Chelonian Conservation And Biology

Vol. 19No.1 (2024) | https://www.acgpublishing.com/ | ISSN - 1071-8443

DOI:doi.org/10.18011/2024.01(1). 1123-1143

IMPROVING MECHANICAL AND THERMAL PROPERTIES FOR UNSATURATED POLYESTER RESIN BY ADDING GYPSUM

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ABSTRACT

This research aims to prepare polymeric composites of unsaturated polyester as a base material for gypsum. Then, their mechanical properties were studied by measuring (hardness, compressive strength, impact resistance, modulus of elasticity). To achieve this goal, samples with different weight percentages of gypsum were prepared, and the addition percentage was from (5%-50%). The study showed an increase in the properties. Mechanical increase in the percentage of reinforcement, and the best percentage was at 30%, and the addition was done at different temperatures (8, 25, 50)°C. After comparing unsaturated polyester before and after reinforcement of the prepared compounds, it was found that there was an increase in all mechanical properties after reinforcement with gypsum at (8,25,50)°C, except for the modulus of elasticity, which decreased at all temperatures. It was also found that the thermal conductivity decreased at temperatures (8, 25, and 50)°C, which indicates that polymeric compounds consisting of unsaturated polyester resins reinforced with gypsum are good thermal insulators.

Keywords: unsaturated polyester, gypsum, hardness strength, compressive strength, impact strength, elastic modulus, thermal conductivity.

Introduction

As a result of scientific research, the need has emerged for polymeric materials with certain specifications that cannot be obtained from a single type. This is why many attempts have emerged to mix two or more types of materials to obtain polymeric materials with the desired industrial specifications

Composite materials are heterogeneous materials consisting of two different, immiscible materials. Their goal is to obtain high properties that cannot be obtained using traditional materials. It has many advantages: light weight, thermal and electrical insulation, mechanical and chemical resistance, design flexibility and other qualities [1].

Researchers [2] studied the mechanical properties of sugar palm yarn with unsaturated polyester compounds reinforced with glass fibers and the effect of fiber endurance and alkali treatment. It was found that when sugar palm yarn and glass fibers were combined in weight ratios of 50:50 with polyester, an increase in mechanical properties was observed.

Researchers [3] also prepared a composite material of epoxy as a base material reinforced with natural rubber and synthetic rubber. They found an increase in mechanical properties by increasing the weight ratio of the reinforcement, and that the best results were when using natural rubber as a reinforcement material.

Researchers [4] studied adding nylon 66 as a reinforcement material to polyester as a basic material in different weight percentages (1%, 2%, 3%, 4%, 5%), and through the results it was found that the highest value was (hardness strength, compressive strength, strength Impact) when strengthened by weight (5%) at room temperature, but when processed at temperatures (8,50°C), it was found that both the tensile strength and the compressive strength increase at 50°C and decrease at 8°C, while the strength The impact strength decreases at temperatures (8,50)°C. It was also found that thermal conductivity decreases at all temperatures (8,50)°C, which indicates that polymeric compounds composed of unsaturated polyester resins and reinforced with nylon 66 are good thermal insulators. ..

The researcher [5] also studied the mechanical and physical properties of epoxy by adding sulfur as a support material to the epoxy resin in specific weight ratios. It was proven during the research that hardness, compression and impact increased after the sulfur reinforcement process, but the thermal conductivity decreased. The aim of this study is to improve some of the mechanical properties of polyester. Unsaturated using available and cheap particulate fillers and studying the thermal conductivity of the resulting polymeric composite, thus reducing the cost of this material used in various applications.

Materials used in the research

Base material:

Unsaturated polyester resin (UPE) from a Turkish company, TURKUAZ poly aster . It has a density of 1.17 and its viscosity ranges between (350-500 cps) at a temperature of 25°C.The hardener (ethyl methyl ketone peroxide) is a colorless liquid. The hardener is added to unsaturated polyester resin at a ratio of (2:1) at room temperature to obtain the samples required for molding.

Reinforcement materials:

Gypsum was used from construction waste, a ubiquitous material in the world of construction. It is much more than meets the eye. It generally consists of hydrated calcium sulfate ($CaSO_4.2H_2O$), which is a white substance used to smooth walls or create artistic impressions. Gypsum is composed of a complex mixture of components, each of which plays a unique role in giving it its properties. These mainly include gypsum gypsum, lime gypsum and cement gypsum, each with its own unique composition and properties. Gypsum is used in building and construction, and to protect structures [6].

The method of work :

Unsaturated polyester resin was used, and then the hardening material was added in a ratio of hardener: unsaturated polyester (2:1). It turns into a sticky substance and then hardens after about 5 minutes at room temperature. The models were prepared using the manual molding process at room temperature. The room is maintained while maintaining the sequence of addition, where the polyester is placed, then the reinforced material, then the hardener in order to obtain high homogeneity upon mixing. Samples consisting of unsaturated polyester only were prepared in order to study their mechanical properties and compare them with the results after the reinforcement process. Then other samples containing proportions are prepared. Its weight of the reinforced material (5%-50%) is dried gypsum from moisture, after which the grinding process was done manually (mortar) using a sieve of size (75 microns) to obtain a very fine powder similar to powder for better homogeneity with the base material. This became a material. Reinforcement and reinforcement ready for use. The overlaid material is then placed in special molds for each size based on the special specifications. After completing the casting process, the material is left for 24 hours at different temperatures (8, 50)°C in order for the process of solidification, homogeneity, and interaction between the material particles to be completed.

