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Preparation of polymeric composites from saturated polyesters Low-density polyethylene (LDPE) and the study of its mechanical properties

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Abstract
This paper prepared polymeric composites from unsaturated polyester as a base material with Low-density polyethylene (LDPE) in different weight ratios (4%, 6%, 8%, 10%, 11%) as a support material. An increase was found after comparison before and after reinforcement of the prepared composites. The shock resistance values decreased in the values of mechanical properties (hardness, compressive strength). Still, an increase in temperature leads to an increase in the values of shock resistance, as well as the values of compressive strength and hardness.
Keywords: Unsaturated polyester, fluorescent powder, mechanical properties.

Introduction

Composite materials are highly versatile and widely used in engineering applications due to their unique properties. They are created by combining two or more materials, resulting in a material that has improved properties while losing any undesirable traits of the individual components. The properties of composite materials can be controlled via their design, manufacturing methods, and the type and proportions of constituent materials. Polymer-based composite materials are among the oldest materials and are often reinforced with ceramic, carbon, or metallic particles. This type of composite material is widely used in various industrial applications and has been the subject of much research. In contrast, composite polymeric materials reinforced with fibers have not received as much attention as those reinforced with particles [1]. Composite materials are typically made by combining two or more materials in order to create a material with unique engineering and physical properties that differ from those of its individual components. The resulting material possesses superior properties compared to its constituents. A composite material comprises two main phases: the matrix phase the reinforcing phase, and the interphase that exists between them [2]. The interest in polymer-based composites increased due to the qualities of engineering materials, especially the applications with high resistance. Among the most important materials used as basic materials are the three types of

polymeric materials that are thermoplastic, thermosetting, and elastic elastomers [6-3]. Plastic composite materials, which are reinforced with different types of supporting materials, include two types of base material, which are a thermoplastic base material and a thermoset base material. It should be noted that thermostats are stronger than thermoplastic materials that are widely used, such as (low-density polyethylene, high-density polyethylene, polypropylene, etc.) The choice of thermostat as a base material is of great importance. One of the most used groups is (polyester, epoxy, phenolic, and polyamides).[7] Unsaturated polyester resin is a thermally hardened resin and cannot be used by itself in engineering applications because it is a fragile material and does not have the appropriate efficiency. Still, when strengthened with particulate materials (which is one of the means of strengthening the base materials as its distribution in the base material is random to obtain composite materials with good mechanical properties and symmetrical orientations), they have equal properties in all directions, The mechanical (isotropic) behavior of the composite material reinforced with minute particles is the result of the mutual effect of the phases that makes up the compound material, which is (the substrate, the reinforcement material, the interface). As for the strength and durability of the composite material supported by the minute particles depends on several variables: (Volumetric or gravitational fraction of minute particles, particle size and distribution, modulus of elasticity and toughness, interface in the composite material). The supporting particles can be divided according to their nature into organic and inorganic particles. Inorganic particle supporting materials are so important because they are available in abundance, naturally, and ready for use directly thus, its used to minimize the cost of the synthesized materials without any loss, and if there were any losses, they are going to be small ones. Plus, these materials improve the characteristics of the synthesized materials in an obvious way as they increase the rigidity, for example.

In this research, polyethylene was used as a supporting material. Among its advantages, it is used as a building material, packaging and local industries on a large scale among thermoplastics. Low-density polyethylene compounds are used in various applications such as roofs and basins, packing films, tubes, and window frames, and as a material in the automobile industry [9,10].

The characteristics of polyethylene (PE) are that it is highly durable, lightweight, easy to manufacture, has low price, has very little water absorption, and is chemically inert (it does not dissolve in any of the solvents at room temperature, but it swells lightly by Liquids such as benzene, It has good resistance to acids and bases, the glass transition degree of polyethylene is very low (120 ° C), which gives it flexibility, high moisture resistance, in addition to electrical insulation properties[11].

