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# Effect of Unsaturated Polyester on Some Properties of Cement Mortar

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**Abstract:** Using polymers to modify mortar improve the workability, adhesion, strength, durability of the cement besides improving cure characteristics. Two mixtures of cement-sand were prepared without water. The first is 1:2 cement: sand and the other ratio was 1:1 cement: sand mixture. Unsaturated polyester was added to the two mixtures at different ratios (30:70, 40:60, and 50:50) polymer to cement- sand mixture. The effect of unsaturated polyester was studied on both mixtures by calculating the density besides measuring the hardness and compressive strength of specimens .The addition of unsaturated polyester showed an improvement in these properties and showed that the increase in the unsaturated polyester percent improve the mechanical properties.

***Keywords****: polymer cement, unsaturated polyester composite, Modified mortar.*

## تأثير البولي أستر غير المشبع على بعض خواص مونة السمنت

**الخلاصة:** ان استخدام البوليمر لتحسين الملاط سيؤدي الى تحسين الخواص التشغيلية والألتصاقية والمتانة وكذلك المطيلية هذا الى جانب انه يتصلب بصورة اسرع. حضر مزيجان من الأسمنت- رمل بدون ماء، الاول بنسبة 1:1 أسمنت:رمل والأخر بنسبة 2:1 أسمنت:رمل. اضيف الى المزيجان بوليمرالبولي أستر غير المشبع بنسب مختلفة (30:70 و40:60 و50:50) بوليمر الى خليط السمنت والرمل. درس تأثير اضافة البولي استر غير المشبع على المزيجين وذلك بحساب الكثافة وقياس الصلادة ومقاومة الأنضغاط للعينات. وجد ان اضافة البولي أستر يظهرتحسن بالخواص بشكل ملحوظ ،كما ان زيادة نسبة البولي أستر غير المشبع تؤدي الى زيادة الخواص الميكانيكية.

## 1. Introduction

Polymer concrete (PC) is a composite material formed by combining mineral aggregates such as sand or gravel with a monomer. Polymer concrete (PC) is a composite material in which the binder consists entirely of a synthetic organic polymer. It is variously known as synthetic resin concrete, plastic resin concrete or simply resin concrete. [1, 2] Mortar and concrete made with portland cement has been a popular construction material in the world for the past 170 years or more.

However, cement mortar and concrete have some disadvantages such as delayed hardening, low tensile strength, large drying shrinkage and low chemical resistance. To reduce these disadvantages, many attempts to use polymers have been made. One such attempt is polymer-modified (or polymer-cement) mortar or concrete, which is

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made by modifying ordinary cement mortar or concrete with polymer additives such as latexes, redispersible polymer powders, water-soluble polymers, liquid resins, and monomers.[3]

Highly flexible polymer-modified cements (mortars) can be formulated using various types of polymers with a low *Tg* temperature.

The key reason for using these materials is their flexibility and allowing waterproofing of concrete structures with "moving cracks." In addition, these materials, due to their high polymer content, exhibit a considerably higher chemical resistance (even in acidic environments) when compared with conventional portland cement mortars or concrete. [4]

Due to its rapid setting, high strength properties and ability to withstand a corrosive environment, PC is increasingly being used as an alternative to cement concrete in many applications, construction and repair of structures, highway pavements, bridge decks, waste water pipes and even structural and decorative construction panels. These widely divergent uses clearly indicate that no commercially available product could be compounded to perform all these tasks well; therefore, the term PC should never suggest only one product, but rather a family of products. Advances in coupling agents and material science in general further optimize the PC mixtures. [5]

Because the use of a polymer instead of Portland cement represents a substantial increase in cost, polymers should be used only in applications in which the higher cost can be justified by superior properties, low labor cost or low energy requirements during processing and handling. [6]

The performance characteristics of polymer modified cement are controlled by characteristics of its individual components. The type of cement paste, type of polymer and their respective quantities largely control the properties of polymer cement composites. However, there are other influences controlling the final properties of the composite such as the type of surface-active agents used, mixing and curing. There are a large number of polymer (monomer) types that are used in modification of portland cement paste. These types of polymers can be further classified by their chemical natures. [2]

Kay A. Bode and Andrea Dimmig-Osburg in 2011 measure the shrinkage of polymer-modified cement mortars (PCMs) and polymer modified cement stones. Two polymers were used in this study (Polymer 1 – redispersible powder with a film formation temperature of 5 °C, Polymer 2 – dispersion with a film formation temperature of 30 °C). Both based on styren-acrylic ester copolymer. The prisms were stored under various climate conditions and show a varying shrinkage accordingly.

