Kufa Journal of Engineering
Vol.9, No. 2, April 2018, PP. 13-30
Received 16 April 2017, accepted 21 June 2017

Influence of Oil Products on Strength and Durability of High Strength Latex Modified Concrete Coated by Epoxy

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http://dx.doi.org/10.30572/2018/kje/090202

ABSTRACT

This paper studies the influence of oil products (gas oil and gasoline misname benzene) on strength and durability of high strength latex modified concrete. Three percentage (5, 7.5 and 10% by weight of cement) of styrene butadiene rubber latex (SBR) were used in this work to produce Latex Modified High Strength Concrete (LM-HSC). Epoxy protective were used as coating for all test specimens. Three exposure periods of oil products were used 30, 90 and 180 days after 28 days water curing. The experimental program in this research including; compressive strength, weight change, sorpitivity and initial surface absorption tests were performed. Generally the results showed that LM-HSC coated by epoxy has good resistance to the effect of oil products relative to LM-HSC without epoxy coating. The results showed that modification of HSC with latex SBR increased the compressive strength and lowered weight change, initial surface absorption, and longer period taken for the capillary soaking resulted in lesser sorptivity value, and in comparison with the HSC control concrete. All samples sunken in gas oil showed better results than samples sunken in gasoline this may be ascribed to the lesser viscosity of gas oil than gasoline.

KEYWORDS: Latex Modified High Strength Concrete, Compressive Strength, Weight Change, Initial Surface Absorption, Gasoline, Gas Oil.

1. INTRODUCTION

Many years previously tanks used to storage petroleum materials were made of steel plate and due to problems of serviceability that were associated with the maintenance of these tanks and the risks associated with the maintenance work has made the tendency to use other kinds of tanks with more safety and have better properties than steel tanks. Reinforced or prestressed concrete tanks were used to store many different liquids, such as: gas oil, bitumen, heavy fuel oil, kerosene, gas oil, lamp kerosene, power kerosene etc.

The following advantages of concrete for oil storage can be listed: (Abdul-Hussain, 2005).

1. Much lower cost compared with steel plates.

2. The availability of its raw materials throughout the world.

3. A significant durability towards different types of environment.

4. Good resistance to fire, explosions and impact.

5. Its adaptability for different types.

6. Relative low maintenance cost.

7. Its suitability for underground, and under-sea storage tank.

As a result of the urban movement witnessed by the oil sector in Iraq in the last ten tears, there is an urgent need to replace the steel fuel storage tanks with other concrete because of rust and corrosion of steel tanks over time. Where concrete tanks were created above or below the ground, so the concrete tanks are became more preferred in fuel storage at all fuel stations. However, and unfortunately the concrete used in the construction of most of the fuel tanks was not of high quality, it was not a high performance concrete, and its durability was not good. Concrete was exposed to the effect of petroleum products, which caused a deterioration in the properties of these concrete. Pukhov, (2001) confirmed that after a few years, significant increase of cracks gotten about by the influence of oil can be observed.

From the other hand in Iraq there are a lot of old concrete structures such as foundations of gas turbine station, other constructions supporting machines, and storage floors that have not been well maintained for about many years so it has become necessary to remove these old concrete parts and replace them with modern concrete with high strength and durability of petroleum products.

The harmful effect of oil products on concrete also the high permeability of concrete have made investigators try to advance 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. It is defined as Portland cement and aggregate of various polymer-modified mortar and concrete, latex-modified mortar and concrete have superior properties, such as high tensile and flexural strength, excellent adhesion, high waterproofness, high abrasion resistance and good chemical resistance, to ordinary cement mortar and concrete.

Polymer cementation materials was used widely since 1970, because of its good durability and good water proof and less permeability (Ali and Faris 2010)**.** Polymers can used as admixtures in concrete as percentages from cement weight and can used as powders like powder polymers or liquid like styrene butadiene rubber (SBR) , or meth acrylic polymers.

There is a lot of research that examined the effect of petroleum products on polymer modified concrete and its properties and the most important properties that examined compressive, tensile and flexural strength. However, very few studies have examined the effect of petroleum products on the durability of high strength polymer concrete and coated by epoxy materials.

2. EXPERIMENTAL PROGRAM

2.1. Materials

2.1.1. Cement

Sulfate Resistance Cement (Type V) manufactured by Tasluja cement plant was used in all mixes. The specifications of this cement comply with the requirements of Iraqi specifications No. 5/1984, Table 1.

2.1.2. Fine Aggregate

Al-Najaf natural sand of 4.75 mm max. size (zone 3) was used as fine aggregate. The fine aggregate conforms with well grading according to the Iraqi specification No.45/1984 was used. Characteristics of fine aggregate are given in Table 2.

2.1.3. Coarse Aggregate

The coarse aggregate used in this work is a mixture of crushed gravel brought from AL-Nebaey region with a maximum size of 10 mm. All aggregates were saturated surface dry. Table 3 Shows the grading of this aggregate after sieving on 10 mm sieve to remove particles with size greater than 10 mm. This table gives the limits specified by the Iraqi specification IQ.S No. 45.

2.1.4. Silica Fume

Densified silica fume Admix SIL DSF was used in this work meets the requirement of ASTM C-1240. Admix SIL DSF is a mass additive allowing the production of high performance cement mortar. Silica fume was added to reference mixes and in all HSC mixes in constant percentage of 10%. The main characteristics are showed in Table 4.

