

# The Effect Of The Hybrid Additions on the Bending and Tensile Behavior for the Hybrid Composite Material Reinforced by Short Fibers and the Zeolite Particles by Multifarious Grain Size

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## Abstract

Consider polymers and polymer matrix composite are the basis of the most prevalent material in all industrial and medical fields because of its properties qualify to occupy an advanced position among other engineering materials because of its good properties .

Therefore, This work focuses on the preparation of base polymer matrix composite materials and study non-saturated polyester as matrix has been strengthened by zeolite particles different grain sizes (25 - 65 - 75)  $\mu\text{m}$  and different volume fractions (1,5 - 3 - 4,5 - 6 - 7,5 - 10) % was strengthened by Carbon short fibers and constant volume fraction (8%),the tests tensile and bending according to ASTM specifications, respectively. Through the results it was observed that the maximum tensile strength improved through hybrid reinforcement when reached the maximum value when the grain size (25  $\mu\text{m}$  ) and at volume fraction (7.5%), reaching ( 94  $\text{N/mm}^2$  ) compared with the rest of sizes and at the same volume fraction reaching (78  $\text{N/mm}^2$  for 65  $\mu\text{m}$  , 69  $\text{N/mm}^2$  for 75  $\mu\text{m}$ ), As for the bending test has been getting maximum Flexural resistance at grain size (25  $\mu\text{m}$ ) at volume fraction ( 6%) reached to(111  $\text{N/mm}^2$ ),if compared with the rest of sizes at the same volume fraction reaching (100  $\text{N/mm}^2$  for 65  $\mu\text{m}$ ,79  $\text{N/mm}^2$  for 75  $\mu\text{m}$ ) while was obtained on the maximum bending modulus at grain size (25  $\mu\text{m}$ ) and at volume fraction (10%) reach to (8099  $\text{N/mm}^2$ ) if compared with the rest of sizes at the same volume fraction reaching (7466  $\text{N/mm}^2$  for 65  $\mu\text{m}$ , 6666  $\text{N/mm}^2$  for 75  $\mu\text{m}$  ). Through the results we note that for the particle size and fiber effect in improving the mechanical behavior of the composite material prepared .

**Keywords:** non-saturated Polyester - matrix composite, Mechanical properties of composites.

## 1.Introduction

The use of polymer composites has become increasingly important. Polymer-based composite materials have been used extensively in a variety of construction, rehabilitation and repair applications such as bridges, pipelines and other

types of constructions. Particularly, filled polymer composites are preferred in making machine tool bodies because of their low cost and their advantages such as chemical resistance, low weight, easy manufacturing and vibration absorption [1].

Structures that are manufactured using cheap filling materials like sand and gravel display brittle characteristics. In order to compensate for this disadvantage, these structures are strengthened with different reinforcement materials so that better mechanical properties can be achieved [2].

Unsaturated polyesters are extremely versatile in properties and applications and have been a popular thermoset used as the polymer matrix in composites. They are widely produced industrially as they possess many advantages compared to other thermosetting resins including room temperature cure capability, good mechanical properties and transparency [1,2].

Curing of unsaturated polyester is due to polymerization reaction that causes crosslinking among individual linear polymer chains. In contrast to other thermosetting resins, no by-product is formed during the curing reaction

Hence resins can be moulded, cast and laminated at low pressures and temperatures. The natural fiber reinforced composites are reasonably strong, lightweight, and free from health hazards, biodegradable and hence they have the potential to be used as building materials[1,3]. Despite the advantages listed above, they suffer from some limitations such as lower modulus, poor moisture resistance especially absorption and low strength compared with synthetic fibers such as glass and carbon [2 ].

The Short fiber reinforced polymer matrix composites are one of the major methods of producing modified polymer materials. The mechanical properties as well as reinforcing and toughening of short fiber reinforced polymer composites have been extensively studied in the past two decades [1,4]. These short fibers include natural fibers such as

wood flour, kenaf fiber, barley husk, cellulosic fibers abaca fiber, cordenka and flax, soy protein isolate and ramie fiber, as well as inorganic fibers such as glass fiber and carbon fiber [4].