Devices used

Hardness testing device

It was equipped by the company (Wolpert-German, type Shore-D), which is located in the College of Engineering, Department of Mechanics. The device resembles a compass, as it consists of a needle located in the middle. The examination method is by installing the device vertically on the sample to be examined and measured until the needle is inserted into the surface of the material, then Wait for 3 seconds and then take the hardness value recorded by the device as in Figure (1)

Figure (1): Hardness measuring device

Impact testing device :

Use the IZOD Impact Test Instrument, supplied by Brooks Inspection Equipment Ltd., Colchester, England (Figure 2), located in the College of Engineering, Department of Mechanics, to conduct the impact test for samples manufactured in accordance with American standard specifications (ASTM-D256-87). With dimensions (75 x 10 x 10), the device consists of a pendulum with a special hammer attached to its end to break the sample, its arm length (L = 0.75 m) and its weight (W = 25.81 Kg), and the hammer is connected at the other end to a circular disk inscribed with special graduations to measure the angle of elevation. Hammer before and after trauma. The examination technique is carried out by raising the hammer to its maximum height at the corner (α = 141.5o) and holding it firmly, and the sample is placed in the designated location in the device in the form of a simple threshold, with the direction of the pendulum being perpendicular to the width of the sample. The energy meter is zeroed first, then the pendulum is released using the lever. Mounted on the scale, and with an oscillating movement due to gravity, the potential energy possessed by the pendulum is transformed into kinetic energy, part of which is lost in breaking the sample. The scale indicator reads the angle of elevation of the hammer after the impact (β). The test was conducted for all samples at laboratory temperature.

Figure (2): impact strength device

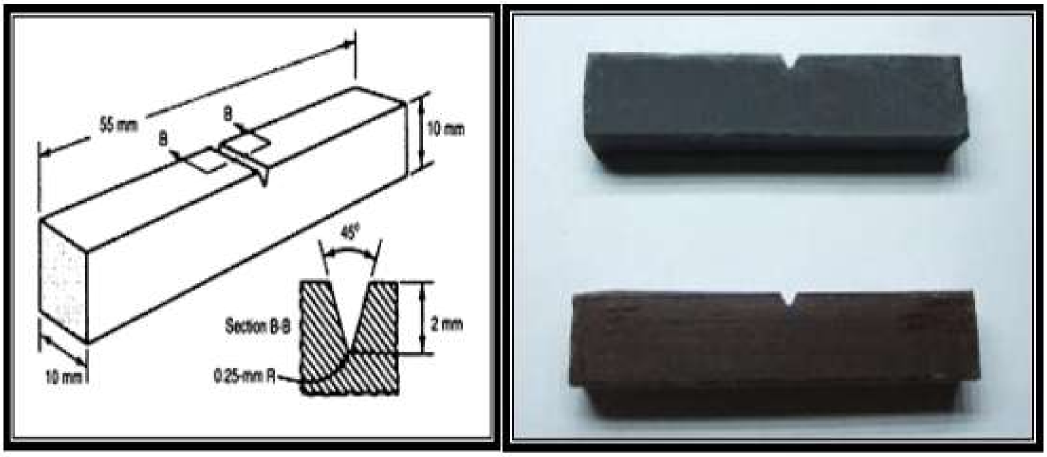

Figure (3): Shape and dimensions of the shock sample

Compressive strength measuring device:

Compressive strength test models were prepared according to the required specifications (ASTM-D168) and using a hydraulic piston (100TON), which has a cylindrical shape, equipped by the company CONTROLUS of Italian origin, located in the College of Engineering, Civil Department, as shown in Figures (4), (5) .

Figure (5): Compressive strength testing device

Figure (4): Sample shape for compressive strength

Thermal conductivity:

Using a device called a Lee disk shown in Figure (7) located in the College of Science, Department of Physics. The models used in this test are (11.23) cm in diameter and (1 cm) thick, as in Figure (6), which are specifications for measurement.

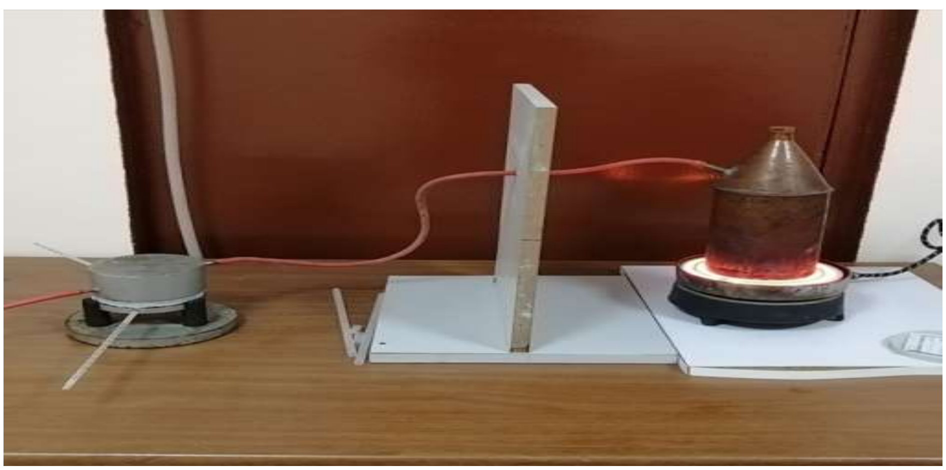

Figure (7): Thermal conductivity testing device

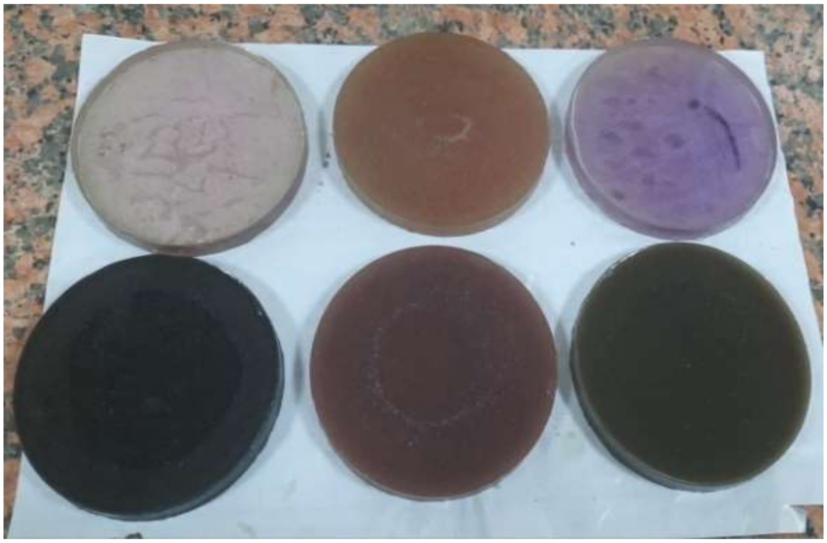

Figure (6): Sample shape for thermal conductivity testing

Tensile testing device :