The aim of the study

This study aims to prepare composite materials that show good hardness, identify the behavior of composite polymeric materials in standard conditions, and compare them and the polymeric material before reinforcement, and then study the mechanical properties (impact strength, hardness, and compression resistance) for all models before and after reinforcement with low-Density poly-ethylene (LDPE)

The practical side

Materials used:

The matrix: An unsaturated polyester made by (B-CHEM SRL) company was used as a base material, which is in the form of glue at room temperature with a yellowish color, and it is one of the types of thermosetting polymers, transforming from a semi-solid state to solid state by adding a hardener (di benzoyl peroxide) which is in the form of white cream, it is added to the unsaturated polyester resin in a ratio of 2: 1 at room temperature [12], low-density poly-ethylene (LDPE) was used as Granules they were used after dissolving with toluene. suitable samples can be obtained for molding at room temperature.

Reinforcing materials: Low-density polyethylene (LDPE) is a support material. Production of (LDPE) in granular form by the State Company for Petrochemical Industries (Basra - Iraq).

Table No. (1) Shows some properties of the low-density polyethylene

Table (1): properties of the low-density polyethylene

Property	LDPE
Trade Name	Scpilex (463)
Density (g/cm^3)	0.921-0.924
Melt Index (g/10 min)	0.28-0.38

Samples preparation

Impact test samples: impact test samples were prepared according to the American standard (256-87ASTM-D) with dimensions (10 × 55 mm 3 × 10), suitable for examination. The groove depth in the models is (2 mm) and with a notch angle of (45 °). The absorbed energy required for the occurrence of the breakage was obtained directly from (Charpy Impact Instrument) provided by (Tokyo Koki Seizosho, LTD). Fig. 1 shows the shape and dimensions of the sample prepared for the impact strength test [13].

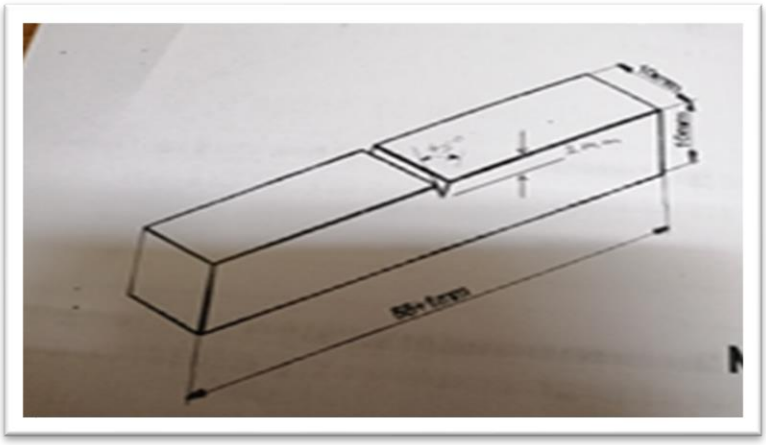

Fig. (1): the shape and dimensions of the sample prepared for the impact strength test

Fig. (2): the sample prepared for the shock-resistant test

Hardness testing samples: Non-standard models were used. Any model of composite material would be suitable for this test. The hardening device of the Rockwell hardness type (Rockwell) was used; the penetration tool is a ball of hardened steel (ball diameter 12.7mm) for the impact load (60kg) of diamond, equipped by the company (WOLPERT - Germany) for measuring the hardness of thermosetting Polymers, The device is placed perpendicularly to the sample for which the hardness is to be measured so that it's touching the surface of the sample whose hardness is to be measured, then wait for three seconds after which the hardness value is taken from the device, at least three readings have been taken in different places of the sample. Then, the average was taken [14].

Samples Compressive Resistance Test: The compressive strength test models were prepared according to the specification (618ASTM-D). It is a cylindrical hydraulic press type (Testing Machine Co.LTD) supplied by (WOLPERT - Germany) to determine the maximum compressive load the model can bear. Then, dividing this load by the cross-sectional area of the model before

deformation occurs. Compression strength was calculated for all models. Figure 3 shows the shape of the sample prepared for the compressive strength test.

