Effect of Hydrocarbon Solutions on Polymer Concrete

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ABSTRACT

The damaging effect of oil products on concrete besides the high permeability of concrete have made researchers try to improve the properties of concrete exposed to oil products, hence improving the durability and serviceability of oil concrete structures.

Polymer concrete exposed to oil products is one of a new field that deals with the enhancement of concrete durability. In the present work polyester resin concrete was used and then immersed in different types of oil exposure liquids (gasoline, gas oil and kerosene) compared with reference concrete which left in the air.

Polyester resin concrete is used as a new type in this field, it is noteworthy that the use of this concrete gives good test results that raise the values of the mechanical properties, so we did the SEM test in an attempt to study the microstructure of this concrete after soaking for 90 days in oil products.
Keywords: Polymer concrete (PC), unsaturated polyester resin, mechanical properties.

INTRODUCTION

Polymer concrete (PC) is a particulate composite where thermoset resins bind inorganic aggregates instead of the water and cement binder typically used in Portland cement concrete (PCC).We thus have a polymeric matrix and dispersed particles of strengthening phases. The polymer constitutes the continuous phase hence the composite behavior is largely determined by the properties of the polymer, which are dependent on time, structure, and temperature. Polyester resins have been used for the purpose [1].

Let us first make a survey of PCs used so far. In 2004, **Jane Proszek and et al.** studied the modulus of elasticity of polymer concrete compounds and comparative assessment of polymer concrete and portland cement concrete, to assess the modulus of elasticity of polymer concrete (PC) compounds produced by using two types of binders: orthophtalic or isophtalic polyester. The concentrations of polymer used were 12% of orthophtalic polyester and 13% of isophtalic polyester by weight of the dry materials. Fly ash was used as filler and compositions with 8%, 12%, 16% and 20% of ash by weight of aggregate were studied. Results indicate that all compositions assessed in this study display high modulus of elasticity values [2]. In 2006, **Namshik Ahn** studied the effects of three metallic monomer powders on polyester and acrylic hardened polymer concretes, polymer concretes incorporating different levels of these materials were investigated for the properties of hardened polymer concrete. The mix design was made and optimized for workability and strength, depending on the resin viscosity. It was concluded that these polymeric materials offer the possibility of improving the properties of polyester- and acrylic-hardened polymer concretes [3]. In 2008, **Namshik Ahn** also studied the moisture sensitivity of polyester and acrylic polymer concretes with commercial metallic monomer powders, polymer concretes containing different levels of these powders were investigated with

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respect to the properties of hardened polymer concrete. The mix design was made and optimized for workability, strength, and economy, which depended on the resin viscosity. The investigated properties included the compressive and flexural strengths of hardened polymer concrete. These polymeric materials offer the possibility of using wet aggregates in polyester and acrylic polymer concrete construction [4]. In 2011,**J.M.L. Reis** studied the fracture mechanics (toughness and energy), at early ages, of polymer concrete made with unsaturated polyester resin as a binder. The results indicate that the fracture parameters (toughness and energy) decrease and the brittleness increases with the age of the polymer concrete [5].

Experimental

For preparing the PC specimens, AL- Ekhaider sand (4.75mm maximum size) and coarse aggregate crushed to 37.5 mm maximum size was used, as well as a commercial unsaturated polyester resin. A dry mixing had been done for both fine and coarse aggregate for 3 minutes and then the unsaturated polyester resin was added to the mix after mixing with the hardener in 0.01% of its weight, after one day, the molds were removed and the specimens were cured in air for a period of 28 days.

Two mixes design were used in this work:

(1: 1: 2) 100*100*100 cubic and **(1: 2: 4)** 100*200 cylindrical specimens were used for the compressive strength and splitting tensile strength tests including polyester concretes. It had no percent of cement and water. The content of unsaturated polyester resin was 11.5 kg/m^3 for cubic and 5.75 kg/m^3 for cylinder for each mixture. Tables (1) and (2) show the details of used mixture.

Table (1) shows the details of cubic specimens mixture used throughout this investigation.

