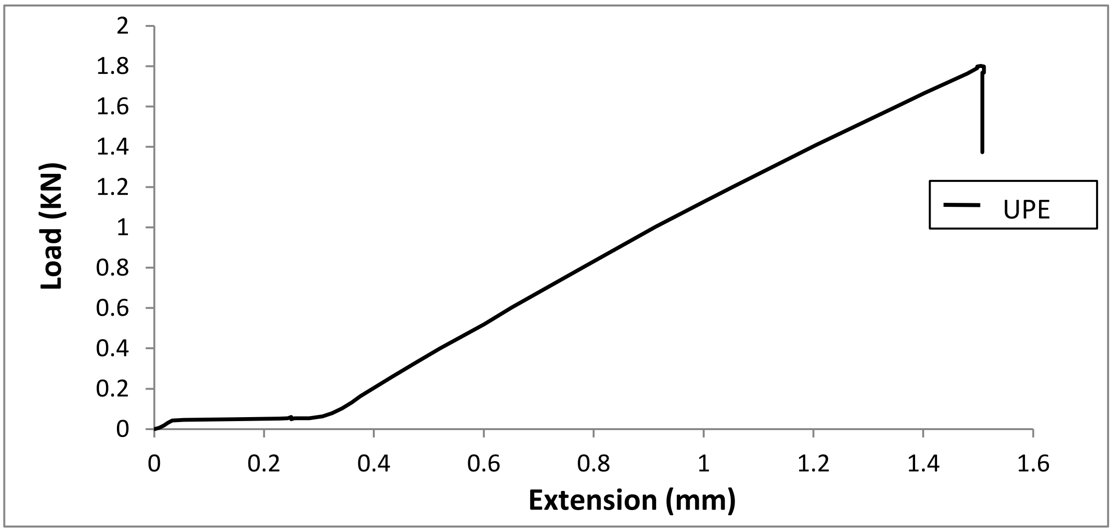


Figure 5: Load - Extension curve for unsaturated polyester resin UPE.

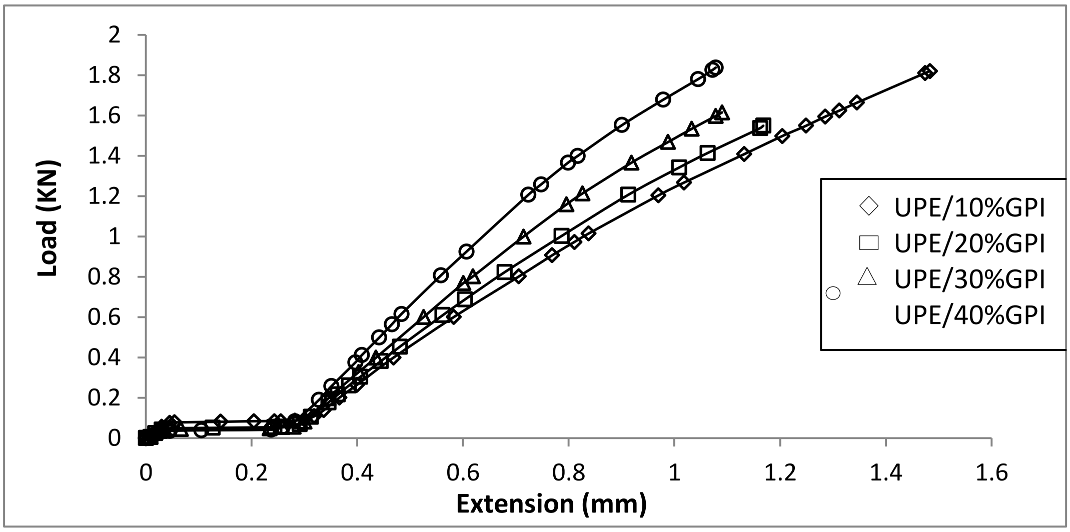


Figure (6): Load - Extension curves for gravel particles GPI and UPE composites.