Fig.(3): The sample prepared for the compressive strength test

Preparation Method:

An unsaturated polyester resin was used; a hardener (di benzoyl peroxide) was added in a ratio of 2: 1 to turn into a solid that gets solidified at room temperature. Then, composite materials samples were prepared from unsaturated polyethylene reinforced by the polyester in weight ratios (4%, 6%, 8%, 10%, 11%).

Hand-lay up Molding was followed in preparing models before and after reinforcement with polyethylene [15]. The resin was prepared by adding a hardener to the unsaturated polyester in a ratio of (1: 2), then the resin was added to the stiffeners, and then the mixture was placed in the molds designated for measurements, which were according to the standard specifications for each examination, and after the completion of the casting process, it was left for 24 hours at a temperature (23 ° C) and (53 ° C) to complete the curing, overlap and homogeneity processes between the particles, and reduce internal stresses formed during the casting, Fig.(4) shows a schematic diagram of the templates used to prepare the samples

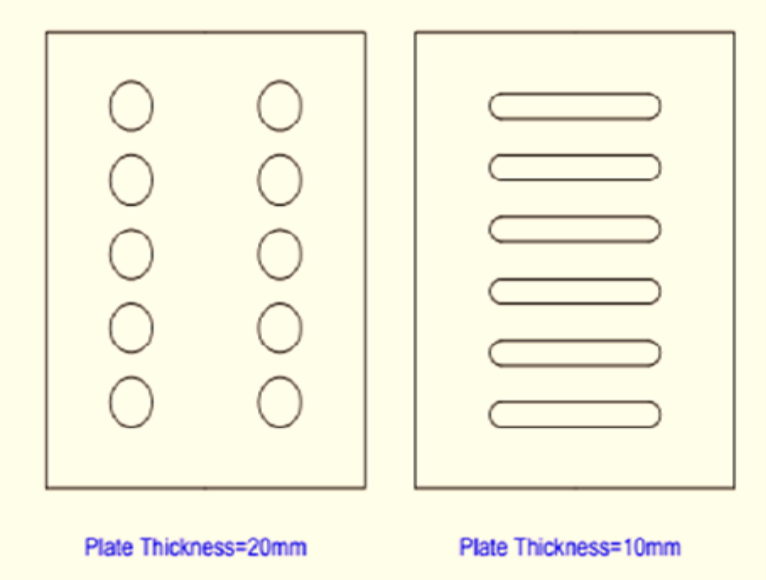

Fig.(4) shows a schematic diagram of the templates used to prepare the samples

Results & Discussion:

Impact Strength I.S

The impact strength test is one of the scientific ways that yields a correct result about the material strength and durability under stress at high speed [16]; the following equation calculates impact strength:

$$I \cdot S = \frac{energy\ of\ \ fracture\ \ (J)}{area\ of\ cross\ \ section\ \ (m^2)} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (1)$$

From Figure (5), we notice an increase in impact strength with the increase in the addition of polyethylene because the polymeric material is, by nature, a brittle material with low impact strength. The addition of polyethylene gives it some ductility and thus the impact strength improves; these added minute particles settle within the molecular chains and act as obstacles to crack and thus need a very large energy to break. The reason is attributed to the fact that the addition of the minute particles leads to the deflection in the fissure formation in the material, which causes a large surface area for the fracture, as the convergence of the fissure with the minute particles during an advance through the material will generate an impediment to its movement by the minute particles that can be considered as a barrier to the progression of the fissure and work to stabilize the fracture In the center of the presence of the minute particles, for the crack to cross this barrier and grow and change its form to small secondary cracks, it tries to cross between the minute particles this leads to an increase in the area of the crack and thus

requires more energy for the fracturing, which leads to an increase in the impact strength value [17].

