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# Some Properties of Polymer Modified Self-Compacting Concrete Exposed to Kerosene and Gas Oil

**Ph. Dr. Nada Mahdi Fawzi**
College of Engineering-University of Baghdad
E-mail:naljalawi@yahoo com

**M.Sc. Aqeel Kareem Weli**
Engineer in oil products distribution company
E-mail:abumalbaqer@yahoo.com

## ABSTRACT

This thesis aims to study the effect of addition polymer materials on mechanical properties of self-compacting concrete, and also to assess the influence of petroleum products (kerosene and gas oil) on mechanical properties of polymer modified self-compacting concrete (PMSCC) after different exposure periods of (30 ,60 ,90 ,and 180 days).

Two type of curing are used; 28 days in water for SCC and 2 days in water followed 26 days in air for PMSCC.

The test results show that the PMSCC (15% P/C ratio) which is exposed to oil products recorded a lower deterioration in compressive strength's values than reference concrete. The percentages of reduction in compressive strength values of PMSCC (15% P/C ratio) was (6.03%) and (9.61%) up to 180 days of exposure to kerosene and gas oil respectively, relative to the same mix immersed in water, while the percentages of reduction in compressive strength values of SCC (reference concrete) was (21.18%) and (25.19%) up to 180 days of exposure to kerosene and gas oil respectively, relative to the same mix immersed in water.

Flexural strength results present improvement for all ages and for all concrete mixes with all percentages of polymer content.

The total water absorption values of PMSCC (15% P/C ratio) showed a better performance than reference concrete mix when exposed to oil products. It was (1.34, 2.21, 2.17) % up to 180 days with samples immersed in water, kerosene, and gas oil respectively, with percentages of reduction of (23.86%), (33.83%), and (31.33%) relative to the SCC (reference concrete).

**Key words:** polymer, self-compacting, kerosene, gas oil.

# بعض خواص الخرسانة المعدلة بالبوليمر ذاتية الرص المعرضة إلى النفط وزيت الغاز

**أ.د. ندى مهدي فوزي**
كلية الهندسة/جامعة بغداد

**م.عقيل كريم ولي**
شركة توزيع المنتجات النفطية

## الخلاصة

الهدف من هذا البحث هو دراسة تأثير أضافه مواد بوليمرية على الخواص الطرية والميكانيكية للخرسانة ذاتية الرص, وكذلك أيجاد تأثير المشتقات النفطية (النفط الأبيض وزيت الغاز) على الخواص الميكانيكية للخرسانة المعدلة بالبوليمر ذاتية الرص والخرسانة ذاتية الرص بـعد التعرض لفترات مختلفـة ( 30 ،60،90،180) يوم.

نوعين من الانضاج تم استعمالهما حيث كانت 28 يوم غمر بالماء للخرسانة ذاتية الرص بينما 2يوم غمر بالماء متبوعة 26 يوم بالهواء للخرسانة المعدلة بالبوليمر ذاتية الرص.

أظهرت نتائج فحص الخرسانة ذاتية الرص والخرسانة المعدلة بالبوليمر ذاتية الرص المغمورة بشكل مستمر في الماء تطوراً في خواصها الميكانيكية عند زيادة فترة الغمر بالماء . بينما تأثرت الخواص الميكانيكية للخرسانة ذاتية الرص والخرسانة المعدلة بالبوليمر ذاتية الرص المعرضة بشكل مستمر للمشتقات النفطية سلبياً.

سجلت نتائج فحص الخرسانة المعدلة بالبوليمر ذاتية الرص المعرضة للمنتجات النفطية ادني تدهور في قيم مقاومة الانضغاط من الخرسانة المرجعية. حيث كانت النسبة المئوية للنقصان في مقاومة الانضغاط (6,03)% ، (9,61)% بعد 180 يوما من التعرض للنفط الأبيض وزيت الغاز على التوالي نسبة الى نفس الخلطة للنماذج المغمورة في الماء, بينما النسبة المئوية

للنقصان في مقاومة الانضغاط للخرسانة المرجعية كانت (21,18)% و (25,19)% بعد 180 يوما من التعرض للنفط الأبيض وزيت الغاز على التوالي نسبة إلى نفس الخلطة للنماذج المغمورة في الماء.

أظهرت نتائج مقاومه الانحناء إلى حصول تحسن في كل الأعمار وفي جميع نسب البوليمر.

أظهرت نتائج امتصاص الماء الكلي للخرسانة المعدلة بالبوليمر ذاتية الرص وبنسبه استبدال 15% من مادة البوليمر إلى الاسمنت أداء أفضل من الخلطة المرجعية عند تعرضها للمنتجات النفطية, حيث كانت نسب الامتصاص الكلي هي (1.34 , 2.21 , 2.17 ) بعد 180 يوما من التعرض للماء والنفط الأبيض وزيت الغاز وبنقصان مقداره (23.86 ، 33.83 ، 31.33)% نسبة إلى الخرسانة ذاتية الرص (الخرسانة المرجعية).