Studied short fiber reinforced polymer composites and discussed the fracture based theory of fiber reinforcement. the bending and Tensile strength is one of the important properties of solid materials for practical applications. For polymer composites, the factors affecting the tensile strength are complicated, such as the nature of the matrix and filler, the compatibility between them, materials processing technology and conditions, the dispersion or distribution of the filler in the matrix, as well as the interfacial structure and morphology, etc. [2,3,4].

The following is a review of different uses of the polyurethane in polymer matrix composites.

The Researcher (M.A. de Farias, et.al. in 2008) had studied the polyester matrix composites, this work was to investigate the effect of bi-dimensional orientation of leaf stalk fibers from peach palm in impact, tensile strength behavior and water absorption profile of (polyester/fiber and polyester/powder) reinforced composites . better results than the composites with both weave and powder, indicating that oriented fibers give better mechanical

properties than randomly oriented fibers. The Izod impact data obtained for the composites with only weave were considerably superior to that of composites containing only powder, suggesting that the reinforcement in the form of powder is inefficient [5].

Researcher (M. Ahmadi, et.al, 2012) reinforced unsaturated polyester (UP) resin by using an organically-modified montmorillonite (OMMT) and toughened with poly(n-butyl acrylate)/ poly(vinyl acetate-co-methyl methacrylate) core-shell rubber (CSR) particles. The results showed that the incorporation of OMMT of up to 3 wt.% increased the UP fracture toughness (KIC) to some extent, while further addition caused the fracture toughness to reach a constant level. Furthermore, the dispersion state of OMMT platelets and CSR particles inside the UP matrix was studied by means of transmission electron microscopy (TEM). On the other hand, addition of 5 and 10 wt.% CSR particles to the UP increased the fracture toughness much more than the OMMT. The incorporation of OMMT increased Young's modulus and also decreased

the tensile strength of the neat and CSR toughened UP specimens with increasing the amount of OMMT [6].

Researcher (Yoldas Seki, et.al, 2012) the huntite mineral used as reinforcement for unsaturated polyester. Tensile and flexural strengths of polyester were obtained to increase until the huntite content of 3% into unsaturated polyester. When 3% huntite was added to the unsaturated polyester, maximum decomposition temperature of polyester increased from 383 C to 398 C. Differential scanning calorimetry (DSC) analyses of polyester and huntite reinforced polyester composites show a well-cured composite [7]. Researcher (Maries Idicula , et.al, 2005). determined The dynamic and static mechanical properties of randomly oriented intimately mixed short banana/sisal hybrid fiber reinforced polyester composites. Dynamic properties such as the storage modulus (E0), damping behavior (tand) and static mechanical properties such as tensile, flexural and impact properties were investigated as a function of total fiber

Volume fraction and the relative volume fraction of the two fibers. Keeping the relative volume fraction of banana and sisal (1:1), the volume fraction of the fiber was optimized. The storage modulus was found to increase with fiber volume fraction above glass transition temperature (Tg) of the matrix and maximum value was obtained at a volume fraction (Vf) of 0.40. The tand peak height was minimum and peak width was maximum at 0.40Vf. Tensile modulus and flexural strength were found to be the highest at 0.40 volume fraction, which indicates effective stress transfer between the fiber and matrix. Sisal/polyester composite showed maximum damping behavior and highest impact strength as compared to banana/polyester as well as hybrid composites. However, maximum stress transfer between the fibre and matrix was obtained in composites having volume ratio of banana and sisal as 3:1, which has lowest tand value and highest E0 value at Tg. The tensile strength and flexural modulus were also the maximum and impact strength was the minimum at this volume ratio [8]. researcher (Abdullah A. Kafi, et.al, 2011). evaluated the performance of jute reinforced polyester bio-composites cured with an out of autoclave curing process. The mode I fracture toughness (GIc), flexural, and thermomechanical properties of the composites were measured for cure cycle times of 5, 30, 60 and 90 min at an optimum cure temperature of 95 C, and were compared to a reference composite laminate cured at room temperature. A balance in properties was obtained after 30 min of cure where an improvement in thermo-mechanical and fracture properties was observed, but on the other hand, was accompanied by a decrease in flexural