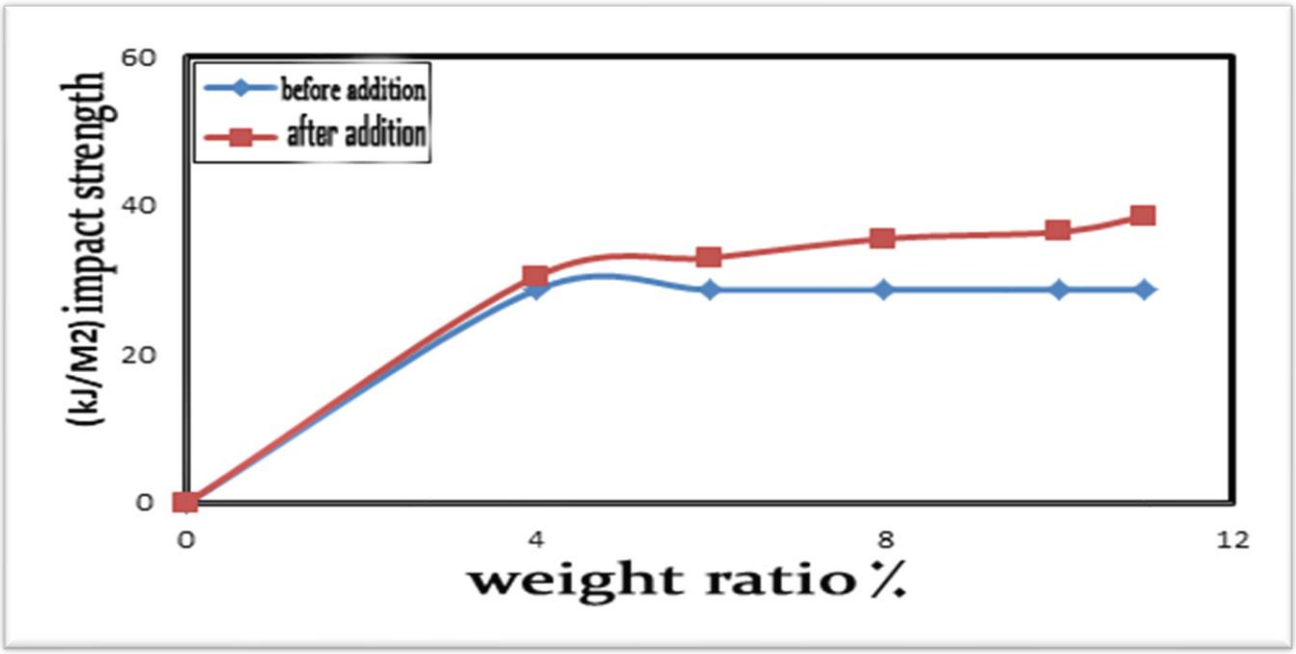

Fig.(5): The relationship between impact strength (I.S) and the weight percentage of unsaturated polyesters Before and after adding the minute particles at 23 °C.