Table 1. Chemical and physical properties of cement used in this work.

Chemical tests	Results	Iraqi specifications No. 5/1984
(%) CaO	59.36	--
(%) SiO_2	19.84	--
(%) Al_2O_3	3.11	--
(%) Fe_2O_3	4.48	--
Lime saturated factor	0.94	1.02 – 0.66
(%) MgO	1.42	Upper limit 5
(%) SO_3	1.03	Upper limit 2.5
Loss on ignition(%)	2.59	Upper limit 4
Insoluble residue	0.82	Upper limit 1.5
(%) C_3A	1.06	Upper limit 3.5 for SRC
Physical Test Results	**Results**	**Iraqi specifications No. 5/1984**
Specific surface area cm2/gm (Blaine method)	2630	Lower limit 2300 for OPC and 2500 for SRC
Initial setting time (minute)	78	Lower limit 45 minute
Final setting time (hrs)	185	Upper limit 10 hrs
Compressive strength at 3 days (N/mm^2)	18.2	Lower limit 15
Compressive strength at 7 days (N/mm^2)	26.8	Lower limit 23

Table 2. Sieve analysis of fine aggregate

Sieve size (mm)	Passing%	Gradation zone (3) IQ.S No. 45/1984
9.5	100	100
4.75	98.2	90 – 100
2.36	96.3	85 – 100
1.18	92.1	75 – 100
0.6	85.7	60 – 79
0.3	22.1	12 – 40
0.15	6.2	0.0 – 10
Finer materials less than 75 micron %	1.2	5% upper limit
Sulphate content %	0.28	0.5% upper limit

Table 3. Sieve analysis of coarse aggregate

Sieve size (Single size 10 mm)	Test result	Gradation according IQ.S No. 45
14	100	100
10	98.7	85 – 100
5	21.6	0 – 25
2.36	2.7	0 – 5
Finer materials less than 75 micron %	0.93	3% upper limit
Sulphate content %	0.042	0.1% upper limit

Table 4. Physical and chemical characteristics of Admix SIL DSF

Physical characteristics	
Appearance	Fine powder
Color	Grey
Bulk density (average)	597 kg/m³
Specific surface	18 m²/g
Specific Gravity	2.4
Chemical characteristics	
Silica (SiO_2) minimum	85
CaO	0.27
% Sol. Na_2O eq.	1.35
Fe_2O_3	0.48
Loss of ignition	2.89
Activity index	105

Table 5. Characteristics of Hyperplast PC 711

Color	Light yellow liquid
Freezing point	≈ -10°C
Specific gravity	1.1 ± 0.1
Air entrainment	Typically less than 2% additional air is entrained above control mix at normal dosages
Chloride content	Nil

2.1.5. Admixture/Hyperplasticizer

Hyperplast PC 711 is a high performance superplasticising admixture based on polycarboxylic polymers with long chains specially designed to enable the water content of the concrete to perform more effectively. It complies with ASTM C 494 Type F. The dosage of Hyperplast PC 711 used in this work is 0.75 per 100 kg of cement. Characteristics of Hyperplast PC 711 are illustrated in Table 5.

2.1.6. Polymer Latex

A polymer latex which is known commercially as (Cempatch SBR) used in this work. Cempatch SBR is a one component styrene butadiene rubber latex bonding agent. It is designed to improve the physical properties of cement mixes and slurries. Added to mortar, it increases internal and external bonding of cement and confers to the product strength, waterproofing, flexibility and resistance to abrasion and to chemicals. Technical properties of Cempatch SBR are illustrated in Table 6. Cempatch SBR liquid is directly added to a previously prepared mixture of cement/sand or and mixed either by a power mixer with low rotation speed (300 rpm).

Table 6. Characteristics of Cempatch SBR

Color	White
Active solid content	48 - 50 %
Specific gravity	Around 1.0

2.1.7. Epoxy Coating

Protective coating which is commercially named as Strongcoat 400 is a solvent free, non-toxic; high build epoxy resin protective coating with outstanding chemical and mechanical properties. Strongcoat 400 is supplied as a two component product in pre-weighed base and hardener packs, ready for site mixing. This material has excellent chemical resistant protective coating for power stations, oil refineries, and sewage treatment plants. Strongcoat 400 complies with the requirements of BS 6920:2000. Table 7 showed technical properties of Strongcoat 400 used in this work.

2.1.8. Oil Products

Two types of oil products were used in this work, gas oil and gasoline. The specification of oil products were got it from Al-Najaf branch for the distribution of petroleum products. Table 8 shows the viscosity and specific gravity of oil products used in this work.

2.2. Mix Design

In this study high strength concrete was designed based on ACI 211- 4R 08 guidelines. After carrying out mix proportioning to produce HSC, proportion of various ingredients of concrete was finalized, mix not containing polymer was designated as control mix. Slump test was carried out according to ASTM C 134 for all mixes. Experimental Engineering variables were divided into two groups. The first group contained three different mix proportions were prepared by varying the relative percentage of polymer latex. Percentage variation of SBR latex polymer was 5%, 7.5% and 10% of cement weight (Kapil and Joshi, 2014) with constant other composition. The second group contained the same mixes in the first group but all samples coated by the epoxy protective to study the effect of Strongcoat 400 on the strength and durability of HSC after exposed to oil products. Table 9 showed compressive strength of various types of concrete mix at 28 days of curing in water.