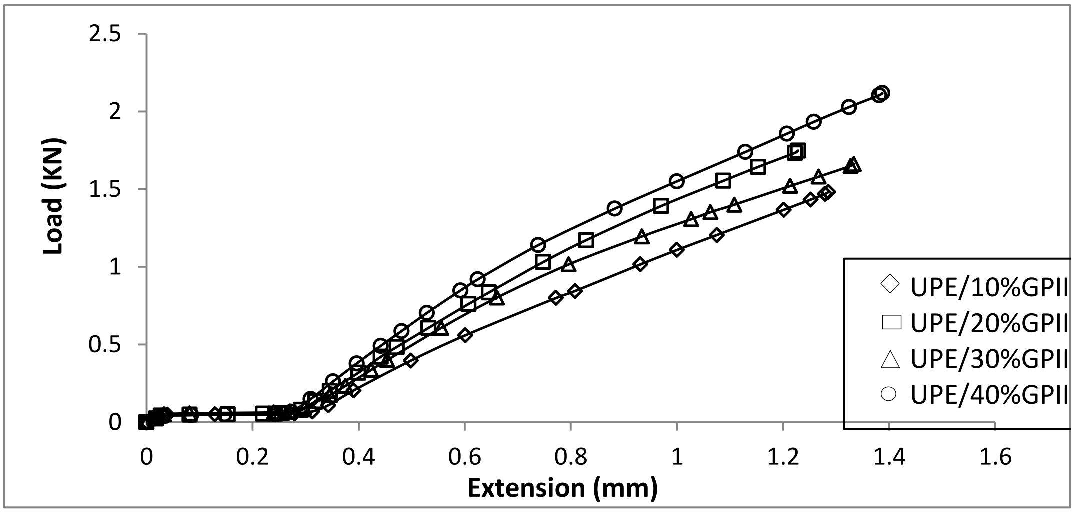


Figure (7): Load - Extension curves for gravel particles GPII and UPE composites.

Results and Discussion

The stress-strain curve of polyester resin UPE is shown at figure 8.The curve shows two regions, elastic and plastic regions. In elastic region (below yield point A), its linear relationship. This means that the molecules slip pass each other normally to a small extent. At yield point (A) the material deforms permanently into sponge structure and numerous micro voids formed in plane normal to the stress forming a craze [4]. Tensile strength of pure UPE (24.66MPa) was increasing by additional of GPI at weight percentage 10% and gained 25.45 MPa, but decreased at weight percentage 20%, 30%, and 40% (21.21, 20.98 and 23.87 MPa) respectively as showing in table 2 and figure 9. Also the results showed the tensile strength of pure UPE was decreased by additional of GPII at weight percentage 10%, 20%, and 30% (19.67, 23.31 and 23.12 MPa) respectively, but increasing at weight percentage 40% and

gained 27.84MPa as showing in table 2 and figure 10. The decreasing of tensile strength can be attributed to the physical properties of this filler and interaction of this filler with the UPE matrix [8].
Also the results show that the samples of UPE / GPII composite gained highest values of tensile strength (27.84MPa) at ratio percent 40% compared with the samples of UPE / GPI composite (25.45 MPa).
According of the table 3 the Young Modulus of pure UPE increased with the addition of 10 % of GPI. This trend still remains when the GPI filler was increased from 20% to 40 %. The samples of GPI composite gained highest values of Young Modulus (1.86 GPa) at ratio percent 40% as showing in table 3. The relative stiffness of a material is indicated by its modulus. It is well known that the incorporation of filler imparts greater stiffness to be composite. The incorporation of gravel nanoparticle has improved the stiffness of the UPE matrix, since the tensile modulus of the composites increased as particle filler loading was increased [8]. Figure 11 is the photographic images showing the fracture surface for pure UPE sample and UPE/ (GPI, GPII) composites samples they can be seen zigzag path of crack.

In the same table, it is shown that the samples of UPE \ GPII composites have a highest value of Young's Modulus (1.56 GPa) at ratio percent 40%.

Also the results shown that the samples of UPE \ GPI composites have a highest value of Young's Modulus (1.86 GPa) at ratio percent 40% as compared with other composites samples.

Table (2): The effect of gravel content (wt. %) on the tensile strength of (UPE/gravel particle GPI, GPII) composites.