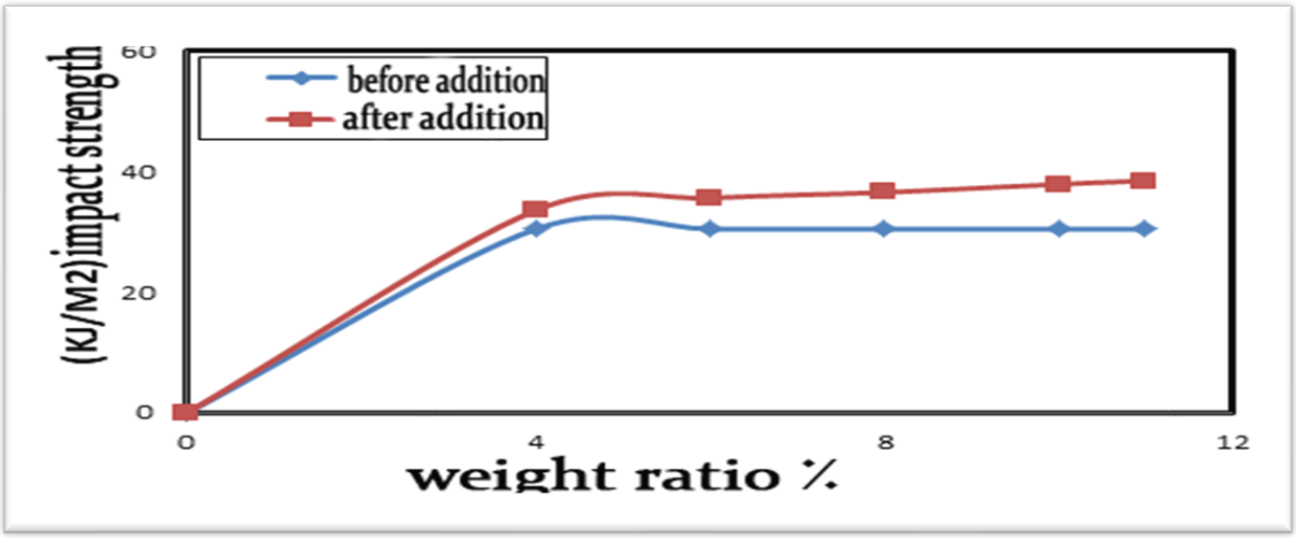

Fig.(6): The relationship between impact strength (I.S) and the weight percentage of unsaturated polyesters Before and after adding the minute particles at a temperature of 53 °C.

Table 2: impact strength values (I.S) for unsaturated polyester before and after reinforcement with different weight ratios at 53 ° C and 23 °C.

Composite at 23°C	Impact strength KJ/m2))	Composite at 53°C	Impact strength KJ/m2))
UPE	28.76	UPE	30.5
UPE+PE 4%	30.5	UPE+PE 4%	33.62
UPE+PE 6%	33	UPE+PE 6%	35.66
UPE+PE 8%	35.6	UPE+PE 8%	36.6
UPE+PE10%	36.5	UPE+PE10%	37.95
PUE+PE 11%	38.62	PUE+PE 11%	38.52

Hardness:

The hardness property is one of the important surface mechanical properties and is known as a measure of plastic deformation - which the material can suffer from under the influence of external stress imposed on it as a result of its exposure to scratching and penetration by tools that are harder than it during its use in various applications [18], through this research It was found that the higher the percentage of adding polyethylene, the lower the hardness values become, and the reason for that is that it works to make the material ductile, which reduces its hardness. The hardness values of all polymeric composites decrease with the increase in the temperature, as shown in Table (3).