They conclude that this polymer modified cementious matrixes show a higher shrinkage than the non-modified ones. But it is also known, that the PCMs show fewer cracks due to shrinkage. [7]

Viswanath, Priya 2012, in this work different polymer were added to Portland cement in various proportions and the mechanical and chemical resistance properties of the resultant composites when exposed to chemical environments were studied.

Most polymers did not improve the compressive strength of the cement paste, it was found that they enhanced the resistance of the virgin cement paste to external chemical environments. The polymers seal the pores in the cement matrix and bridge the microcracks within the composite. Polymers also decreased the leachability of water soluble components of virgin cement resulting in composites having improved durability. [8]

The aim of this work is to modify the cement to more flexible construction material by mixing it with polymer and to reveal the effect of adding polymer to cement-sand mixture on some mechanical properties of polymer- cement composites.

## 2. Experimental Work

The experimental work was carried on to complete the aim of the research starting from preparing of materials to the ending with testing the preparing specimens.

### *2.1. Specimens preparation*

1. The polymer used in this work was unsaturated polyester which composed of:
   **a-** Resin …. Unsaturated polyester (in a liquid state).
   **b-** Accelerator …. Cobalt Naphthalate (in a liquid state).
   **c-** Hardener …. Methyl ethyl Ketone Peroxide (MEKP) (in a liquid state).
2. The cement used in this study was Iraqi ordinary Portland cement. It was stored in dry place to minimize the effect of humidity on cement properties .The chemical and physical properties of cement are given in table (1) which conformed to Iraqi Standard Specification No.5/1984.

Table 1. Chemical composition & physical properties of Portland cement.

| Chemical composition | | | Physical properties | | |
|---|---|---|---|---|---|
| Item | Content % | Specification Limit according to IQS/5/1984 | Item | Test result | Specification Limit according to IQS/5/1984 |
| $SiO_2$ | 20.66 | - | Fineness($m^2$/kg) | 310 | 230 |
| $Al_2O_3$ | 4.34 | - | Autoclave exp | 0.24 | 0.8% |
| $Fe_2O_3$ | 3.40 | - | Compressive Strength (MPa) | | |
| CaO | 63.71 | - | 3-days age | 17.2 | 15.0 |
| MgO | 2.07 | 5.0 max | 7-days age | 26.0 | 23.0 |
| $SO_3$ | 1.17 | 2.8max | Time of setting | | |
| L.O.I. | 2.52 | 4.0 max | Initial (min) | 75 min. | 45 |
| I.R. | 1.03 | 1.5 | Final (hour) | 4.15 | Ax 10 |

**3.** The fine aggregate used throughout this study was Iraqi sand .The grading of fine aggregate is shown in table (2).The used sand within zone 2 according to the requirements of the Iraqi Standard Specification No.45/1984.

Table 2. Grading of fine aggregate

| Sieve size (mm) | % Passing by Weight | Specification Limit according to IQS/45/1984 |
|---|---|---|
| 4.75 | 93.2 | 90-100 |
| 2.36 | 84.2 | 75-100 |
| 1.18 | 68.0 | 55-90 |
| 0.60 | 37.8 | 35-59 |
| 0.30 | 19.6 | 8-30 |
| 0.15 | 8.8 | 0-10 |

### *2.2. Density*

Bulk densities were calculated for each specimen of polymer-cement composites cubes (in g/cm$^3$); by weighing these cubes and divide their weight by the volume of these cubes (5×5×5) cm$^3$.

### *2.3. Hardness Test*

According to the ASTM D2240, Rockwell Hardness was used to find the hardness of composites cubes which is found by taking six readings on each face of the cube, the faces of the cube was cleaned from dust and any obstacles to ensure probably reading by the device .the hardness was calculated by taking the average of all readings for each cube of different percentages.