The tension device (Test machine Universal), which is of German origin, was used under the influence of a load of up to (50 KN) as in Figure (8) located in the College of Engineering, Civil Department, where the standard specification (ISO-R527) was adopted in preparing tensile strength test models. The models were in the form of slices, as in Figure (9). This test was used to determine the properties of the composite material under the influence of an axial load in two directions

Figure (8): Tensile testing device

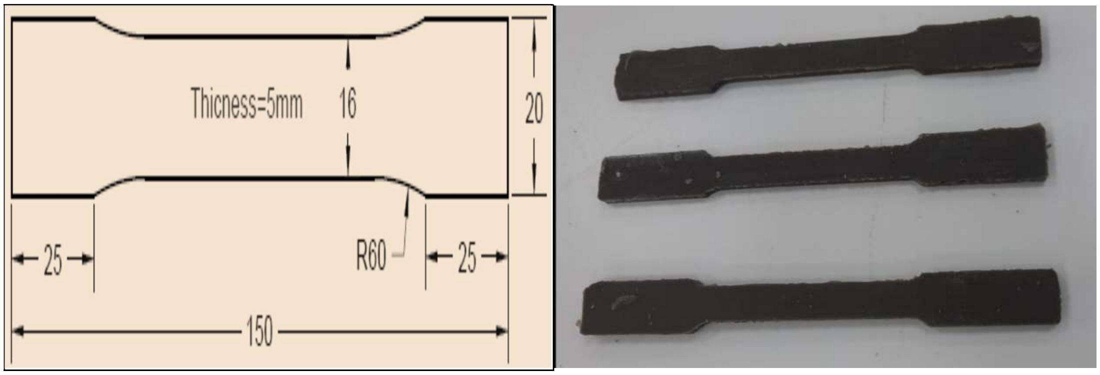

Figure (9): Shape and dimensions of the sample prepared for tensile testing.

Results and discussion

1- Hardness test

The hardness property is one of the important surface mechanical properties, which can be defined as a measure of plastic deformation - which a material can suffer under the influence of external stress placed on it as a result of its general exposure to scratching and penetration by harder equipment during its use in applied fields [7].

From the results, we notice that the hardness values improved after reinforcing the unsaturated polyester with plaster. This is due to the increase in interlocking and stacking resulting from the cross-linking between the unsaturated polyester and the plaster, which reduces the movement of the polymer molecules and thus increases their hardness, which leads to an increase in their resistance to deformation [8]. .

The hardness of the overlay material increases with the increase in the percentage of added plaster, and the highest value of hardness is at the weight percentage of 30%, as shown in Table (1) in Figures (10,11). The hardness values calculated at room temperature of 25°C improved after reinforcing the unsaturated polyester with plaster. Because it has the ability to bear the majority of stresses [10,9].

Table (1): Hardness values of unsaturated polyester before reinforcement and then at a temperature of 25°C

Composites	Hardness resistance at 25°C
UPE	82
UPE + Gypsum 5%	86
UPE + Gypsum 10%	86.4
UPE + Gypsum 15%	87.2
UPE + Gypsum 20%	88.2

UPE + Gypsum 25%	88.7
UPE + Gypsum 30%	89
UPE + Gypsum 35%	88.6
UPE + Gypsum 40%	88.1
UPE + Gypsum 45%	87.7
UPE + Gypsum 50%	86.15

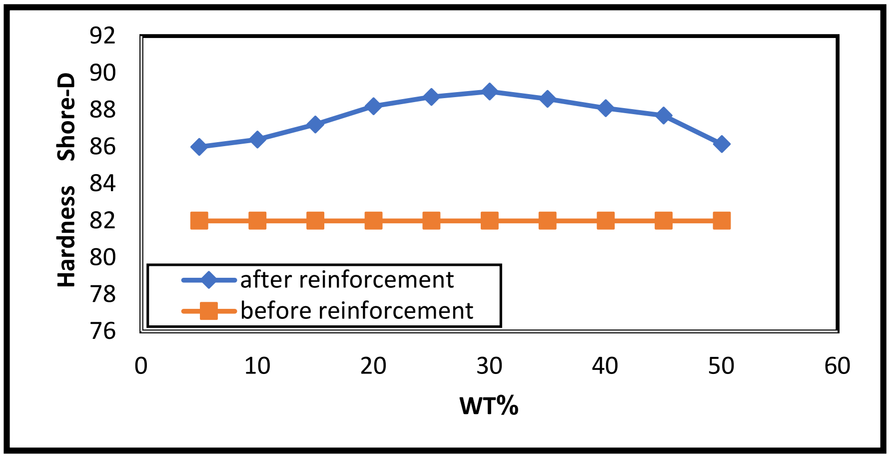

Figure (10) The relationship between hardness values and weight percentages of polyester resin unsaturated before and after consolidation at 25°C

However, the hardness values decrease with the increase in temperature. We notice that the hardness values at 50°C were lower than their value at 25°C. The reason for this is that the increase in temperature led to an increase in the ductility of the material due to the movement of the primary units and the relaxation of the bonds between them, and this leads to a weakening of its resistance to scratching. And the stitches are as in Table (2) [7]. But at 8°C as the temperature decreases, the polymeric chains become restricted and cannot move, resulting in weak resistance as shown in Figure (11) and Table (2) .