Table 7. Technical properties of Strongcoat 400.

Color	White, S. grey & blue
Solid content	100 %
Specific gravity	1.60 ± 0.1
Bond strength: ASTM D4541-85	> 2 MPa
Pot life	100 min @ 25°C : 45 min @ 35°C
Re-coatable time	Minimum 5 - 16 hr @ 25°C
Full cure	After 7 days @ 25°C

Table 8. The viscosity and some properties of oil products used in this work

Properties	Gas oil	Gasoline
Specific gravity	0.85	0.775
viscosity (centipoises)	5.6 at 40 ºC	0.652 at 20 ºC

Table 9. Compressive strength of various types of concrete mix at 28 days of water curing.

Mix.	Cement kg/m^3	Silica fume kg/m^3	Fine agg. kg/m^3	Coarse agg.(kg/m^3	HRWRA l/m^3	SBR latex %	w/b	Slump (140±5) mm at 23 °C	Compressive strength N/mm^2 at 28 days
P 0- HSC	500	50	720	1050	3.75	0.0	0.36	136	63.6
P 5-HSC	500	50	720	1050	3.75	5	0.34	139	68.5
P 7.5-HSC	500	50	720	1050	3.75	7.5	0.33	141	71.3
P 10-HSC	500	50	720	1050	3.75	10	0.32	145	74.8

2.3. Preparation of Test Specimens

After 28 days of water curing the specimens were taken out from curing tank and are dried in room temperature for three days. After that all specimens were putted in two steel tanks closed tightly, one contain gas oil and the other contain gasoline. The exposure time to the oil products were (30, 90 and 180) days after the initial curing.

2.4. Test Procedures

2.4.1 Compressive Strength Test

The compressive strength test was determined agreeing with B.S.1881, part 116. This test was made on 100 mm cubes using an electrical testing machine with a capacity of 2000 kN. The test was carried out at ages of 30, 90 and 180 days of exposure to oil products after 28 days water curing, Fig. 1.

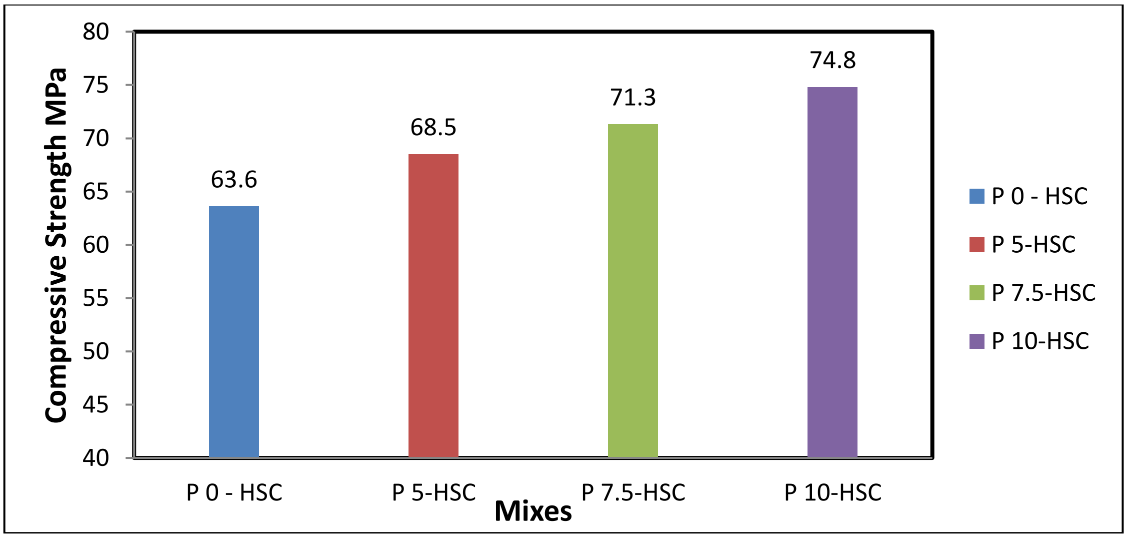

Fig. 1. Compressive strength of various types of LM-HSC mixes at 28 days of water curing.

2.4.2 Weight Change Test (Method C)

After 28 days of curing, the initial weight of the cylinder specimens of 100 x 200 mm was determined before immerging in the tanks of gas oil and gasoline. Then, the specimens were reserved incessantly submerged in these tanks for the time of test as recommended by ASTM C267-03. During the test period, the cylinder specimens were removed weekly from tanks, washed with tap water, without cleaning by brush, and left to dry for 30 min before weighing and visual review. The gas oil and gasoline were renewed with each new weighing to sustain persistent concentration ASTM C192-07. Cumulative weight change (WC) for each specimen was determined as follows:

$$\text{Weight change, } \% = [(W - C) / C] \times 100 \tag{1}$$

Where:

C: Conditioned weight of specimen, g, and

W: Weight of specimen after immersion, g.