Mixed type	Mixed component by weight kg/m3						
	Cement kg/m3	Water Lit.	FineAggregate kg/m3	Coarse Aggregate kg/m3	Polyester kg/m3	P/C ratio %	W/C
Polyester concrete	0	0	529	1058	529	0	0

Table (2) shows the details of cylindrical specimens mixture used throughout this investigation.

Mixed type	Mixed component by weight kg/m3						
	Cement kg/m3	Water Lit.	Fine Aggregate kg/m3	Coarse Aggregate kg/m3	Polyester kg/m3	P/C ratio %	w/c
Polyester concrete	0	0	1704	852	426	0	0

Test Procedures

Compressive strength:

The compressive strength test was determined according to B.S.1881, part 116 [6]. This test was made on 100 mm cubes using an electrical testing machine with a capacity of 2000 kN. The test was conducted at ages of 30, 60 and 90 days of exposure to oil products after 28 days air curing. The compressive strength of the specimen was calculated by dividing the maximum load carried by the specimen during the test by the average cross-sectional area of the specimen.

$$\text{Compression} = \text{force} / \text{area} \quad \ldots(1)$$

Compression: [MPa].
Force: [N].
Area: [mm²].

Splitting tensile strength:

A concrete cylinder is placed with its horizontal axis between platens of a testing machine; the splitting tensile strength test was done according to ASTM C496-86[7] specification. Cylinders of 100×200 mm were used and load was applied continuously up to failure using a standard testing machine of 2000 kN capacity. The test was conducted at ages of 30, 60and 90 days of exposure to oil products after 28 days air curing.

$$T = 2P / \pi D L \quad \ldots(2)$$

Where:
T: splitting tensile strength, (MPa).
P: Maximum applied load, (N).
D: diameter of specimens, (mm).
L: length of the specimens, (mm).

Results and discussions

Compressive strength

Compressive strength is the most important property of concrete since the first consideration in structural design is that the structural elements must be capable of carrying the imposed loads. Figure (1) summarizes the results of compressive strength values for polyester resin concrete at various periods of immersion in oil products relative to reference concrete which left in air. The compressive strength results for polyester concrete specimens show an increasing may be due to many reasons such as high density, less porosity, good dispersion of polymer particles within the pore volume, elimination of the large pores, and good compatibility with aggregate. While the test results for concrete specimens immersed in oil products showed a continuous decrease in compressive strength with immersion time increase. The reasons of this behavior may be because of that the oil products decrease the compatibility and bond strength between the resin polymer with aggregate due to penetration of oil products into the microstructure of concrete leading to weak adhesion and cohesion forces [8].Figure (2) shows the specimens after inspection.

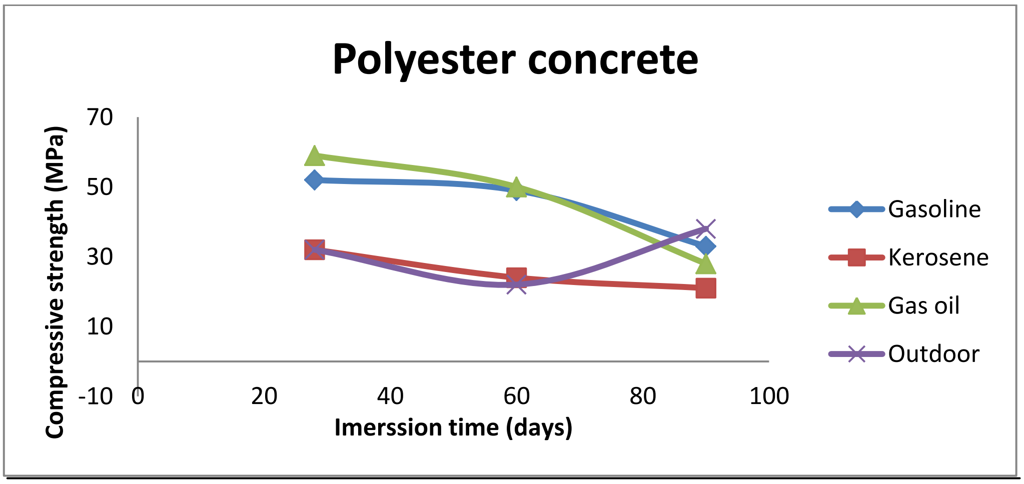


Figure (1) Compressive strength results for polyester concrete specimens at various ages of immersion in oil products and outdoor concrete.