Table (2): Hardness values of unsaturated polyester before Reinforcement and after it at temperatures 8, 25, and 50 °C

Temperatures °C	Hardness before reinforcement	Hardness after Reinforcement
8	82.5	88.8
25	82	89
50	82.4	88.2

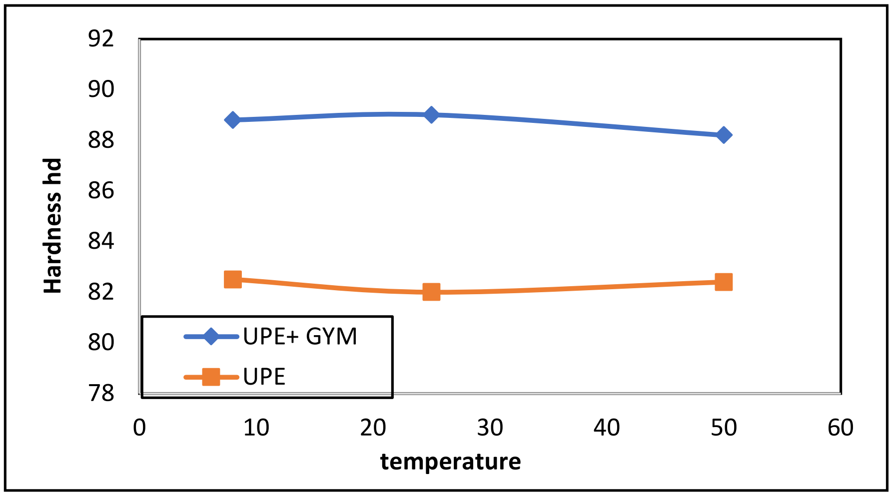

Figure (11): Hardness of unsaturated polyester before reinforcementand several temperatures at 8,25,50°C

Impact Test

Impact is defined as the property of metal to resist breaking when exposed to sudden stresses . The impact test is very important from a practical standpoint because through it is possible to calculate the absorbed energy required to crush and break the sample [11]. This value is given directly from the testing device, which can be calculated through the following relationship.

$$\text{Impact strength (I.S)} = \frac{\text{Freatur energy}}{\text{Area (m)}^2}$$

Impact strength is considered low in general for unsaturated polyester due to its fragility, but after reinforcement with plaster, we notice that the shock resistance increases more than it was in the unreinforced polyester. We notice an increase in the shock resistance, as in Table (2), than it was in the unreinforced polyester. The reason is due to This is because the plaster will bear the bulk of the shock energy applied to the composite material, which leads to improved resistance and thus increased shock resistance [13,12].

Table (3): Impact resistance values of polyester before and after reinforcement with different weight percentages at a temperature of 25°

composites at 25°C	Impact Strength KJ/M^2
UPE	18.5
UPE + Gypsum 5%	19
UPE + Gypsum 10%	19.4
UPE + Gypsum 15%	19.7
UPE + Gypsum 20%	20.1
UPE + Gypsum 25%	20.5
UPE + Gypsum 30%	21.3
UPE + Gypsum 35%	21.1
UPE + Gypsum 40%	21
UPE + Gypsum 45%	20.9
UPE + Gypsum 50%	20.7

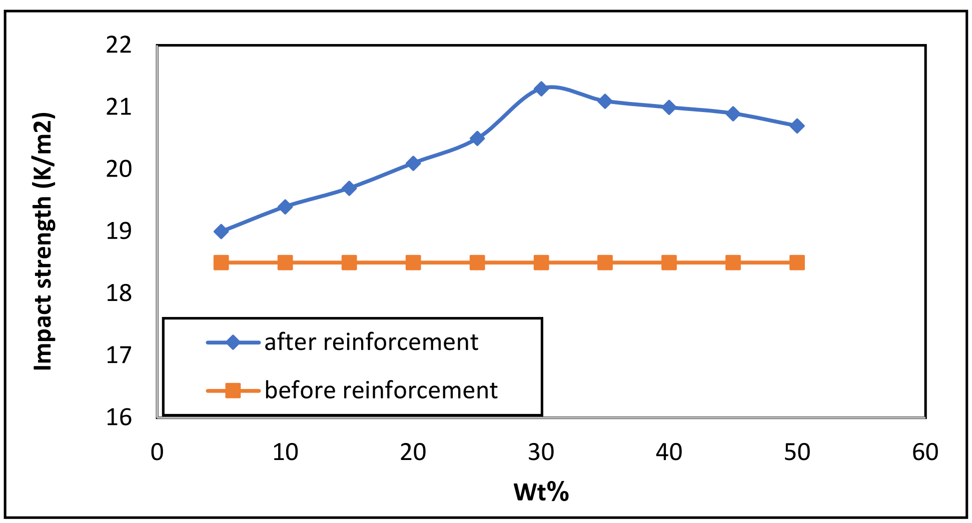

Figure (12): The relationship between impact resistance and the weight percentage of polyester unsaturated before and after consolidation at 25°C .

Based on the results above, the weight percentage that represents the highest impact value, which is 30%, is taken and subjected to heat treatment at degrees (8, 25, 50)°C, where the samples remain at the mentioned temperatures for 24 hours, and then the impact resistance is measured. From the results, the impact values increased noticeably, clearly and unevenly as a result of the loosening of the bonds between the molecules of the material and their sliding movement, which gives it the possibility of absorbing part of the energy, which leads to an increase in the energy required for fracture. This is because the gypsum material acts as a filler that causes homogeneity of the polymer chains by filling the voids and thus reducing Free volume, which leads to an increase in the density of the material, which leads to an increase in the degree of glass transition, that is, the material becomes more crystalline, thus distributing the applied stress over a larger area, thus reducing the concentration of stress in a specific area. Also, the presence of reinforcement materials prevents the growth of small cracks that occur as a result of the impact to increase crystallization, as well as the fact that The impact resistance of ductile polymers is higher than the impact resistance of brittle polymers, and the increase in impact is a result of the increased durability of the material. As shown in Table (4) and Figure (13) [14].