2.4.3 Sorptivity Test

Sorptivity was carried out based on ASTM C1585 04. 100x50 mm discs were used. This test method is used to determine the rate of absorption (sorptivity) of water by hydraulic cement concrete by calculating the increase in the mass of a specimen resulting from absorption of water as a function of time when only one surface of the specimen is exposed to water. It is measured as the rate of uptake of water. The cumulative liquid absorption (per unit area of the inflow surface) increases as the square root of elapsed time (t).

$$I = \frac{m_t}{a * d} \quad \text{and} \quad S = I / t^{0.5} \tag{2}$$

Where:

I = the absorption,

m_t = the change in specimen mass in grams, at the time t,

a = the exposed area of the specimen, in mm^2, and

d = the density of the water in g/mm^3.

S= sorptivity in $mm/sec^{0.5}$.

2.4.4 Initial Surface Absorption Test (ISAT)

The 150 mm cube sizes were also equipped for ISA and performed as in agreement to BS 1881/208. The concrete specimens were water cured for 28 days before exposed to oil products. The concrete specimens were oven dried to constant mass at 105±5ºC to be configured for test.

3. RESULTS AND DISCUSSION

3.1. Compressive Strength

Table 10 and 11 reviews the results of compressive strength values for LM-HS concretes at various times of immersion in oil products. The change in compressive strength of LM-HS concretes due to oil products relative to control mix of HSC are plotted in Figs. 2 to 5. The results showed that there was a decrease in the compressive strength of high strength concrete without SBR due to exposure to oil products and that this decrease was increased by increasing the exposure time (Ali and Faris, 2010). After 180 days of exposure in gas oil the percentage decrease in compressive strength was 2.9% compared to the 30 days exposure time. While the decrease in compressive strength at 180 days of gasoline exposure was 5.4% relative to 30 days of exposure. This may be ascribed to the lesser viscosity of gas oil than of gasoline (see Figs. 2 and 3), which enable gasoline to enter through concrete In an easier way than gas oil (Watson and Oyeka,1981). The results also showed that there is an improvement in the strength of concrete as the polymer content increased in the mix of various percentage of SBR latex of HS concretes tested in this investigation. The maximum increase in compressive strength at 10 % SBR latex content for HS concretes was 30.4% at 180 of gas oil exposure and 27.2% at 180 days of gasoline exposure compared to control mix of HSC. This can be due to latex's role in the concrete where latex is added to conventional unmodified concrete lowered the amount of water essential to attain the suitable viscosity for cast of the mix. This lower water necessity results in a cured concrete with developed compressive strength. The latex systems elastic films throughout the matrix of concrete, dropping the creation of voids and fine cracks during the curing period (Mishra, 2014). The Latex Modified HS concrete (LM-HSC) repels penetration of oil and accordingly increasing the compressive strength. Figs. 4 and 5 demonstrated that there is an increase in compressive strength of latex HSC coated by epoxy compound relative to latex HSC without epoxy coating. This may be due to the epoxy coating provide a barrier to prevent or reduce penetration the oil products to the concrete surface which leading to increase the compressive strength.

Table 10: Compressive strength of LM-HSC mixes exposed to oil products

Mix.	Compressive Strength N/mm²					
	Gas Oil Exposure			Gasoline Exposure		
	30 days	90 days	180 days	30 days	90 days	180 days
P 0- HSC	62.4	61.4	60.6	61.1	60.2	58.8
P 5-HSC	70.6	71.5	72.0	67.8	68.3	68.8
P 7.5-HSC	73.5	74.7	76.1	70.6	71.3	72.2
P 10-HSC	76.2	77.3	79.5	72.5	73.6	74.8

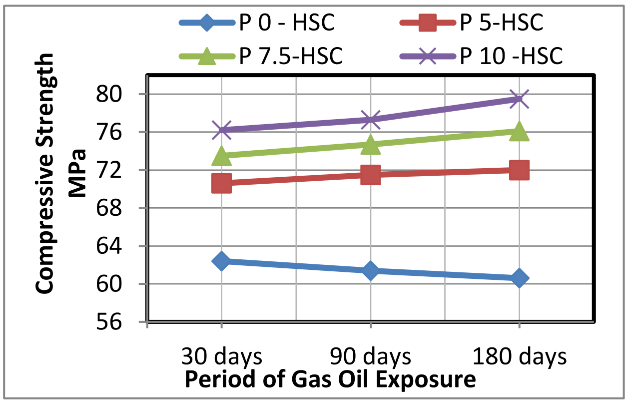

Fig. 2 Compressive strength of LM-HSC mixes exposed to gas oil

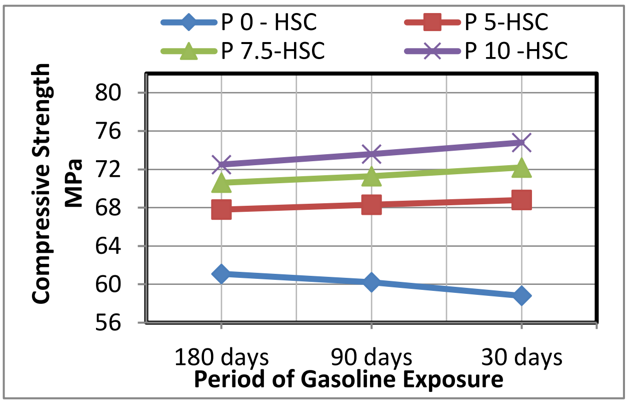

Fig. 3 Compressive strength of LM-HSC mixes exposed to gasoline

Table 11: Compressive strength of LM-HSC mixes exposed to oil products and coated by epoxy