### *2.4. Compressive strength*

According to ASTM C 109/C 109M- 13,the cubic specimens were tested by using the hydrostatic compression test machine with a maximum capacity of 800kN, and the maximum compression load that each specimen having the dimensions of (5×5×5) cm had been recorded. Finally the compressive strength was calculated.

## 3. Results and Discussion

The important factors affecting the properties of polymer-modified mortars based on styrene-like dispersions polymerized with various monomer ratios are the variations of the polymer film strength, polymer film formability, and pore size distribution with changing bound styrene content and polymer to cement ratio. Only when the above requirements have been satisfied, the various possible advantages to be gained from the use of polymer dispersions may be put forward.

- **Density**

Adding the polymer to the cement- sand mixture effect many properties such as the physical properties and mechanical as well.

It was noticed that the density of all the manufactured composites of both cement- sand mixtures (1:1 and 1:2) will decrease as the polymer ratio increased as shown in the figure (1) and (2). The most acceptable explanation for this result is that the unsaturated polyester density is (1.2 gm /$cm^3$) [9], while the cement –sand mixture density is higher so when the ratio of the added polymer increased the density of it become dominant more than the density of cement –sand mixtures which cause decrease in the weight, so as a result the composite density will decrease because composite materials gain its characters from its components. [10]

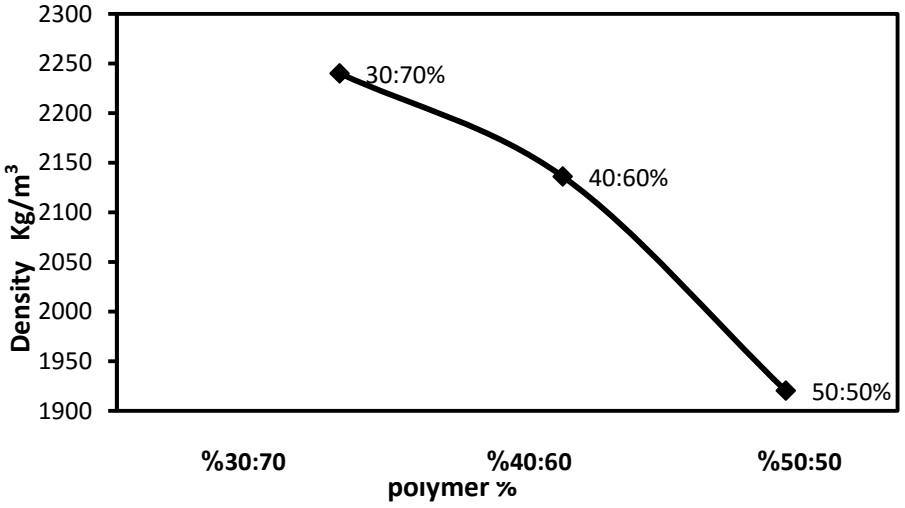


Figure 1. The effect of increasing polymer percents on the density of cement-sand mixture (1:1)

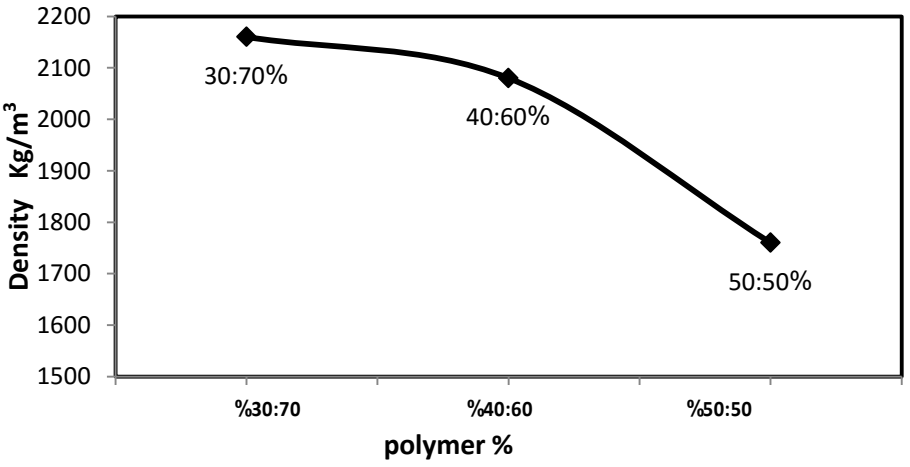


Figure 2. The effect of increasing polymer percents on the density of cement-sand mixture (1:2)

The comparison between the densities of both cement –sand mixtures (1:1 and 1:2) show closer values after the addition of the unsaturated polyester; whatever the cement to the sand ratio as shown in the figure (3). This refers to the homogeneity that the polymer creates it in both cement- sand mixtures.