Figure (2) the polyester resin concrete specimens after compression test.

Splitting tensile strength

Splitting tensile strength is an important property, since cracking in concrete is most generally due to the tensile stresses that occur under load, the failure of concrete in tension is governed by micro cracking, associated particularly with the interfacial transition zone (ITZ)[9]. Figure (3) summarize the results of splitting tensile strength values for polyester resin concrete at various periods of immersion in oil products relative to reference concrete which left in air. Results demonstrate that the splitting tensile strength shows a considerable increase at all testing periods for specimens cured in air and this increasing may be because of the formulation of three-dimensional networks of polymer molecules through the concrete increases the binder system due to good bond characteristics of the polymer, Or the partial filling of pores with polymer which reduces the porosity, and hence increases the strength [10].On the other hand when the specimens were exposed to oil products they showed decrease in splitting tensile strength values during 90 days of exposure that may be due to the deterioration of concrete exposed to oil products and the effect of bond between aggregate and polyester resin due to increase in micro cracks in the microstructure of concrete specimens [11].Figure (4) shows the specimens after inspection.

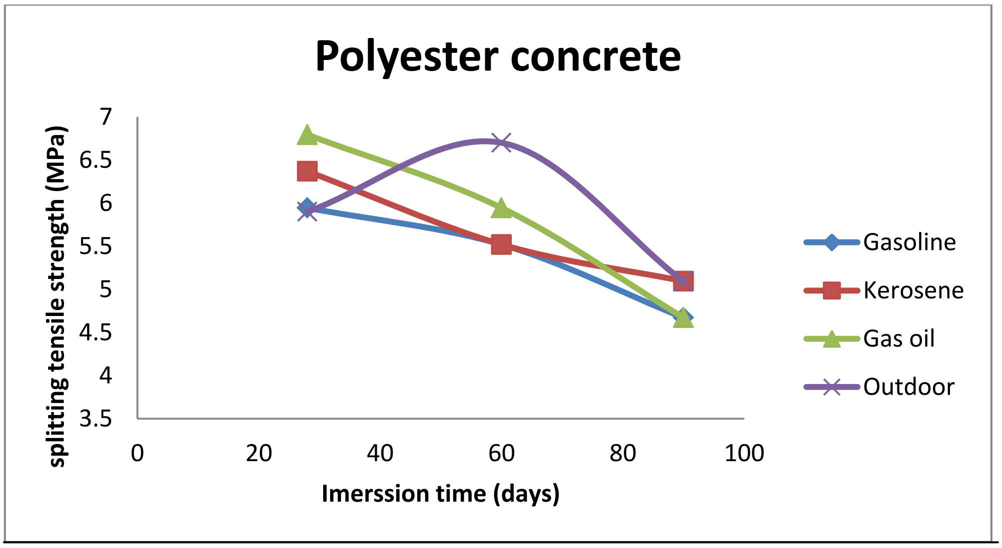


Figure (3) Splitting tensile strength results for polyester concrete specimens at various ages of immersion in oil products and outdoor concrete.

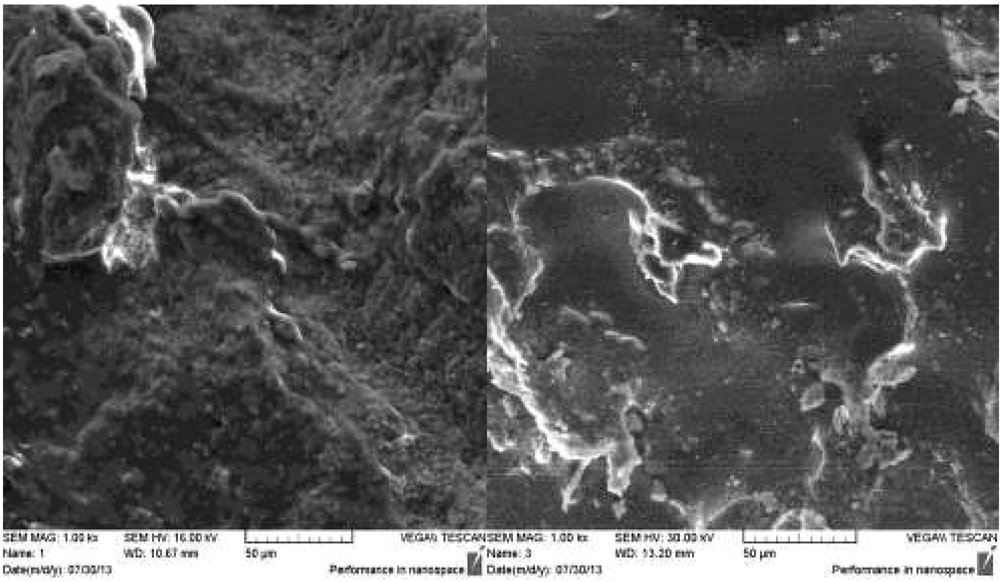
Figure(4) the polyester resin concrete specimens after splitting tensile test.