Mix.	Compressive Strength N/mm²					
	Gas Oil Exposure			Gasoline Exposure		
	30 days	90 days	180 days	30 days	90 days	180 days
P 5-HSC	75.2	76.7	77.8	72.6	73.9	74.3
P 7.5-HSC	78.1	80.6	82.2	75.2	76.5	76.9
P 10-HSC	80.5	83.0	86.4	78.0	79.6	80.7

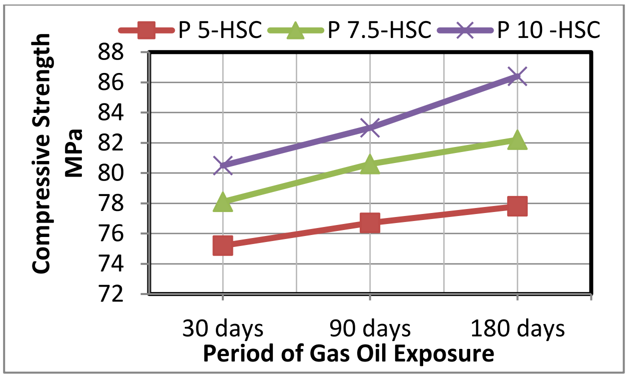

Fig. 4 Compressive strength of LM-HSC mixes exposed to gas oil and coated by Epoxy

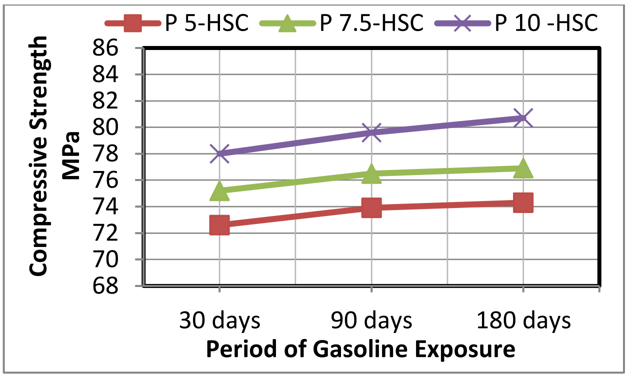

Fig. 5 Compressive strength of LM-HSC mixes exposed to gasoline and coated by Epoxy

3.2. Weight Change Test

Fig. 6 show the relationship between weight change of various mixes of latex HS concretes and different exposure times of gas oil and gasoline. Generally, it is shown from this Figure that a slight increase in weight change happened as the time of exposure increases for the specimens exposed to gas oil and gasoline (Abdul-Hussain, 2013). It is also shown that weight change of latex HS concretes decreases with the increase in SBR percent. At the ratio of 10% SBR the decrease in weight change after exposure time 180 days is significant compared with the mix of 0% SBR content for both gas oil and gasoline exposure.

From Fig. 7 the results showed the coating of latex HS concrete with protective epoxy leading to important decrease in weight change compared with latex HS concretes without coating at the same periods of oil products exposure.

3.3. Initial Surface Absorption (ISA) Test

The results indicated that the ISA reduced with time of test and the reduced values were very low as shown in Figs. 8 and 9. Latex HS concretes specimens with different percentages of SBR latex showed significant reduction in ISA at all testing periods and for all exposure conditions compared to HSC without SBR latex. This behavior may be due to the important water decrease caused by increasing SBR dosages for a specified workability leading to a significant decrease in capillary porosity. In addition the use of SBR latex leads to form a continuous grid of latex molecules through concrete which works to fill and separate the pores (Al-Jalawi and Atwan, 2011). Figs. 10 and 11 illustrated that the specimens of latex HS concretes coated by epoxy gave far lower results of ISA compared to those specimens not coated with epoxy. This is due to the role of epoxy in closing the surface pores and creating an important defensive line against penetration of oil products.

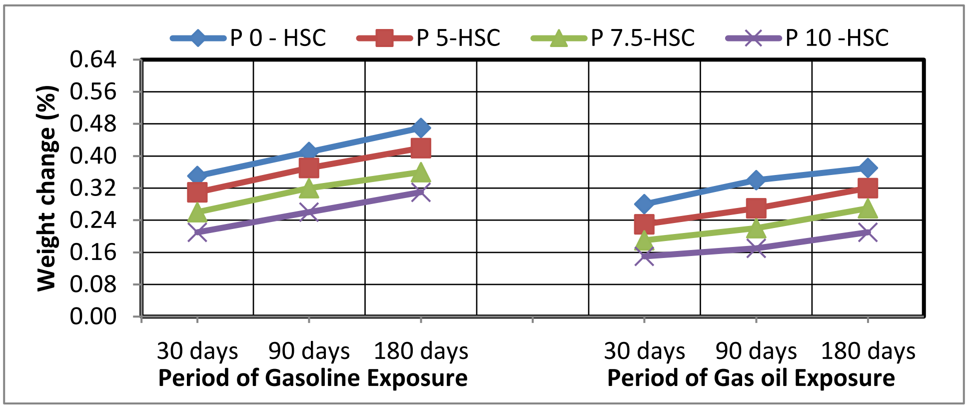

Fig. 6. Weight change of LM-HSC exposed to oil products.