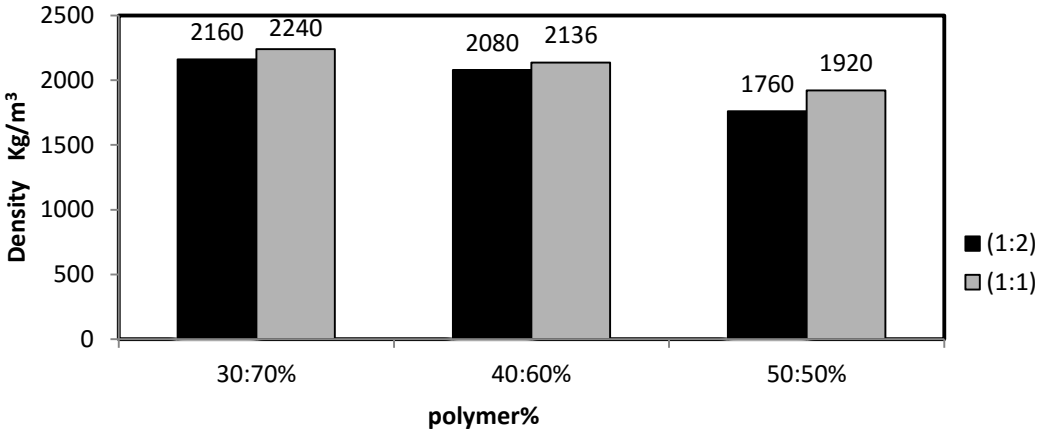


Figure 3. A comparison between both the cement-sand mixture (1:1) and (1:2) showing the effect of increasing polymer percents on the density.

- **Hardness Test**

The hardness for both mixtures (1:1 and 1:2) increased as the unsaturated polyester percent increase in the composites. Figure (4), (5) show this behavior and the comparison between them in figure (6). The hardness is the measure of a material resistance to deformation by surface indentation or by abrasion [9], and increase in hardness can be attributing to the fact that the polymer described as a material with minimum pores [11]; so the polymer will close the cement –sand porosity which introduce a smooth surface with higher hardness.

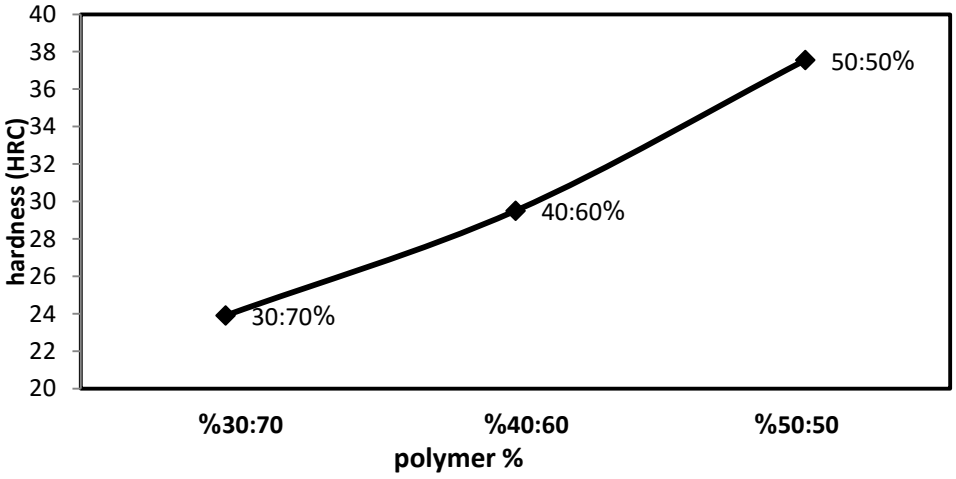


Figure 4. The effect of increasing polymer percents on the hardness of cement-sand mixture (1:1)