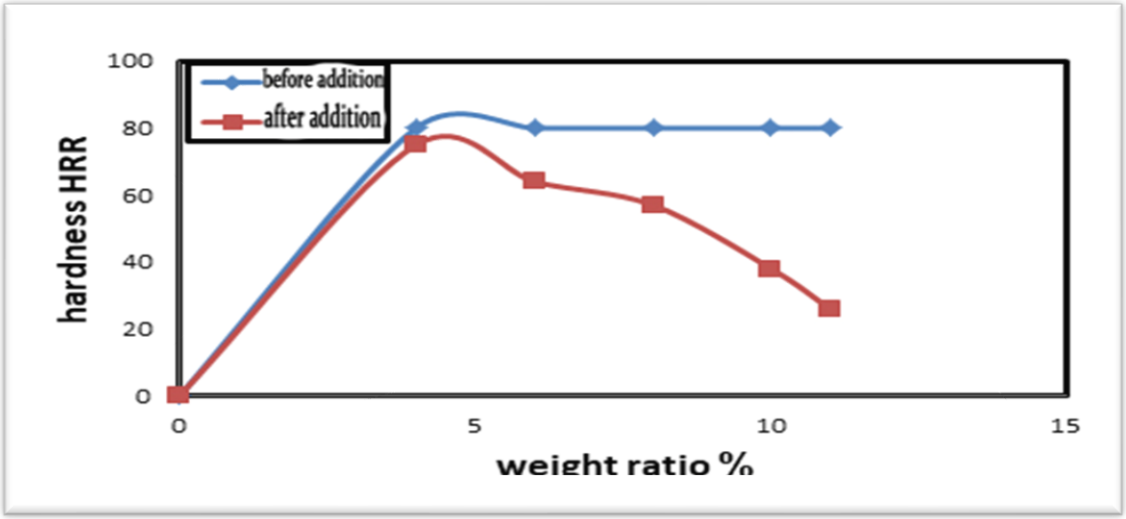

Fig. (7): Relationship between Hardness Rockwell (R) values and weight percentage for unsaturated polyesters before and after addition at a temperature of 23 °C.

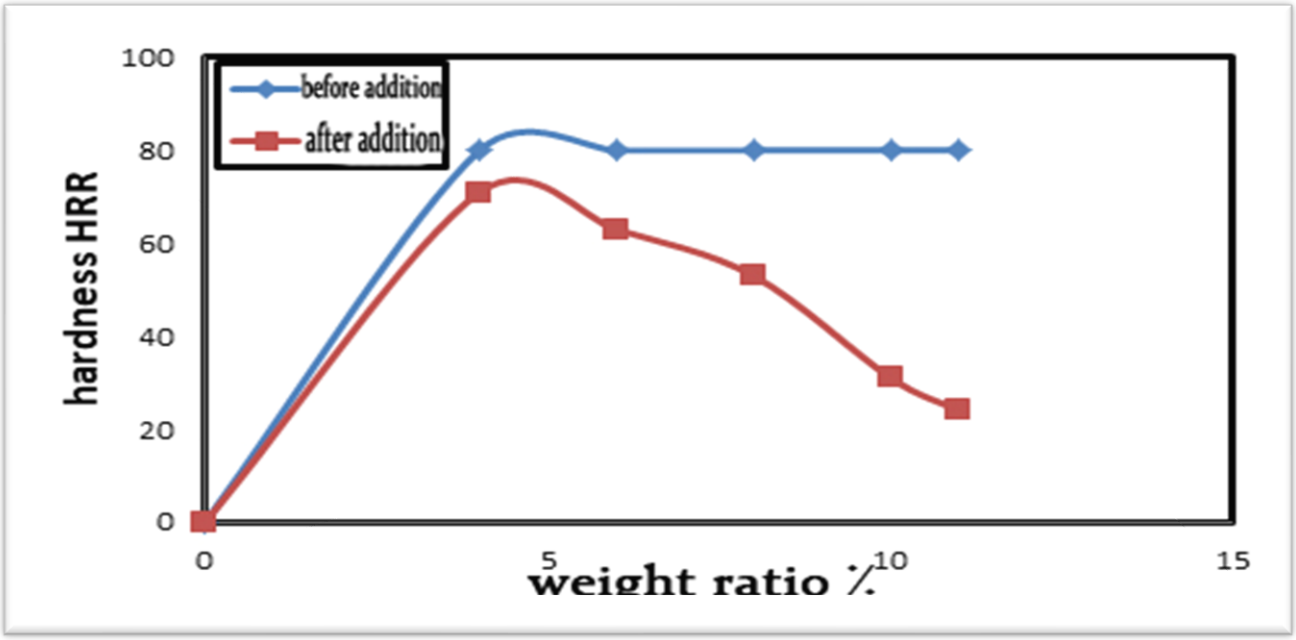

Fig. (8): Relationship between Hardness Rockwell (R) values and weight percentage for unsaturated polyesters before and after addition at a temperature of 53 °C.

Table 3: Hardness values for unsaturated polyesters before and after the addition with Different weight ratios at 53 ° C and 23 ° C.