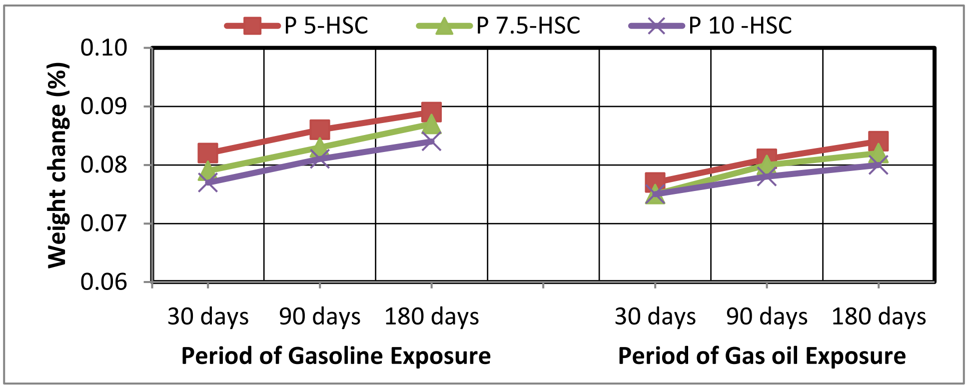

Fig. 7. Weight change of LM-HSC exposed to oil products and Protected by Epoxy coating.

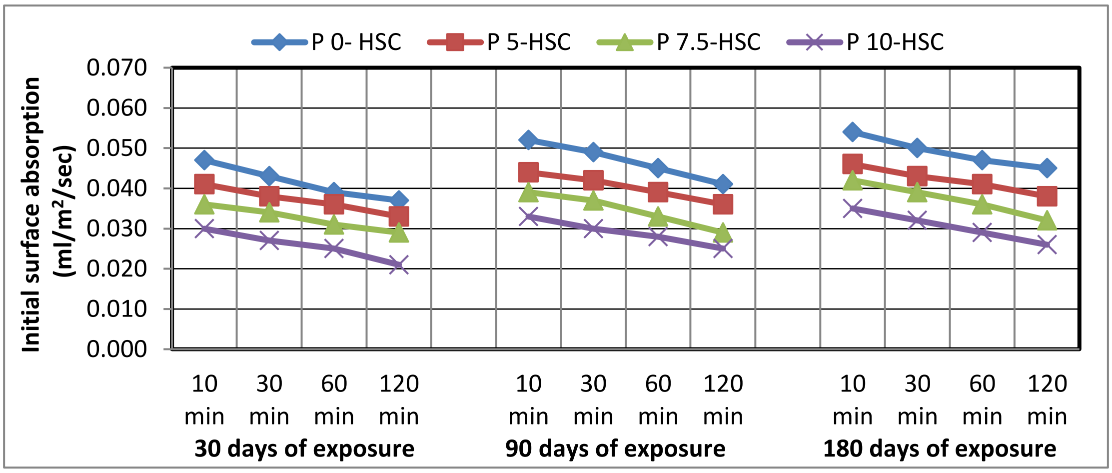

Fig. 8. Initial surface absorption of LM-HSC exposed to gas oil.

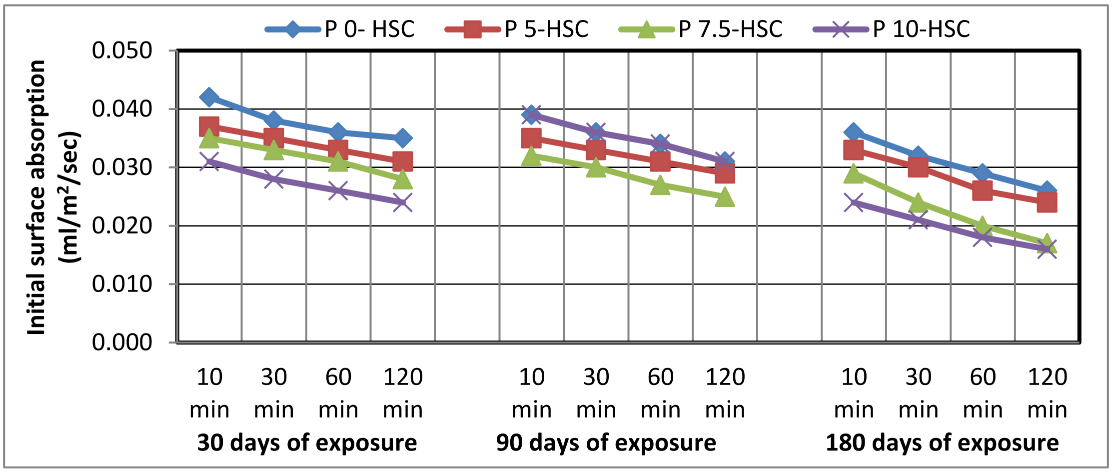

Fig. 9. Initial surface absorption of LM-HSC exposed to gasoline.