Table (4): Impact resistance of unsaturated polyester before reinforcement and then at temperatures of 8,25,50°

Temperatures °C	Impact Strength before reinforcement	Impact Strength after Reinforcement
8	18.1	20.1
25	18.5	21.3
50	18.75	20.9

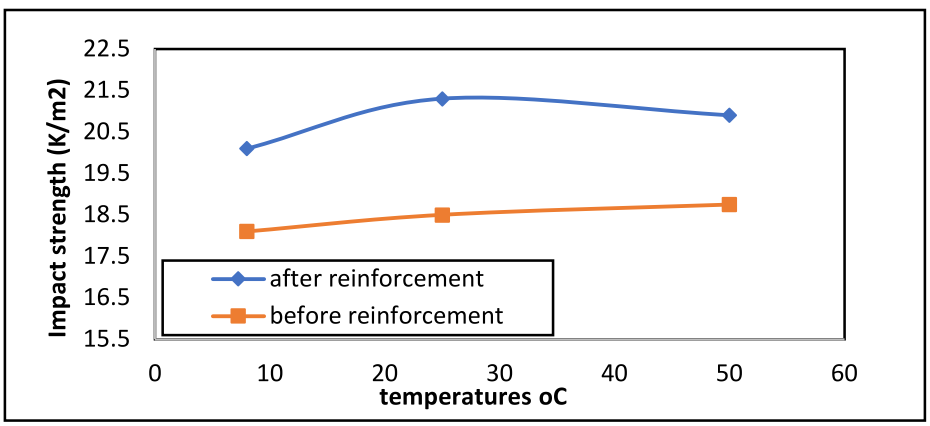

Figure (13): The relationship between shock resistance and temperature Before and after consolidation at a temperature of 8,25,50°

Flexibility test :

Studying the change in the dimensions of the polymer network as a function of stress, which is one of the important mechanical properties of all polymers. When a force is applied to a model of a polymer at a constant speed and then the deformation occurring in it is measured, either in terms of the change in length, change in area, or volume, the behavior of the polymer under the influence of stress can be identified.

From the nature of the stress-strain curve, very useful information can be obtained about the properties of the polymer in terms of its strength, durability, flexibility, the maximum effort that the model can withstand, and the maximum elongation that may occur in the model, in addition to a lot of very important engineering information.

Stress is the force applied per unit cross-sectional area of the model and is symbolized by (σ):

$$\sigma = \frac{F}{A} \quad \ldots\ldots\ldots\ldots \quad (2)$$

The strain (ε) represents the amount of elongation of the model as a result of exposure to stress relative to the original length of the model.

$$\varepsilon = \frac{\Delta L}{L^{\circ}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Through the tension device, measurements were obtained representing the relationship between stress and strain of polyester before and after its reinforcement with plaster, and the value of the modulus of elasticity (Yong's modulus E models) was determined from the slope of the curve, which represents the ratio between stress and strain, according to the following relationship [15].

$$E = \frac{\sigma}{\varepsilon} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

The stress (load) is directly proportional to the strain, and when the effect of the applied load disappears, the material returns to its original state, meaning that within the limits of elasticity, the strain is directly proportional to the stress. The results of the Young's modulus test showed that the composite material reinforced with plaster has a lower modulus of elasticity than the polymeric material before reinforcement, and the elastic modulus decreases as the weight percentages increase, to increase the crystallinity of the material, as the density increased and the specific volume decreased, and thus the number of free volumes decreased, which led to an increase in the hardness of the composite material and thus decreased. The modulus of elasticity is as shown in Table (5) and Figure (14).

Table (5): Elastic modulus values for unsaturated polyesterBefore and after consolidation at a temperature of 25 °C

composites at 25°C	Elastic modulus
UPE	3.195
UPE + Gypsum 5%	2.991

UPE + Gypsum 10%	2.972
UPE + Gypsum 15%	2.995
UPE + Gypsum 20%	2.911
UPE + Gypsum 25%	2.891
UPE + Gypsum 30%	2.879
UPE + Gypsum 35%	2.866
UPE + Gypsum 40%	2.801
UPE + Gypsum 45%	2.77
UPE + Gypsum 50%	2.717

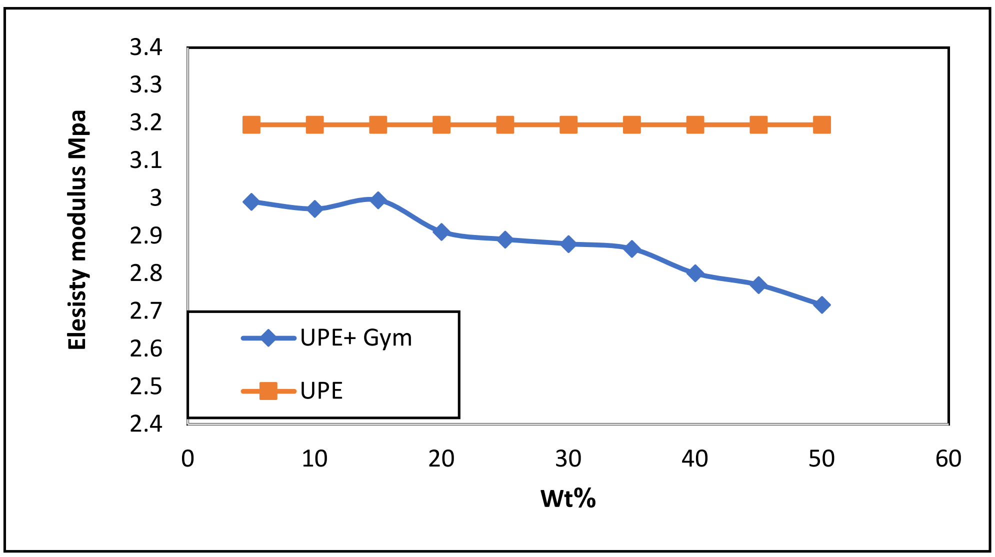

Figure (14): The relationship between the modulus of elasticity and the weight percentage of unsaturated polyester before and after reinforcement at a temperature of 25 °C

When heat treating at temperatures (8,50) °C and choosing the highest weight percentage of 30%, the results showed that flexibility increases at a temperature of 50 °C before reinforcement. This is due to the relaxation of bonds resulting from increasing the temperature before reinforcement [16], and when temperatures decrease. This leads to a decrease in elasticity values, and the reason is due to the constriction of bonds resulting from the decrease in temperature and the decrease in the movement of the polymer chains, as in Table (6) and Figure (15) [17] .