strength and modulus compared to the reference sample. Shorter (i.e. 5 min) and longer cure cycle times (above 30 min) used by the Quickstep were found to be detrimental to the properties of the resulting composites [9]. Researcher (M. Uzun, et.al, 2011). utilized and evaluate the mechanical properties of the chicken feather quill and fiber reinforced vinylester and polyester composites. Findings: It was found that the impact properties of the CFF reinforced composites are significantly better than the control composites however both the tensile and the flexural properties of the CFF reinforced composites have poorer values compared to the control composites. For the 10% CFF reinforced vinylester composite, Charpy impact value was 4.42 kgj/mm<sup>2</sup> which was 25% higher than the control vinylester composites (3.31 kgj/mm<sup>2</sup>) and also for the 10% CFF reinforced polyester (4.56 kgj/mm<sup>2</sup>) composite had three times better impact resistance than the control composite (1.85 kgj/mm<sup>2</sup>). The CFF reinforced composite have potential applications due to its improved impact behavior [10].

**2. Experimental Work:**

**2.1. Mould Preparation.**

The required moulds for preparing the tensile and bending specimens for tests were made from glass with dimensions of (250×200×5) mm. The mould was coated with transparency film on the base while the internal walls were covered with fablon to avoid sticking between cast material and the mould.

**2.2 Preparation Specimens.**

The masses of the filler material zeolite. were calculated according to the required weight fractions of the filler materials which were (1.5, 3, 4.5, 6, 7.5,10) Vf%. of polymer resin, except for carbon short fiber that be 8%Vf fixed with all fillers. The masses of the resin (unsaturated polyester) were calculated according to the required volume of cast, the accelerator and the hardener, were added as weight % with an amount of (0.5%) and (2 %) respectively. The filler of (zeolite) and the polyester were mixed for about 20 minute at room temperature continuously and slowly to avoid bubbling during mixing, and then the hardener was added to the mixture with gentle mixing, The mixture was poured from one corner into the mould (to avoid bubble formation which

causes cast damage) and the uniform pouring is continued until the mould is filled to the required level. The mould was placed on an electrical vibrator to remove any residual bubbles,

The mixture was left in the mould for (24) hrs. at room temperature to solidify. and to relieve residual stresses. The specimens were cut according to the standard dimensions for each test, Three samples were prepared for each test.the tensile test is performed according to (ASTM D638M- 87b) at room temperature ,the bending test is performed according to (ASTM D790) at room temperature, As shown in table (1). use three samples for each volume fraction and to each test.

The maximum flexural strength in this test can be calculated by the following equation:-

$$\sigma_f (N/m^2) = 3PL/(2bh^2)$$

Where:

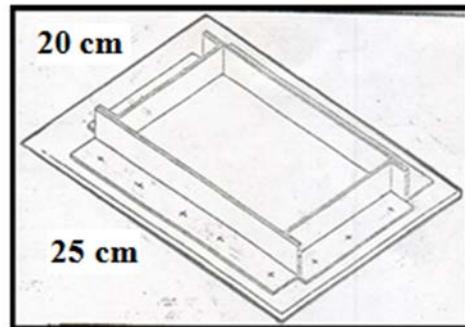
- P: the load at fracture (N).
- L: Length of specimen (m).
- h: Thickness of specimen (m).
- b: Width of specimen (m).

The flexural modulus in this test can be calculated by the following equation:-

$$E_f = (mgL^3)/48I\delta$$

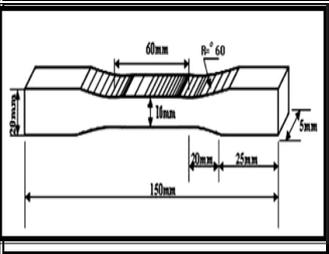
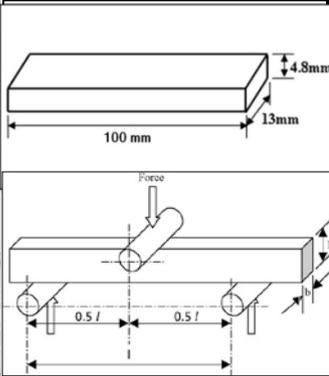
Where

- E<sub>f</sub> : flexural modulus
- m: mass of applied load (Kg)
- g: acceleration (9.81 m/s<sup>2</sup>)
- L: Length of specimen (mm).
- δ: deflection of applied load (mm)
- I: moment of inertia (mm<sup>4</sup>)