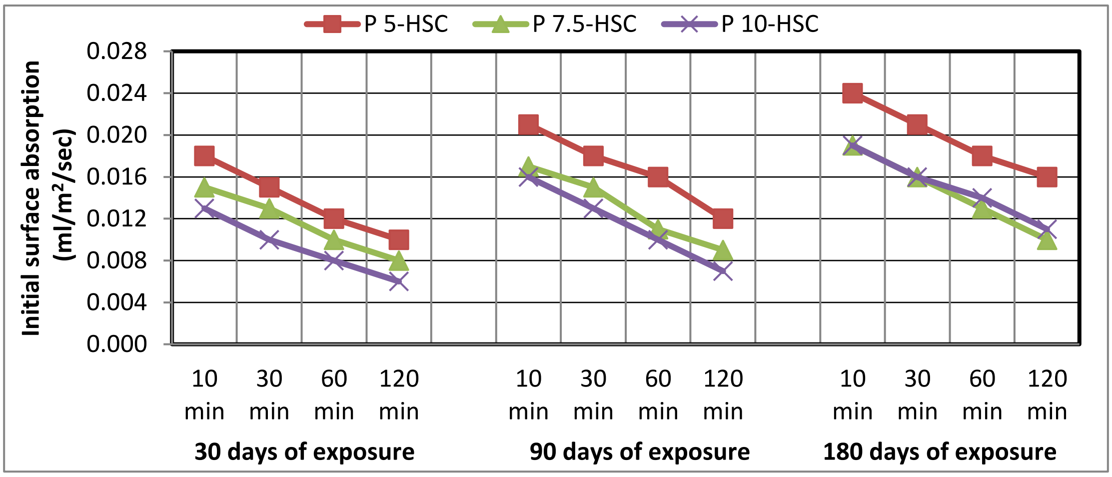

Fig. 10. Initial surface absorption of LM-HSC exposed to gas oil and coated by epoxy.

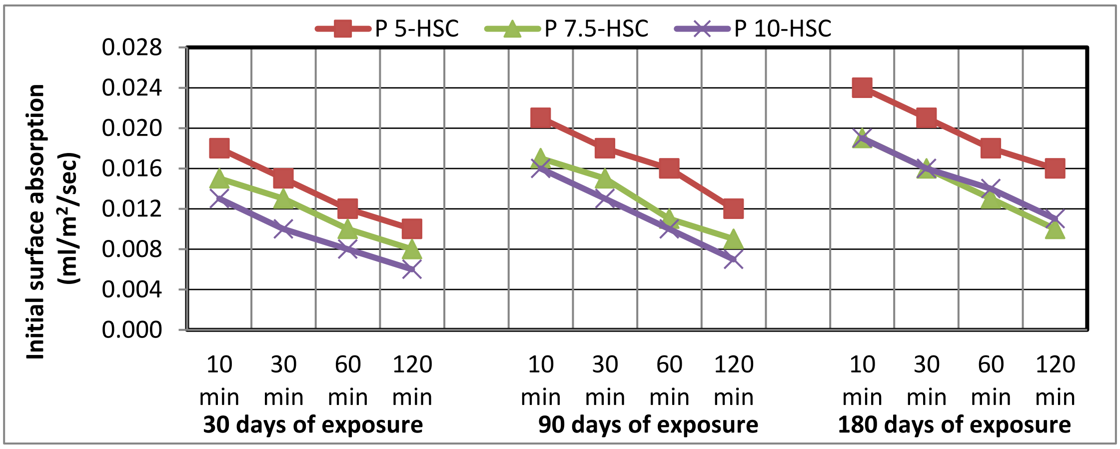

Fig. 11. Initial surface absorption of LM-HSC exposed to gasoline and coated by epoxy.

3.4. Sorptivity Test

The results of sorptivity test for various types of latex high strength concretes exposed to oil products are showed in Table 12 and 13 and plotted in Figs. 12 and 13. Results show that all latex HS concretes displayed continuous reduction in sorptivity values with time of exposure. This may ascribed to continuous pore filling progression which is related with progress of hydration and the polymerization reaction. Modification of HS concretes with SBR latex causes the reduction of sorpotivity values regardless of the exposure conditions. This behavior could be related to the role of the latex SBR in filling the pores and cracks and therefore improving the surface condition. The results plotted in Figs. 8 and 9 demonstrated that the all mixes of latex HS concretes coated by epoxy showed a significant reduction in the sorpitivity values compared to the mixes of latex HS concrete not coated. At 180 days of exposure in gas oil the decreasing ratio of sorpitivity were 87% relative to latex HS concretes without epoxy coating, whereas the decreasing ratio were 90.8% at 180 days of exposure in gasoline.

Table 12: Sorptivity of polymer concrete mixes exposed to exposed to oil products

Mix.	Sorptivity value in 10^{-4} mm/sec$^{0.5}$					
	Gas Oil Exposure			Gasoline Exposure		
	30 days	90 days	180 days	30 days	90 days	180 days
P 0- HSC	4.73	4.11	3.50	5.52	5.08	5.02
P 5-HSC	3.91	3.49	2.87	4.45	4.12	4.05
P 7.5-HSC	3.29	2.26	2.06	4.04	3.89	3.45
P 10-HSC	1.64	1.44	1.23	2.34	2.12	2.07

Table 13: Sorptivity of LM-HSC mixes exposed to oil products and coated by epoxy

Mix.	Sorptivity value in 10^{-4} mm/sec$^{0.5}$					
	Gas Oil Exposure			Gasoline Exposure		
	30 days	90 days	180 days	30 days	90 days	180 days
P 5-HSC	0.23	0.21	0.20	0.28	0.26	0.23
P 7.5-HSC	0.19	0.18	0.18	0.25	0.25	0.23
P 10-HSC	0.18	0.17	0.16	0.21	0.19	0.19