Table (6): Shows the elasticity values of unsaturated polyester before reinforcement after consolidation at temperatures of 8, 25, and 50 °C

Temperatures °C	Elasticity before reinforcement	Elasticity after Reinforcement
8	3.105	2.719
25	3.195	2.879
50	3.211	2.966

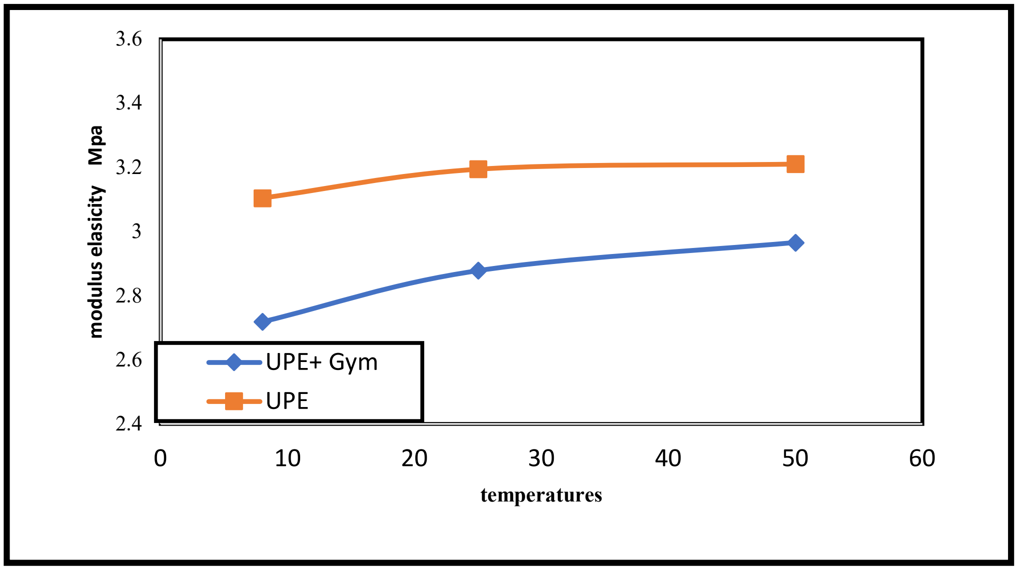

Figure (15): The relationship between the modulus of elasticity and the temperature before after strengthening at temperatures 50,25,8

Compressive strength test:

Testing the compressive strength of the material is an important test to determine the strength and endurance of the polymer. There are many materials that may be brittle in tension but appear ductile in compression. Therefore, we find that the compression test is used to determine the yield strength in addition to the compressive strength [18].

In general, compressive strength is defined as the maximum stress that a solid can with stand under vertical pressure

$$:\text{Compressive Strength (C. S)} = \frac{\text{Maximum load shedding}}{\text{Cross−section} \quad \text{area}} - - - - - - -(5)$$

The results of the compressive strength values at a temperature of 25°C, based on equation (5), showed that the material reinforced with plaster has a higher compressive strength than that without reinforcement, because the fillers bear most of the stress applied to the material, as the resistance of the composite material to compression increases with the increase in the percentage of added plaster due to To distribute the load on the filler material, as well as the efficiency of bonding between the base material and the plaster, which increases the compressive strength values and enables . Note this in Figure (16)[20,19]

Table (7): Compressive strength of unsaturated polyester Before and after consolidation at a temperature of 25 °C

composites at 25°C	Compressive Strength
UPE	**18.3**
UPE + Gypsum 5%	**19.5**
UPE + Gypsum 10%	**22.2**
UPE + Gypsum 15%	**22.8**
UPE + Gypsum 20%	**23.9**
UPE + Gypsum 25%	**24.7**
UPE + Gypsum 30%	**25.5**
UPE + Gypsum 35%	**25.1**
UPE + Gypsum 40%	**24.6**
UPE + Gypsum 45%	**24.1**
UPE + Gypsum 50%	**23.5**

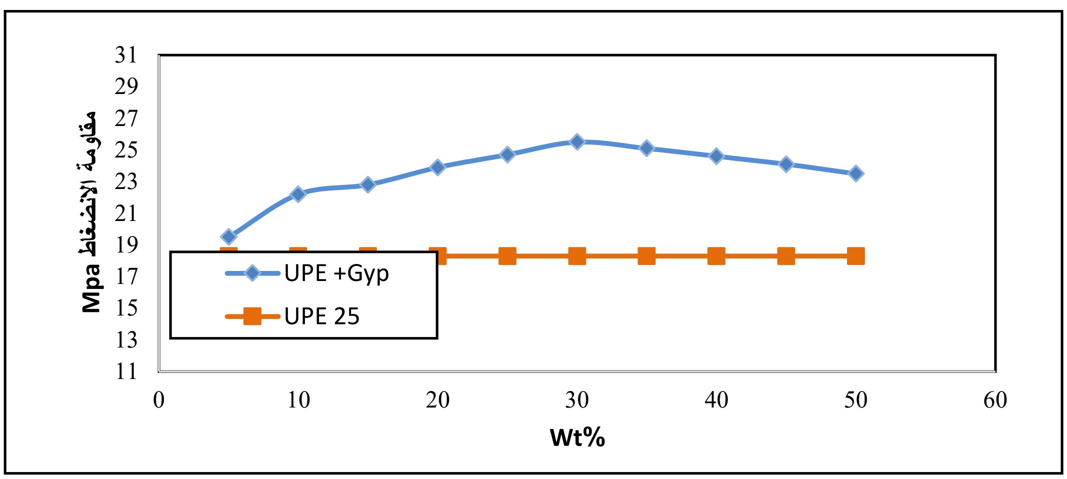

Figure (16): The relationship between the weight ratio and the compressive strength For unsaturated polyester before and after consolidation at 25 °C