**Figure 1:** The shape of the prepared Mould

Table (1)

device Type	standard specificaton	device Picture	Specimens Picture	Test Type	n
Tinius olsen Tensile Test machine	ASTM D638M-87b			Tensile Test	1
Tinius olsen bending Test machine. Three point Test	ASTM D790			bending Test	2

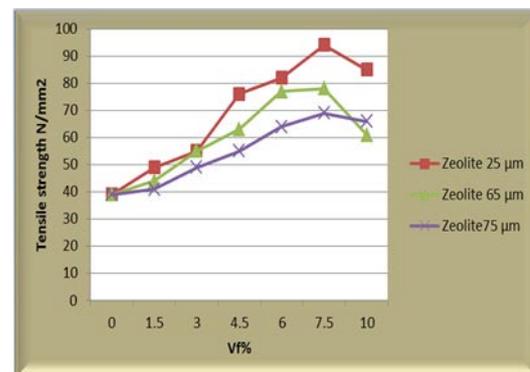
**3.Results and Discussion:**

**3.1Tensile Test.**

Figure (1) shows the relationship between the tensile strength and the volume fraction of the filler particles of (zeolite) which were added to the unsaturated polyester resin, respectively It's obvious that the grain size of (25µm) filler particles has a noticeable effect on the tensile strength more than the grain size (65,75) µ, and the maximum tensile strength of (25 µm reaches 94.573 N/mm<sup>2</sup> at 7.5% wt) and (78.117 N/mm<sup>2</sup> at 7.5% vf for 65 µm) and (69.218 N/mm<sup>2</sup> at 7.5% vf for 75 µ) compared to the tensile strength of the reference which is equal to (39.388 N/mm<sup>2</sup>).Also the specimen exhibits lower tensile strength after 7.5 vf % this may be due to filler particles have defects during fabrication (Such as sharp edges and internal and external cracks in the same grain and impurities), when it is added to unsaturated polyester resin, that lead to formation of high viscose mixture (viscosity directly increase with increased volume fraction) that lead to decrease resin wettability in turn affected in resultant mechanical properties of composite[11]. This decrease in strength may be due to non-wetting of the filler particles with the matrix and may be due to the non-uniform distribution of the particles [12-13 ] as a result of excessive particles that were not well dispersed in the polymer creating stress concentrations in the polymer matrix and decrease the tensile strength [14 ]. This means volume fraction 7.5% represent

critical volume fraction, beyond which the strength decreases with increase in filler content.

It is observed that, the (25 µ) specimens exhibit upper tensile as the filler content increases in the unsaturated resin. This may be due to the rigidity and toughness of the composite increased with increase in content of (25 µm) filler particles in the composite and may be due to little particle size [15 ].

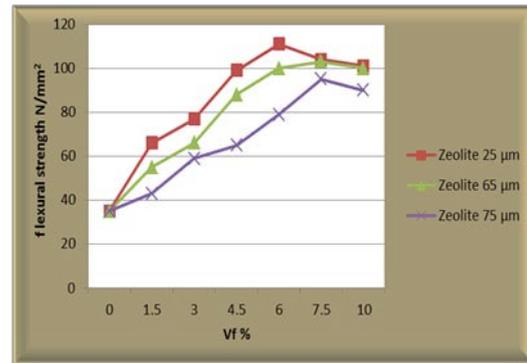


**Figure 1:** shows the relationship between the the tensile strength and the volume fraction of the filler particles of ((65,75 and 25) µm from ( zeolite).