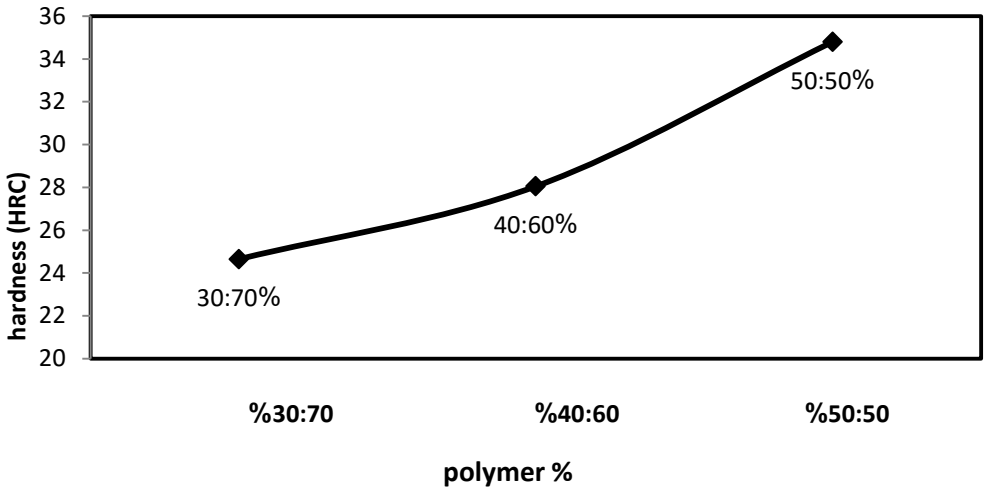


Figure 5. The effect of increasing polymer percents on the hardness of cement-sand mixture (1:2).

In spite of the close values between the composites of (1:1 and 1:2) but it's obvious that as the polymer ratio increased the hardness increase for (1:1) cement – sand composites more than (1:2) cement –sand composites. It is well- known that the increasing in sand ratio will produce loose mixtures with higher porosity which makes it decrease the hardness of the composites.

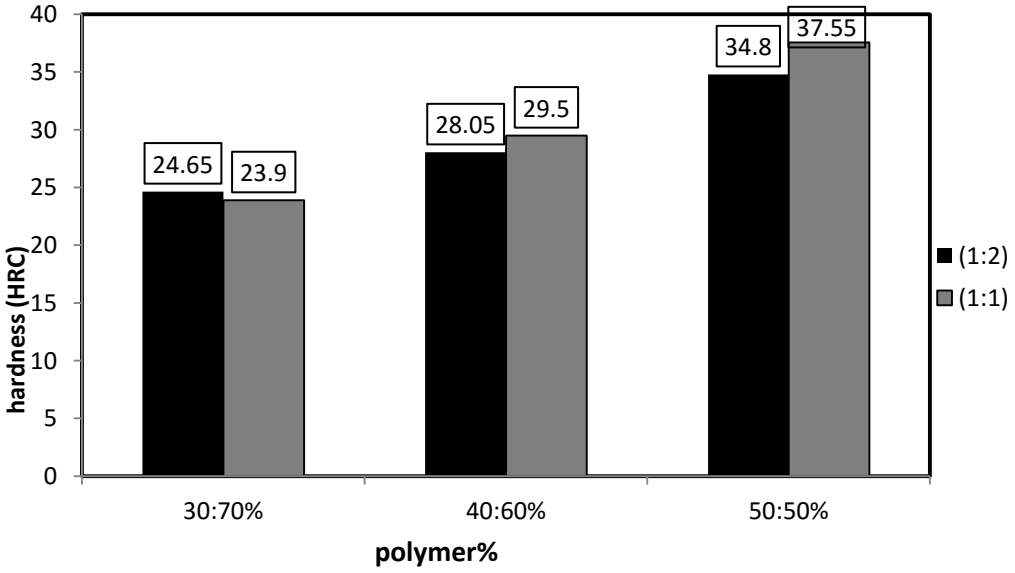


Figure 6. A comparison between both the cement-sand mixture (1:1) and (1:2) showing the effect of increasing polymer percents on the hardness.

- **Compressive strength**

As in the hardness results the compressive strength were increased as the unsaturated polyester ratio increased for all the composites. As shown in the figures (7) and (8).