Composite at 23°C	Hardness Rockwell(HRR)	Composite at 53°C	Hardness Rockwell (HRR)
UPE 23°C	80	UPE 53°C	77
UPE+PE 4%	75	UPE+PE 4%	71
UPE+PE 6%	64	UPE+PE 6%	63
UPE+PE 8%	57	UPE+PE 8%	53
UPE+PE10%	38	UPE+PE10%	31
PUE+PE 11%	26	PUE+PE 11%	24

Compressive Resistance Test

It is one of the most important tests to determine the durability and strength of the polymer. There are several materials that may be brittle in tension state but appear to be ductile in compression. Therefore, the compressive resistance test is used to determine the submissive strength in addition to the compressive strength [22]; it is defined as the amount of mechanical stress that a solid material endures under perpendicular stress. , Without breaking, shattering, or changing in its shape after the stress is removed. This test is widely used to examine fragile materials such as glass, concrete pieces, rocks, mastic iron, and heat-hardened polymers because these materials

have more strength in compression than in tension conditions, test samples used are cubic or cylindrical [23].

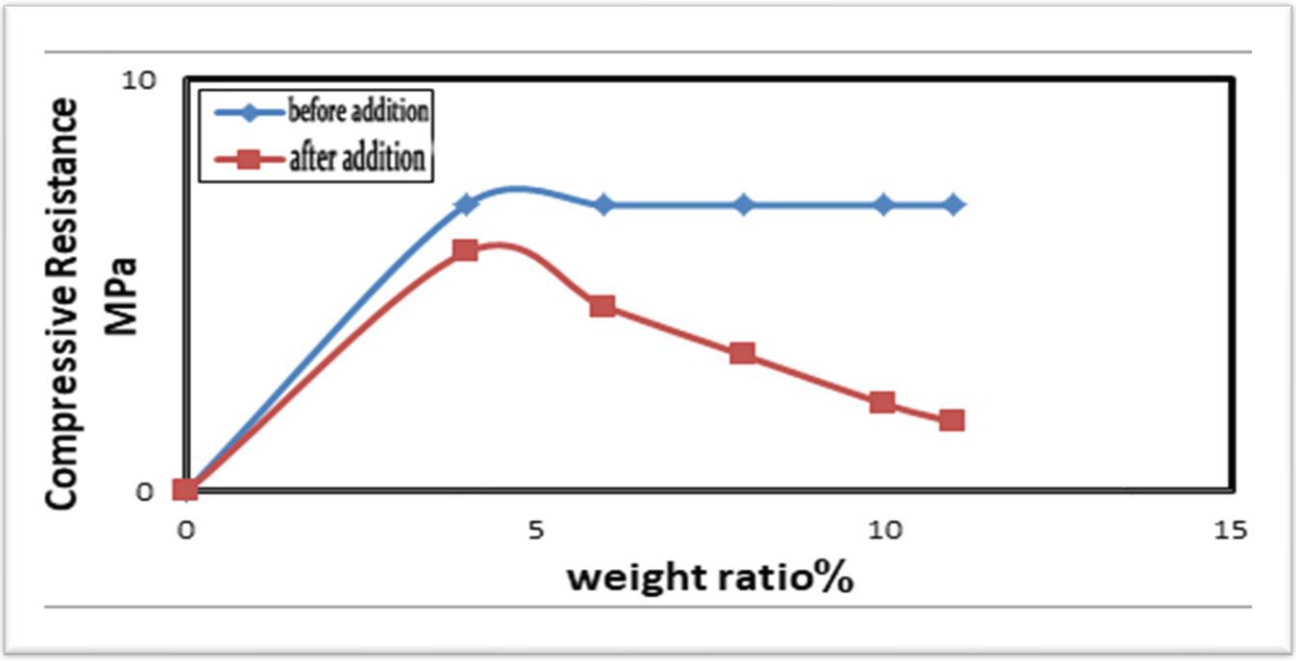

Fig. (9): Relationship between compressive resistance (C.S) and the unsaturated polyester's weight percentage before and after addition at 23 ° C.