**3.2 Bending test.**

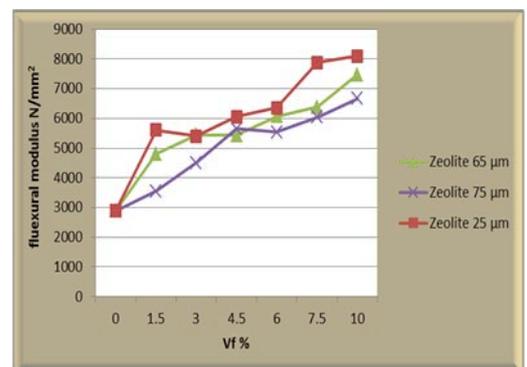
Figure (2) shows the relationship between the bending strength (Flexural Strength) and the volume fraction of the filler particles of ((65,75 and 25)  $\mu\text{m}$  from) zeolite) powder, which were added to the unsaturated polyester resin, respectively. The results had revealed that the maximum amount of bending strength (111.916  $\text{N/mm}^2$  at 6 vf % of 25 $\mu\text{m}$ ); (103.899  $\text{N/mm}^2$  at 7.5 vf % of 65 $\mu\text{m}$ ); (95.997  $\text{N/mm}^2$  at 7.5 vf % of 75 $\mu\text{m}$ ); compared to the bending strength of the reference which is equal to (35.373  $\text{N/mm}^2$ ). The increase in bending strength may be also due to the elastic modulus of the filler material compared with that of the matrix material. The decrease in the bending strength after adding (7.5 vf %) zeolite fillers can be related to the decrease in the wettability that was mentioned before, especially the bending strength largely depends on the bonding force between the matrix and the filler material(interaction) and may be due to the no uniform distribution of the particles. The non-observed improvement in bending strength when 25 $\mu\text{m}$  was added, may due to the high viscose mixture (viscosity increases directly with volume fraction) that lead to decreased resin wettability in turn affecting resultant mechanical properties of composite. The composite material containing 25 $\mu\text{m}$  filler

particles has shown a greater bending strength than the other filler particles. The properties of bending usually depend on the nature of the bonding between the filler and the matrix materials. The effect for grain size zeolite on the strength of bending have been observed through use of zeolite sizes small particulate range ( 25  $\mu\text{m}$ ) and volume fraction (6%) led to increase in strength of bending and compared with the values of samples which supported of zeolite at like volume fraction (6%) and sizes particulate large range (65  $\mu\text{m}$  and 75  $\mu\text{m}$ ) This is due to the use of minutes zeolite small sizes will facilitate foundation material for strengthening material thereby increasing the contact area between the components of prepared composite material and then increase the bonding strength between them and in the end increase the susceptibility on external stresses applied[16] . This is because the use of large size reduce the vulnerability and decrease of wetting of the composite material and increase the creation of defects and Glades aerobic and thus reduce the affordability composite material foreign loads at high powder loading, it is more difficult for the resin to penetrate the decreasing spaces between the fibers, leading to poor wetting, and hence, a reduction in the stress transfer efficiency across the zeolite-fiber-resin interface[17].



**Figure 2:** shows the relationship between the bending strength (Flexural Strength) and the volume fraction of the filler particles of ((65,75 and 25)  $\mu\text{m}$  from( zeolite).

Figure (3) illustrates the bending modulus that increases with increasing volume fraction of (25,65 and 75)  $\mu\text{m}$  zeolite filler particles, and reaches its maximum amount (8099.847 of 25 $\mu\text{m}$  ; 7466.659 for 65 $\mu\text{m}$  ; 6666.489 of 75 $\mu\text{m}$ )  $\text{N/mm}^2$  at addition volume fraction of 10% vf. compared to the bending modulus of the reference which is equal to (2880.698  $\text{N/mm}^2$ ). The increase in bending modulus may be also due to the high elastic modulus of the filler material compared with that of the matrix material [14-15 ].In addition, the short fibers give extra power to increase the link between the reinforcing material and matrix materials , added the fiber and zeolite particles is working on reducing the defects and Glades between materials and increasing the durability for composite material by the linking the power through increasing interface dividing power between the reinforcing material and matrix materials and thus increase the efficiency of the transfer of external loads inflicted on composite materials [13,14,16]



**Figure 3:** shows the relationship between the bending modulus and volume fraction of the filler particles of ((65,75 and 25)  $\mu\text{m}$  from( zeolite).

### 3 Visual Test.

Figure (4) shows Through microscopic examination for samples with ratio 7,5% vf and grain size 25  $\mu\text{m}$ , turned out good distributed for particles and fiber within the structure of composite material and is what made this ratio and size of the particles give good and clear results compared with the rest of the ratios because of the distribution homogeneity for the reinforcement phases within the composite material, which reduces the chances of the emergence of defects.



**Figure 4:** shows the distribution homogeneity for reinforcement phases for samples with ratio 7,5% Vf and grain size 25  $\mu\text{m}$  at a magnification of (X800).