We also notice that the values of compressive strength decrease as the temperature increases at (50°C) and increase when the samples are cooled to (8°C), that is, inverse proportion. The reason for this is that when the temperature increases, the samples become flexible due to the weak bond strength between the reinforced materials and the polyester as a result. The bonds between the polymer chains break, and this breakage results in the local movement of the chains, which leads to an increase in the free volumes not occupied by the polymer molecules, so the density decreases, and as a result of the decrease in density, there is a weakness in the compressive resistance of the samples, and the samples suffer from compression to a certain extent. When the samples are cooled at (8°C), the decrease in temperature leads to restricting the movement of the chains, and then the free volume not occupied by the polymer molecules decreases, so the density increases, and thus the resistance of the samples to the compressive force increases, as shown in Table (8) and Figure (17) [21,22].

Table (8): Compressive strength values of unsaturated polyester Before and after consolidation at temperatures of 8, 25, and 50 °C

Temperatures °C	Compressive Strength before reinforcement	Compressive Strength after Reinforcement
8	18.1	26.1
25	18.3	25.5
50	18.4	23.9

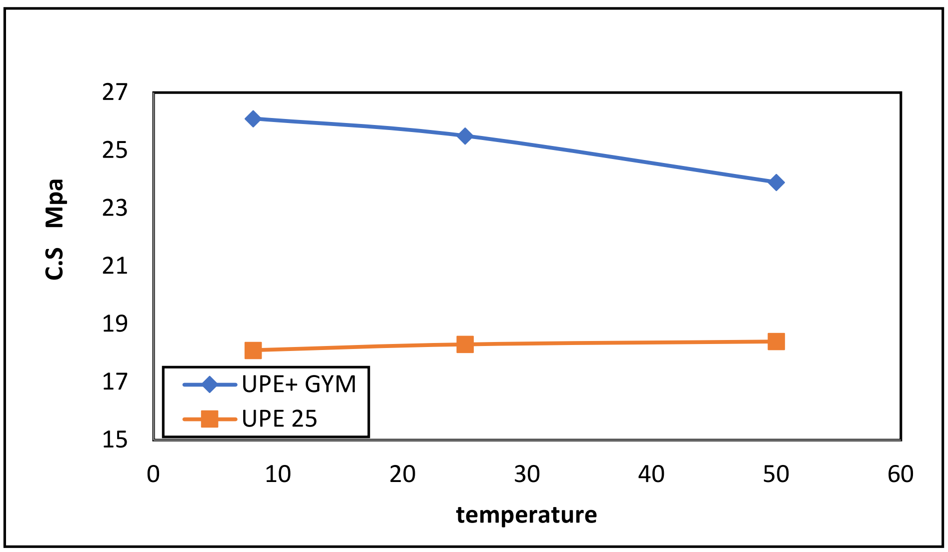

Figure (17): The relationship between compressive and temperature resistance values at temperatures of 8,25,50°C

Thermal conductivity

It is defined as the spontaneous transfer of thermal energy through matter from an area with a high temperature to another area with a lower temperature than the previous one in an effort to achieve thermal uniformity in a number of forms (conduction, convection, and radiation). Heat can be transferred in one or more ways. Of these forms, it should be noted that heat transfer by conduction or convection is slower than heat transfer by radiation, because the speed of radiation is equal to the speed of light, which is (2-3 x 108 km s). Where the particles are free to move. Thermal conduction is the process of transferring thermal energy through the spread and microscopic collision of particles inside the body as a result of the temperature gradient. Conduction occurs in all forms of matter with weight, such as solids, liquids, gases, and plasma.

Through research, we showed that thermal conductivity decreased with increasing temperature because polymers contain free electrons to transfer heat, as thermal conductivity depends on structural vibrations in its internal structure, as these vibrations decrease when fillers are added to the polymer, which hinder vibration and thus the conductivity decreases.The reinforcement materials work to impede vibration in the internal structure of the resin, and thus the values of the thermal conductivity coefficient decrease, as in Figure (18).[24,23]

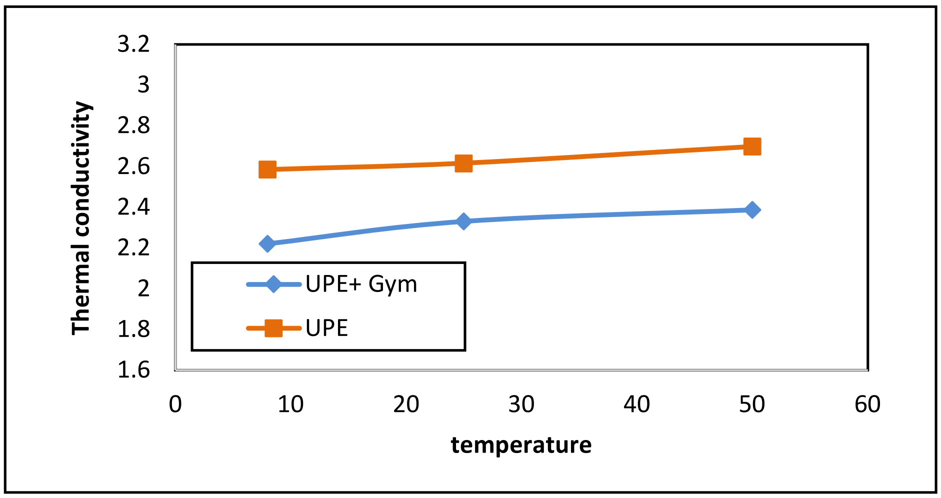

Figure (18): The relationship between temperature and thermal conductivity

Conclusions

The most important conclusions reached during this research are summarized as follows:

1-Adding gypsum to unsaturated polyester led to an increase in the values of all the mechanical properties that were conducted in the research, namely the properties (impact resistance, hardness, and compression resistance) except for the modulus of elasticity, where its value decreased.