Morphological analysis

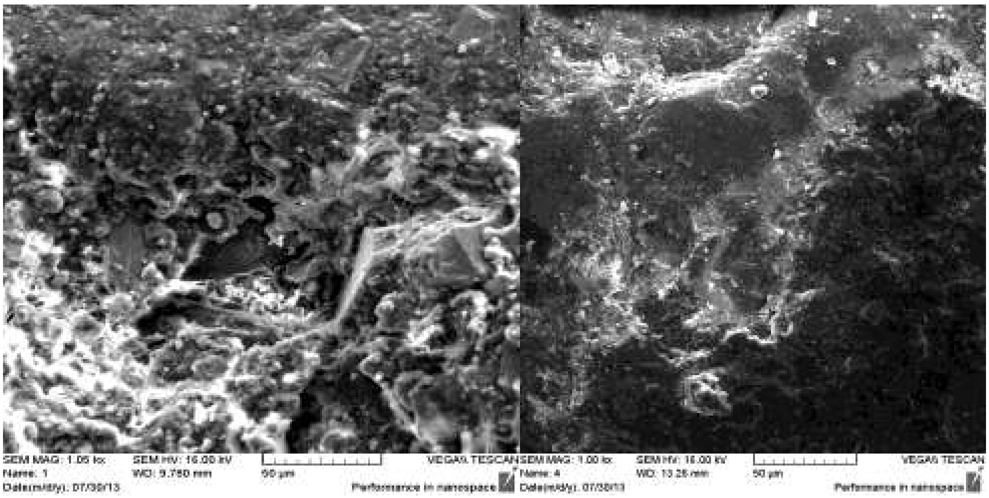
The study of concrete microstructure of polyester resin specimens continuously exposed to oil products relative to that which left in air has benefited greatly from the use of microscopic examination and in particular scanning electron microscopy (SEM). SEM has been developed to imaging the complex microstructure of concrete and to provide images with sub-micrometer definition. The application of SEM enhances our ability to characterize concrete microstructure, and will aid in evaluating the influence of supplementary additive material, evaluation of concrete durability problems, and in the prediction of its service life [12].

Specimen preparation is important in any microscopical technique with proper preparation methods facilitating examination and interpretation of micro structural features. A slice from specimens to be examined is taken from the species of specimens after failure to get a suitable thickness of (5mm) from 1cm depth from the surface of the cube specimens. The slices are oriented in any required manner to make polished section to be examined by this technique [13]. The surfaces of the fractured zone of the manufactured polyester resin concrete, before and after exposure, are analyzed by scanning electron microscope.

The mechanical performance can be connected to the morphology evaluated by SEM. Figures (5 A to D) show the fracture zone after testing the PC. For non-immersed PC an analysis of both; silica sand and polyester resin was carried out. First, sand particles were well visible, contributing to the material resistance against deformation under a compressive load. Then, the particles tend to disintegrate. The mechanical features are decreased with increasing the exposure period, moreover, crack formation in the resin is seen, and thus, a separation between the sand particles and the resin occurs. This causes lowering in compressive strength. After 90 days of exposure, apparently the resin contraction occurs. Then, if a sand particle is present in a resin matrix, it will be surrounded by the resin. With time, the resin will start its polymerization, which will cause the following effects: breakdown of the resin (cracks) and resin contraction with pulling out from the sand particles. The high compressive strain values can be explained in terms of surface morphology of the polymer concrete.



a- 5 mm from the surface of the Outdoorspecimen. **b- 5 mm from the surface of the Gasoline specimens.**



c- 5 mm from the surface of the Gas oil specimens. **d- 5 mm from the surface of the Kerosene specimens.**

Figure(5 a, b, c and d) SEM show the fracture analysisof PC specimens continuously immersed in oil products and outdoor specimens for 90 days.