### 4. Conclusion

Through the results note that the tensile strength increased with increasing volume fraction for particles to volume fraction 6% was the maximum tensile strength recorded at grain size 25  $\mu\text{m}$  and at volume fraction 7.5% compared with other sizes (65 and 75)  $\mu\text{m}$  at the same volume fraction with the stability of the volume fraction for carbon short fiber is 8%. the results for bending test showed that the bending resistance increased with the increase in volume fraction of the zeolite to 6% for the particle size 25  $\mu\text{m}$  As for the other sizes get maximum resistance of bending at volume fraction 7.5% with the stability for the volume fraction for carbon short fiber is 8%, and also the results showed that the bending modulus increased with the increase in the volume fraction for zeolite is

Positive relationship and the highest value when the grain size 25  $\mu\text{m}$  and when the volume fraction 10% compared with the rest of sizes at the same volume fraction with the stability for the volume fraction for the carbon short fiber and is 8%, through Results note that the best mechanical behavior when grain size where 25  $\mu\text{m}$  gave the best results and so it is th low particle size of the zeolite it gives the properties of tensile and bending of the best of the large grain sizes.

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## تأثير الاضافات الهجينة على سلوك الشد والانحناء لمادة متراكبة هجينة مقوات باللياف قصيرة ودقائق الزيوليت بأحجام حبيبية متنوعة

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### الخلاصة :-

تعتبر البوليمرات والمواد المتراكبة ذات اساس بوليمر من اكثر المواد انتشارا في كافة المجالات الصناعية والطبية لما تتمتع به من خواص تؤهلها لاحتلال مركز متقدم من بين المواد الهندسية الاخرى لما تتمتع به من خواص جيدة . لذلك , في هذا العمل ركز على دراسة مادة متراكبة ذات اساس بوليمري حيث تم دراسة البولي أستر الغير مشبع كأرضية وتم تقويته بدقائق الزيوليت بأحجام حبيبية مختلفة ( 25 – 65 – 75 )  $\mu\text{m}$  وكسور حجمية مختلفة ( 1,5 – 3 – 4,5 – 6 – 7,5 – 10 ) % وتم تقويته باللياف كاربون قصيرة وبكسر حجمي ثابت مقداره ( 8% ) , وتم اجراء اختبار الشد والانحناء حسب المواصفات الامريكية على التوالي .ومن خلال النتائج لوحظ ان مقاومة الشد القصوى تحسنت من خلال التقوية الهجينة الماخوذة وبلغت قيمتها القصوى عند الحجم الحبيبي ( 25 )  $\mu\text{m}$  وعند كسر حجمي ( 7,5% ) حيث بلغت ( 94  $\text{N/mm}^2$  ) مقارنة مع باقي الاحجام وعند نفس الكسر الحجمي حيث بلغت ( 78  $\text{N/mm}^2$  للحجم 65  $\mu\text{m}$  – 69  $\text{N/mm}^2$  للحجم 75  $\mu\text{m}$  ) اما بالنسبة لاختبار الانحناء فقد تم الحصول على اقصى مقاومة انحناء عند الحجم الحبيبي ( 25 )  $\mu\text{m}$  وعند كسر حجمي ( 6% ) حيث بلغت ( 111  $\text{N/mm}^2$  ) اذا ماقورن مع باقي الاحجام عند نفس الكسر الحجمي حيث بلغت ( 100  $\text{N/mm}^2$  للحجم 65  $\mu\text{m}$ , 79  $\text{N/mm}^2$  للحجم 75  $\mu\text{m}$  ) بينما تم الحصول على اعلى معامل انحناء عند الحجم الحبيبي ( 25 )  $\mu\text{m}$  وعند كسر حجمي ( 10% ) حيث بلغت ( 8099  $\text{N/mm}^2$  ) اذا ماقورن مع باقي الاحجام عند نفس الكسر الحجمي حيث بلغت ( 7466  $\text{N/mm}^2$  للحجم 65  $\mu\text{m}$ , 6666  $\text{N/mm}^2$  للحجم 75  $\mu\text{m}$  ) من خلال النتائج نلاحظ ان للحجم الحبيبي والالياف تأثير في تحسين السلوك الميكانيكي للمادة المتراكبة المحضرة .