2- The values of all the mechanical properties mentioned above increase with the increase in the weight percentage of the plaster.

3- The values of (hardness and impact) decrease with increasing temperature and also decrease at 8°C, but the values of (compressive strength and modulus of elasticity) increase when treated at a temperature of 50°C.

4- Low thermal conductivity of unsaturated polyester after reinforcement at all temperatures.

References:

1. Bhong, M., Khan, T. K., Devade, K., Krishna, B. V., Sura, S., Eftikhaar, H. K., & Gupta, N. (2023). Review of composite materials and applications. Materials Today: Proceedings.
2. Nurazzi, N. Mohod, A. Khalina, S.M. Sapuan.R.A. ilyas, (2019)‘” Mechanical Properties of sugar palm yarn/Woven glass fibre reinforced unsaturated polyester composites: effect of fibre loadings and alkine treatment” ,64(10),665-675.
3. Dalia, Rabie Saadallah, Ebtahag ,Zeki Sulyman, (2022),” Preparation and study of mechanical and thermal properties of an Epoxy Composites with isobutyl rubber (damaged water taps powder and signals”, International Journal of Health Sciences, 6(S2), 5200–5210.
4. Anwar M. Ahmed, Ebtahag Z . Sulyman,(2022),” Study of the mechanical and thermal properties of Polyester Composites Prepared with Nylon66”, International Journal of Health Sciences, 6(S1), 6265–6277.
5. Muhammad, Safa Zia, (2021) “Study of the mechanical and physical properties of epoxy when sulfur is added” Mosul University, College of Education for Girls, Department of Chemistry.
6. Karni, J., & Karni, E. Y. (1995). Gypsum in construction: origin and properties. Materials and Structures, 28, 92-100.
7. Rwaa .E. Ibrahiem , Ebtahag .Z . Sulyman, (2019) "Preparation Polymeric Composites from Epoxy with Randomly Woven Fibre Glass and Studies the Mechanical roperties." Rafidain Journal of Science 28.3, 104-115.
8. Florian H.; Gojny Malte;H.G. Wichmann , (November 2005,) , Composites Part A: Applied Science and Manufacturing, 36(11), 1525-1535.
9. Al-Safi, R.A., (2001) " Study of thermal and mechanical properties Nouveau and its overlays", Master's Thesis, Technological University.
10. Esraa S. Waad Ala, Ebtahag .Z . Sulyman,,(2020) " Preparation of Polymeric Composites from Saturated Poly ester glass powder (flourscent) and Study of it s mechanical properties " , Iraqi Journal of Labor Research and Consumer Protection , 13.1.
11. Sirichai Kanking, Piyaporn Niltui, Ekachai Wimolmala and Narongrit Sombatsompop, (2012) “Use of bagasse fiber ash as secondary particulate in silica or carbon black filled natural rubber compound,” Materials and Design 41: 74–82.
12. Dalia, Rabie Saadallah, Ebtahag ,Zeki Sulyman, (2022), Preparation and study of some mechanical and thermal properties of epoxy composites with natural styrene butadiene rubber (damaged tires), International Journal of Health Sciences, 6(S1), 6278 – 6291.
13. H. M. Kawade and N. G. Narve, (2017) "Natural FibreReinforced Polymer Composites: A Review" ,International Journal for Scientific Researchand Development,. 5(9), 445-449.

14. Marwa H. Mohammed Ameen, Ebtahag .Z . Sulyman,, (2023).," Preparation of Polymeric Composites from Epoxy and High-Density Polyethylene and Study of Some of Their Mechanical ",Journal of Survey in Fisheries Sciences 10(1S), 5368-5378
15. Chianelli-Juniora, R.; Reisb, J.M.L.; Cardosoa, J.L.; Castroa, P.F. (2013). Mechanical characterization of sisal fiber-reinforced recycled hdpe composites. Materials Research, 16(6), 1393-1397.
16. Seymour, R. B. ,(1999)," Polymer Composite", 1st edn, Utrecht, The Nether Land, 165-176.
17. Anwar M. Ahmed, Ebtahag Z . Sulyman,(2022)," Preparation and study of mechanical and thermal properties of polymeric composites of unsaturated and polyester cellulose fibers". International Journal of Health Sciences, 6(S1), 9305–9321.
18. Hibbeler, R.C. (2011), "Mechanics of Materials", 8th ed, Pearson prentice Hall, 81-83.
19. Abd AL-Hussien, H. J. (2015). Effect of immersion in chemical solution on the mechanical & physical properties for composite material reinforced by Nano alumina Particles. Iraqi Journal of Science, 1952-1963.
20. Maysam K. Jassem Al-Atrash, Ebtahag ,Zeki Sulyman,(2022)," Thermal and mechanical study of polymeric composites prepared from epoxy with iron filings", International Journal of Health Sciences, 6(S4), 7908–7919.
21. Ahmad.A.M.(2022) "Studying The Effect Of Adding (Preparation Of Polymeric Composites From Unsaturated Polyester With Some Types Of Fibers And Study Its Mechanical And Thermal Properties)" Mosul University, College of Education for Girls, Department of Chemistry.
22. Al-Habbar.M.H.(2023) "Preparation and study of the mechanical and thermal properties of polymeric composites of epoxy with some polymeric residues" Mosul University, College of Education for Girls, Department of Chemistry.
23. JarJis, Ayad Jyad, (2013) "Studying the effect of polymer granules on some thermal and mechanical properties of PTFE Portland cement paste" Mosul University, College of Science, Volume 16, Issue 4, 19-25.
24. Rand W.Jassim1, Ebtahag Z. Sulyman,(2023)," Study Of Some Mechanical Properties Of The Prepared Polymeric Composites Unsaturated Polyester With Gyrex Clay", Journal of Survey in Fisheries Sciences , 10(2) 1085-1094