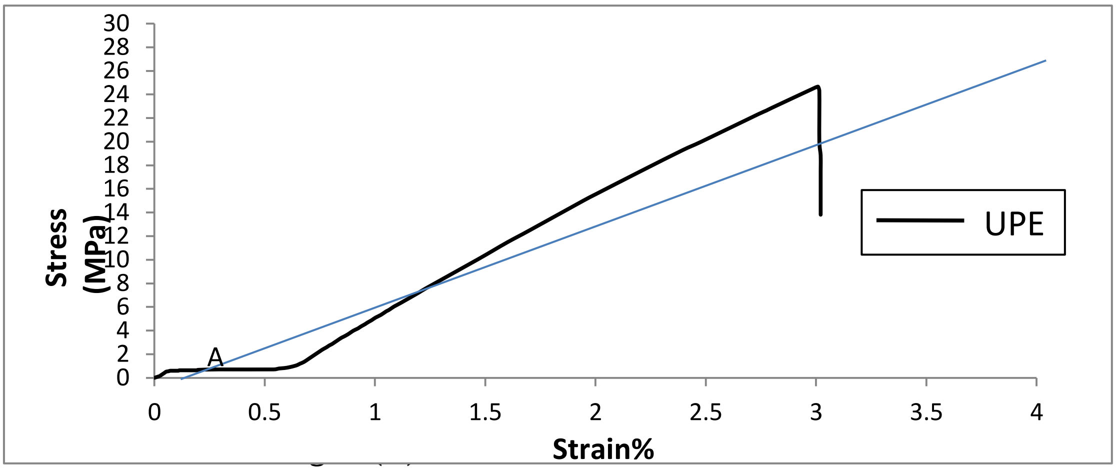
Composition	**Tensile Strength (MPa)**			
	Gravel particles content (wt. %)			
	10%	20%	30%	40%
UPE/ GPI	25.45	21.21	20.98	23.87
UPE/GPII	19.67	23.31	23.12	27.84

Tensile Strength $_{UPE}$ = 24.66 MPa

Table (3): The effect of gravel content (wt. %) on the Young's modulus of (UPE/ gravel particle GPI, GPII) composites.

Composition	Young's Modulus E (GPa)			
	Gravel particles content (wt. %)			
	10%	20%	30%	40%
UPE/ GPI	1.31	1.57	1.38	1.86
UPE/ GPII	1.05	1.51	1.22	1.56

Young's modulus $_{UPE}$ = 1.18 GPa



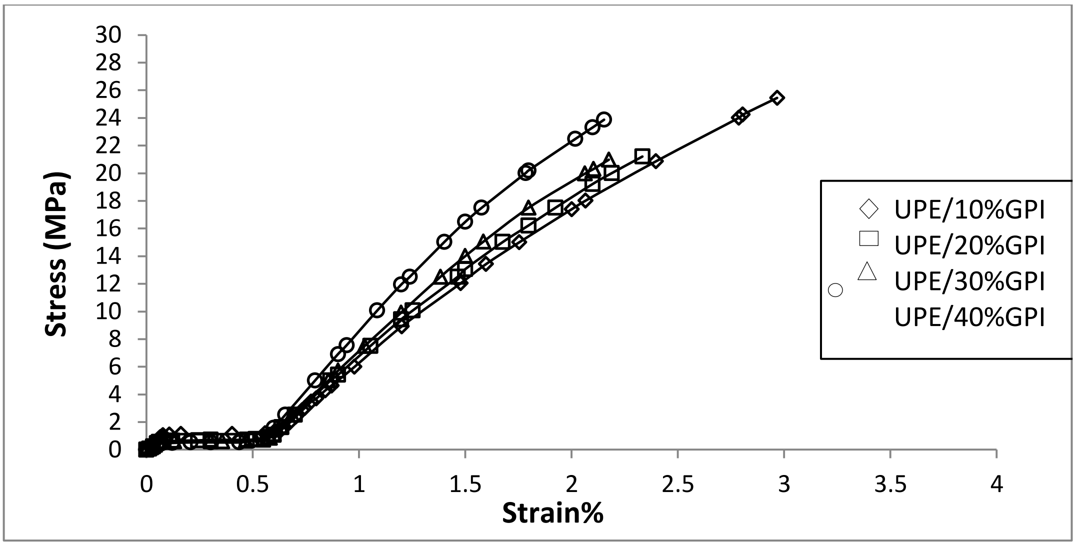


Figure (9): Stress - Strain curves for gravel particles GPI and UPE composites.