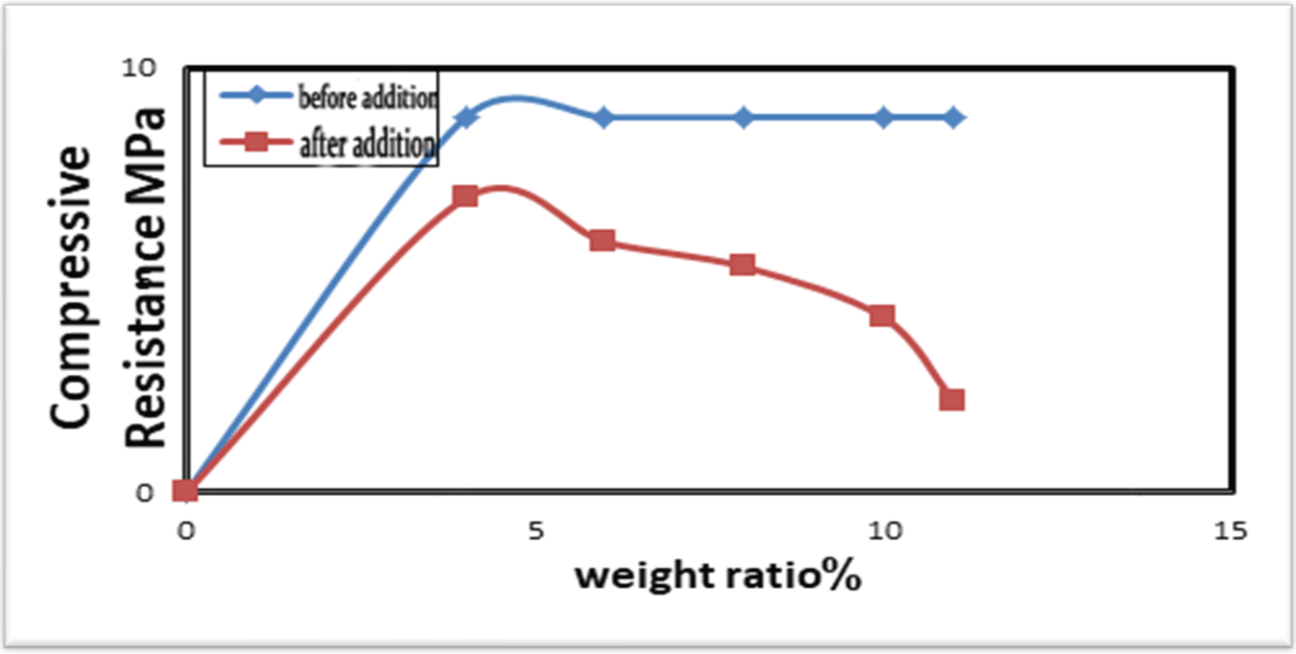

Fig. (10): Relationship between compressive resistance (C.S) and the unsaturated polyester's weight percentage before and after addition at a temperature of 53°C.

Table 4: compressive resistance of unsaturated polyesters before and after the addition in Different weight proportions at 53 ° C and 23 °C.

Composite at 23°C	Compressive strength Mpa	Composite at 53°C	Compressive strength Mpa
UPE 23°C	6.96	UPE 53°C	8.84
UPE+PE 4%	5.8	UPE+PE 4%	6.93
UPE+PE 6%	4.48	UPE+PE 6%	5.9
UPE+PE 8%	3.3	UPE+PE 8%	5.31
UPE+PE10%	2.13	UPE+PE10%	4.11
PUE+PE 11%	1.68	PUE+PE 11%	2.16

Conclusions

The hardness decreases with the increase in the percentage of adding polyethylene. The Impact Strength increases with the increase of the addition of the percentage of polyethylene. The compressive resistance decreases with the increase in the addition of polyethylene

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