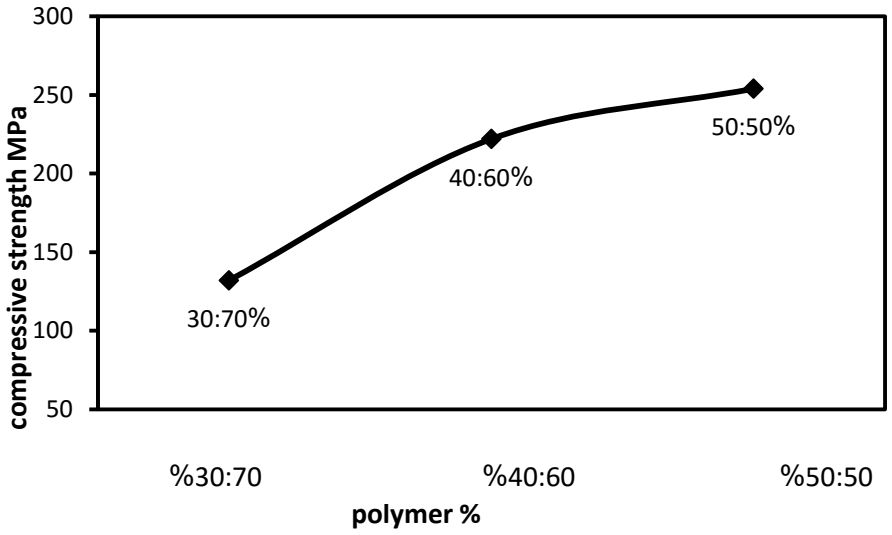


Figure 7. The effect of increasing polymer percents on the compressive strength of cement-sand mixture (1:1)

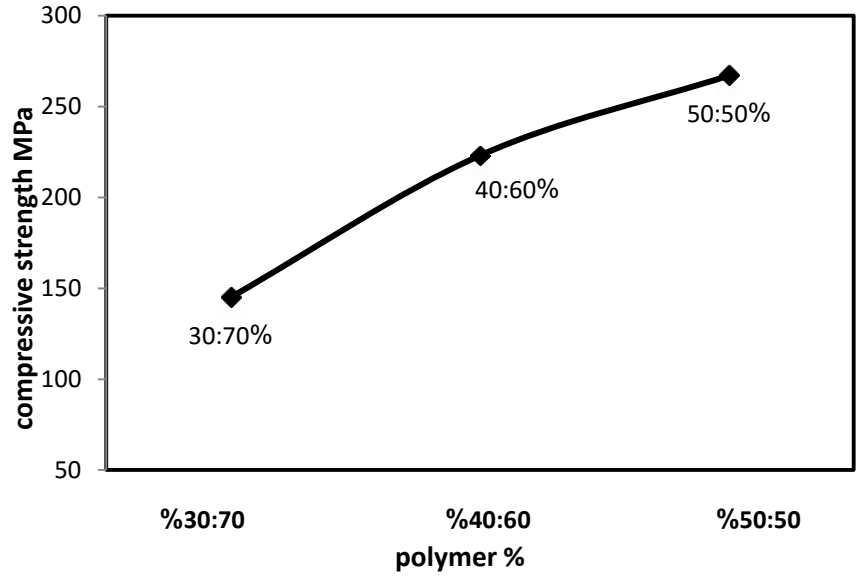


Figure 8. The effect of increasing polymer percents on the compressive strength of cement-sand mixture (1:2).

Also the comparison between the composites shows an increase in the compressive strength for (1:2) more than (1:1) composites. As shown in the figure (9).