Figures (6) to (9) show the SEM micrographs in different magnification for polyester resin concrete continuously immersed in gas oil, gasoline, and kerosene after exposure period of 90 days. It is clear that the micro structure of PC exposed to different oil products shows deterioration of concrete due to high volume of voids and different microstructure in comparison with microstructure of the reference concrete which was left in air (outdoor).

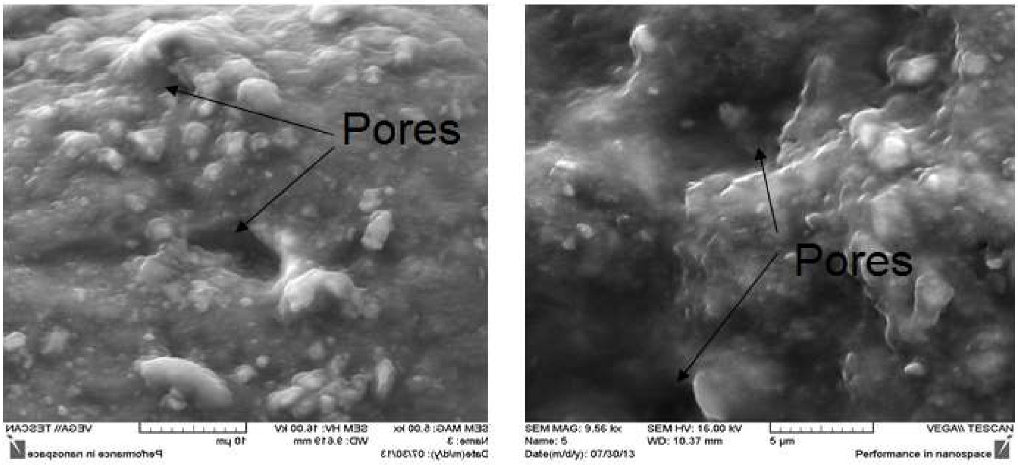
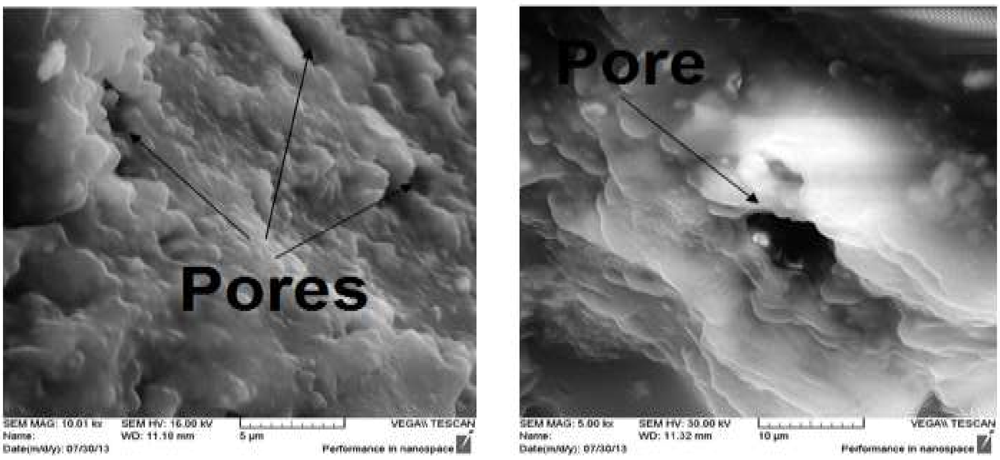


Figure (6) SEM imagesof5 mm from the surface of PC specimens left in air for 90 days.