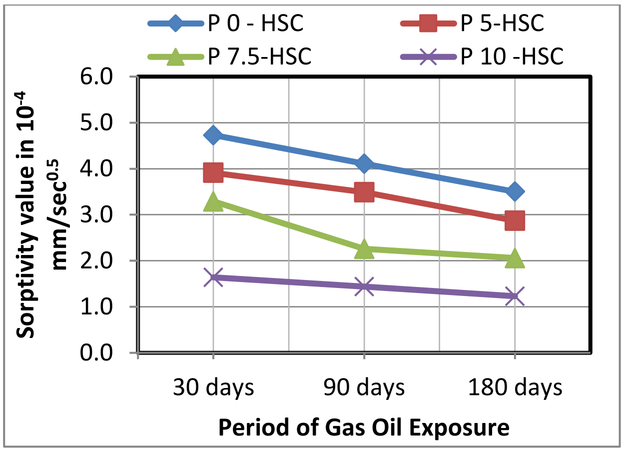

Fig. 12. Sorptivity of LM-HSC mixes exposed to gas oil.

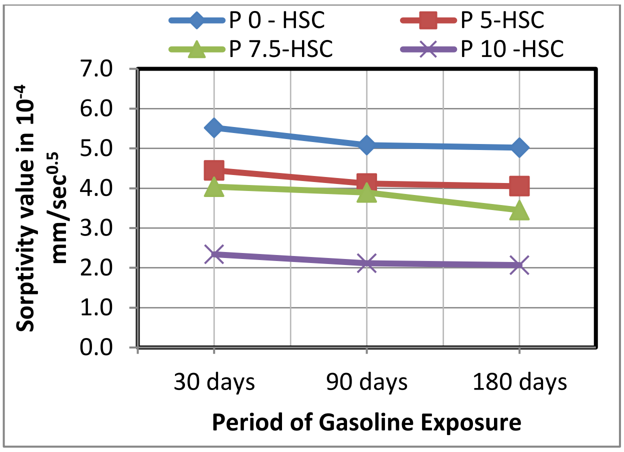

Fig. 13. Sorptivity of LM-HSC mixes exposed to gasoline.

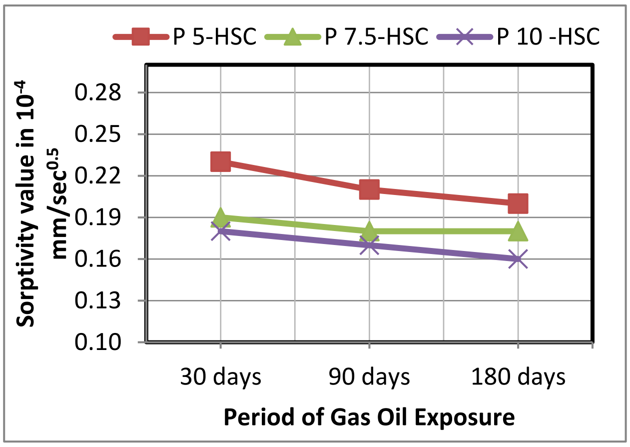

Fig. 14 Sorptivity of PCM exposed to gas oil and Protected by Epoxy coating

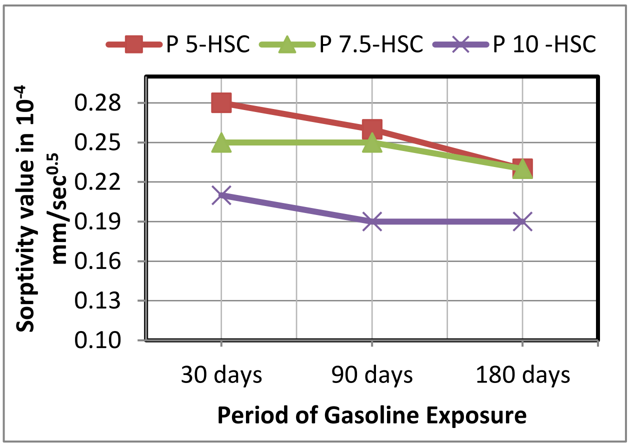

Fig. 15 Sorptivity of PCM exposed to gasoline and Protected by Epoxy coating

4. CONCLUSION

Based on the experimental results in this research, several conclusions can be drawn:

1. For the HSC specimens exposed to gas oil and gasoline, a decrease in compressive strength occurred as the time of exposure increases. The decreasing ratio was 2.9% at 180 days of gas oil exposure compared to 30 days of exposure and the decreasing ratio became 5.4% when the specimens exposed to gasoline at 180 days relative to 30 days of exposure.
2. The compressive strength of all latex HS concretes specimens exposed to gas oil is slightly higher than that of specimens exposed to gasoline at the same exposure time.

This may be attributed to the lower viscosity of gas oil than that of gasoline, which enables gasoline to penetrate through concrete easier than gas oil.

3. Modification of HS concretes with SBR latex causes the reduction of change weight, initial surface absorption and sorpotivity values regardless of the exposure conditions compared to the HSC without SBR latex. The better results were at the ratio 10% of SBR latex.

4. The specimens of latex HS concretes coated by epoxy provided best results of all tests conducted in this research relative to specimens not coated by epoxy.

5. REFERENCES

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