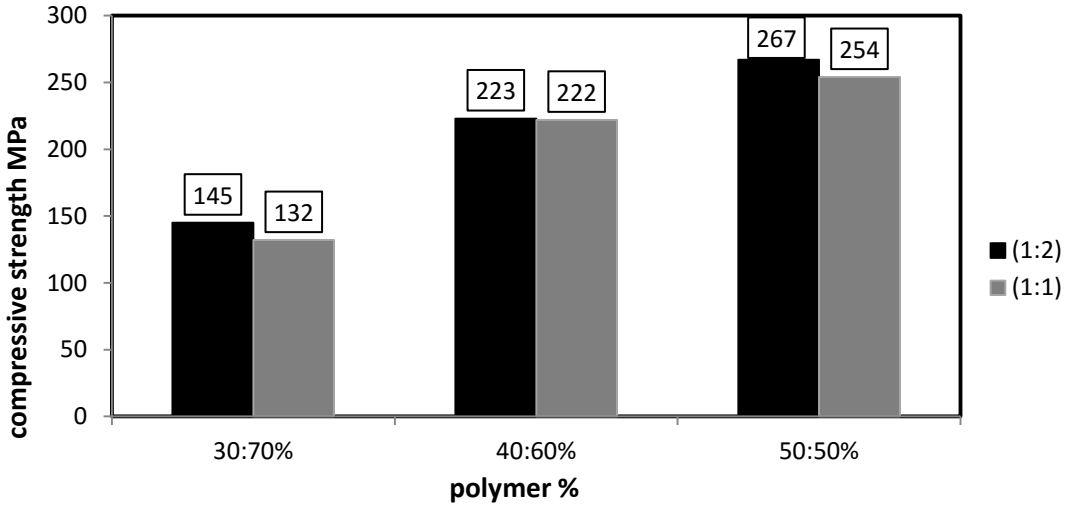


Figure 9. A comparison between both the cement-sand mixture (1:1) and (1:2) showing the effect of increasing polymer percents on the compressive strength.

The cement –sand mixture consider as brittle material and brittle materials cannot predict its behavior against failure easily unlike the ductile materials [12], so the addition of unsaturated polyester made it more homogeneous, more compact and give it some elasticity which distribute the load more uniformly on the composite specimens that cause increasing in the strength and delaying the failure. This can clarify the increasing of the compressive strength in all composites.

It can be concluded when studying the hardness with the compressive strength that the increasing in the hardness conjugated with increasing in the compressive strength as the unsaturated polyester ratio increased, as shown in the figure (10).

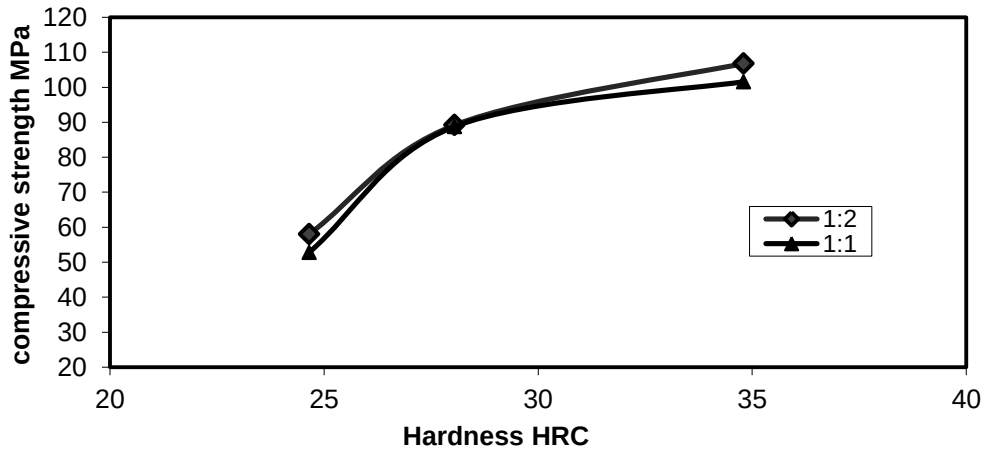


Figure 10. A relationship between both the cement-sand mixture (1:1) and (1:2) showing the effect of increasing the hardness with increasing the compressive strength

## 4. Conclusions

1. The addition of unsaturated polyester improves the properties of cement-sand composites whatever the percent of the polyester.

2. The unsaturated polyester decreases the density of cement –sand composites by decreasing its weight.
3. The unsaturated polyester increases the hardness of cement –sand composites.
4. The unsaturated polyester increases the compressive strength of cement – sand composites.

**Abbreviations**

| | |
|---|---|
| PC | Polymer concrete |
| PCMs | polymer-modified cement mortars |
| MEKP | Methyl ethyl Ketone Peroxide |
| MPa | Mega Pascal |

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