Figure(7) SEM images of 5 mm from the surface of PC specimenscontinuously immersed in gasoline for 90 days.

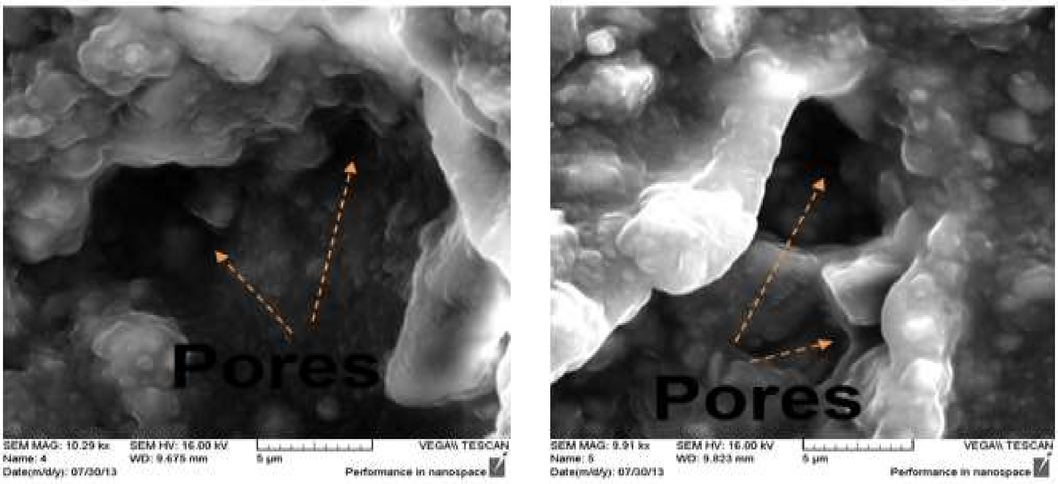


Figure (8) SEM images of 5 mm from the surface of PC specimenscontinuously immersed in gas oil for 90 days.

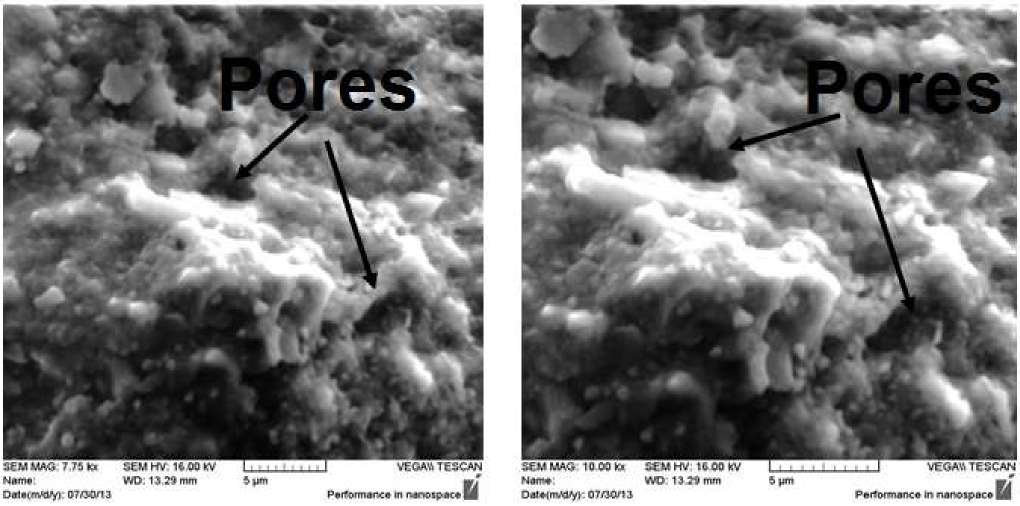


Figure (9) SEM images of 5 mm from the surface of PC specimens continuously immersed in kerosene for 90 days.

CONCLUSION

1- The compressive strength and splitting tensile strength values for specimens continuously left in air increase with time increase.
2- Specimens soaked in oil products show a decrease in compressive strength and splitting tensile strength, values with time increase.
3- The compensation curing method (air curing) is the best method with respect to polymer concrete to achieve the optimum properties.
4- The polyester resin concrete develops high compressive strength.

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