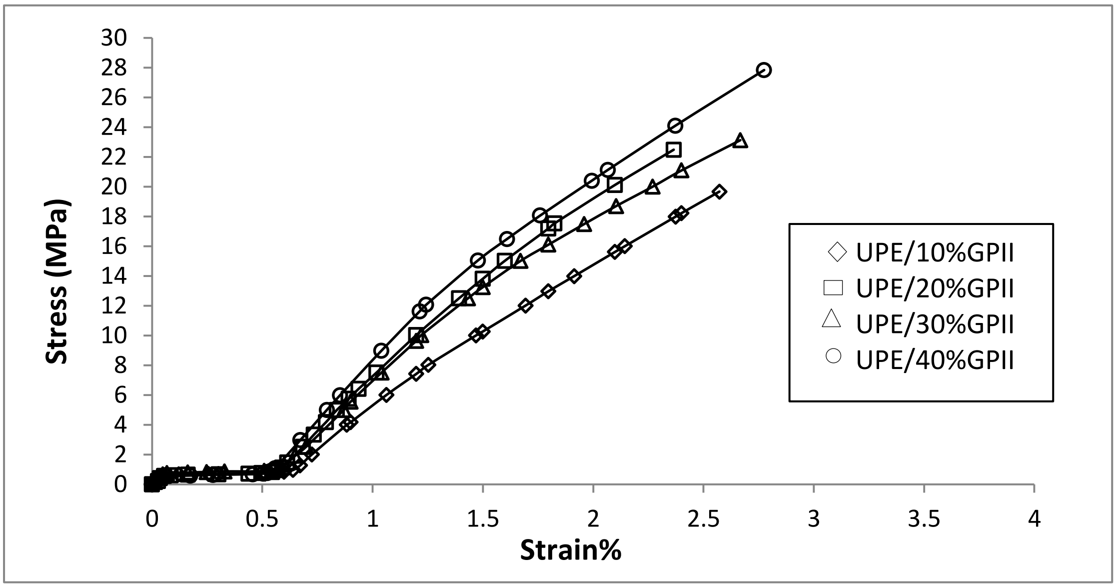
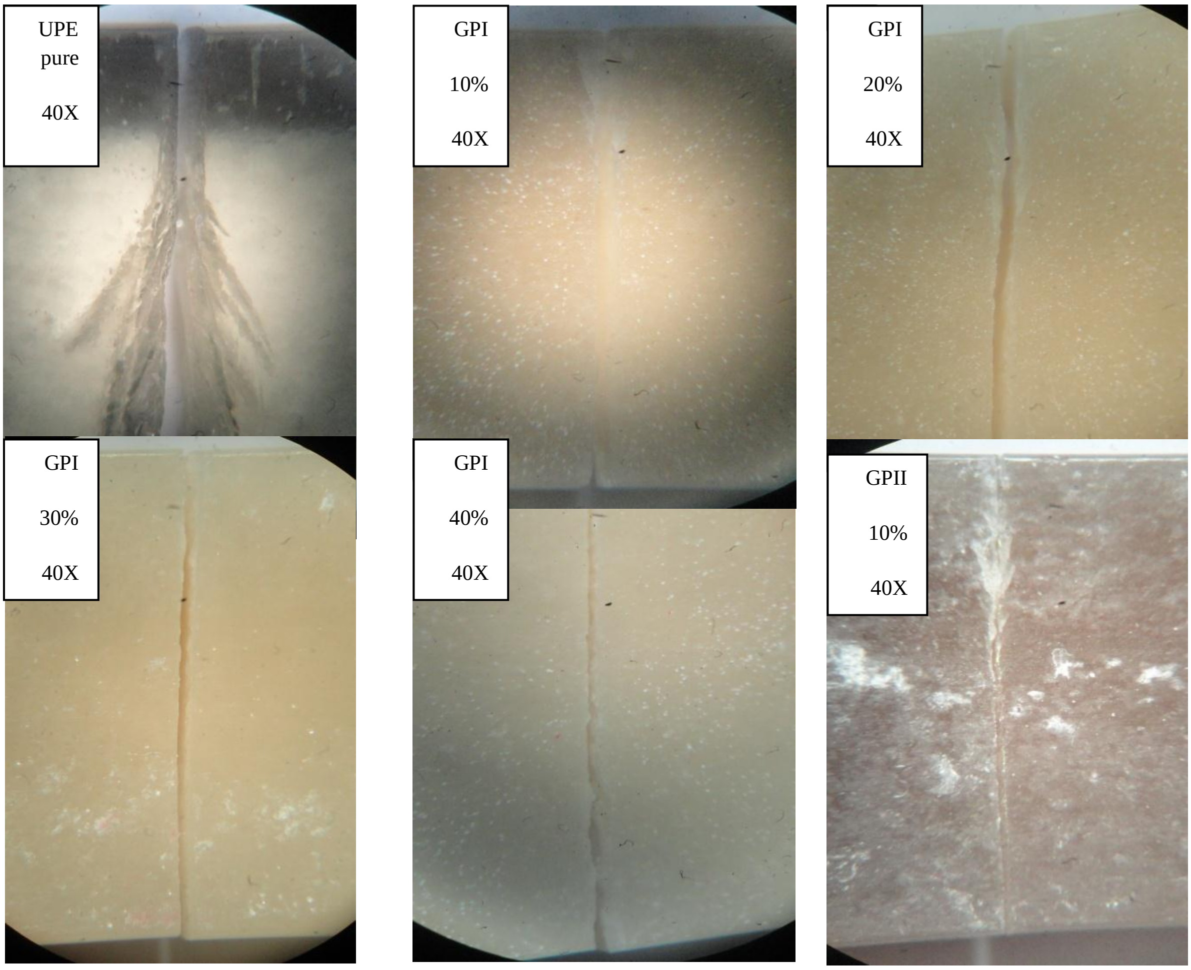


Figure (10): Stress - Strain curves for gravel particles GPII and UPE composites.



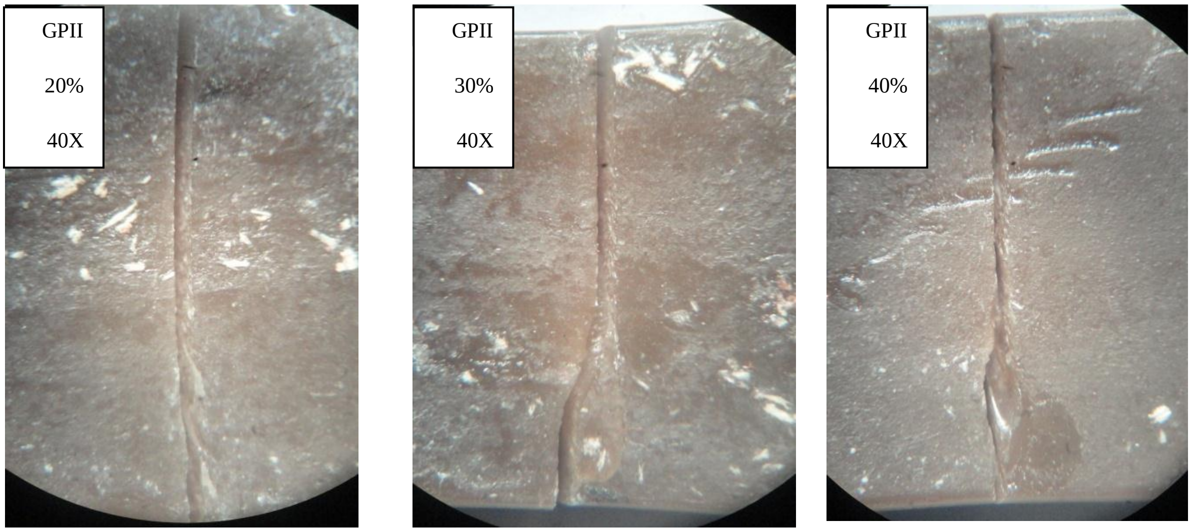


Figure (11): photographic images show the fracture region for pure UPE sample and UPE/(GPI, GPII) composites samples.

Conclusions

This experimental investigation of mechanical behaviour of gravels particles as fillers filled polyester composites leads to the following conclusions:

- The polyester resin is a good adhesive material which can use as a matrix with gravel particles.
- The above experimental results indicate that this gravel particle may be a good filler material for polymer composite materials.
- We can produce a composite hard, strong by use small particle size of gravel as fillers.

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