**الكلمات الرئيسية:** بوليمر, ذاتية الرص, النفط الابيض, زيت الغاز.

# 1. INTRODUCTION

Oil has become one of the most vital energy resources from the beginning of the previous century for its unique economic and operative characteristics. This has enabled it to exceed the other available power resources, and its importance has increased rapidly with its wide spread use and the discovery of huge oil reserves in different parts of the world**, Ra'ed, 2002**.

The main problems that restrict the successful use of concrete to store fuel oil are: the leakage of oils especially the lighter products (that have specific gravity 0.875 at temperature $15C^0$) through the structure pores, shrinkage cracks and joints**, lea, 2004.**

There is a difference in behavior of the petroleum storage concrete tanks, and water storage concrete tanks**, Matti, 1976.** has shown that the leakage from concrete water tanks may reduce with time due to the closure of some of the voids, disconnection of the capillary channels and healing of some of the cracks due to the continuous hydration, and or accumulation of impurities. Because of the inert nature of the petroleum towards concrete, such continued hydration is less likely to occur in concrete petroleum tanks, but the wax deposits that are found in crude oil may decrease the permeability of concrete. So, it is very important to decrease the cracks to a lower bound to avoid any leakage of oil from the structure and to protect the concrete from deterioration**.**

Due to the dominant improvements in the properties of concrete containing different types of admixtures, it is very important to study the effect of these admixtures on the behavior of concrete exposed to oil products, **Al hamadani, 1997.**

## 1 .2: Polymer Modified Self-Compacting Concrete (PMSCC)

Polymer modified self-compacting concrete achieves the advantages of both Self-Compacting Concrete (SCC) and Polymer Modified Concrete (PMC). Polymer modified SCC may be used successfully in repair of concrete elements or construct new concrete elements especially when concrete is subjected to sever conditions, **Aliabdo , 2012.**

### 1.2.1 : Polymer modified concrete

One of the ways to make a material of high mechanical properties with satisfactory durability in various environment and high aesthetic values is through a polymer modification of concrete. These relatively new materials offer the advantages of higher strength ,improved durability, good resistance to corrosion, reduced water permeability and greater resistance to damage from freeze-thaw cycles.

The polymer materials are a group of carbon-containing (organic) materials, have macromolecular structure of this sort. Polymer Latexes (or dispersions) which consist of very small (0.05-5mm in diameter) polymer particles dispersed in water and usually produced by emulsion polymerization. The polymer latexes are copolymer systems of two or more different monomers, **Ohama, 1998**.

Styrene-Butadiene-Rubber (SBR) is the type of polymer (Elastomers) which is used in this study. It is a copolymer produced from butadiene and styrene. SBR has good low-temperature, good water and weather resistance**, Bolton, 1998.**

1.2.2 Self-compacting concrete

SCC represents one of the most outstanding advances in concrete technology during the last decade. At first developed in Japan in the last 1980s, SCC meanwhile is spread all over the world with a steadily increasing number of applications, **Holschemacher, and Klug, 2002.**

Due to the highly flowable nature of SCC, care is required to ensure excellent filling ability, passing ability and adequate stability. This ability is achieved by ensuring suitable rheological properties of fresh concrete: a low yield stress value associated with adequate plastic viscosity. The use of superplasticizer and optimization of fine-particles packing and flow behavior are those two of the central aspects of (SCC) mix proportioning . Fine particles including both cement and filler materials (Pozzolanic or non Pozzolanic) are used in mix proportioning. Among non Pozzolanic fillers, (limestone and dolomite) fines are most frequently used to increase the content of fine particles in mixes, **Bosiljkov, 2003.**

## 2. LITERATURE REVIEW

**, Ali, 2006.** has studied the effect of oil products on mechanical properties i.e. compressive, splitting tensile, and flexural tensile strength of original and polymer modified reactive powder concrete in different exposure periods. He has concluded that

- for the specimens made of mixes containing polymer in different percentages, it appears that, the increase in polymer to cement ratio (P/C) leads to continuous increase in compressive strength up to P/C ratio of 0.14. The percentage of increase in compressive strength for specimens cured in water up to 180 days was 10.8% compared with reference concrete (original reactive powder concrete).
- the specimens made of mixes containing polymer in different percentages, showed significant increase in flexural strength with the increase in P/C-ratio.
- for all types of concrete, the amount of increase in compressive, splitting tensile and flexural strengths for the specimens cured in water is larger than that obtained from specimens exposed to oil products up to the older ages of exposure to oil products.
- polymer modified reactive powder concrete shows higher reduction in total absorption for both specimens cured in water or exposed to oil products. The percentages of reduction in total absorption of polymer modified RPC compared to original RPC up to 180 days are (40%) , (31%) and (42.8)% , for water, kerosene and gas oil respectively.

**, Ali, 2013**. has studied the effect of oil products on properties of self-compacting concrete. He has concluded that:

- The compressive strength of SCC decreases as the exposure period to oil products increases. The reduction for exposure period at 60 -180 days is between 11.59 -27.93% and 14.62 -40.74% , 11.24 -37.69%and 2.66 % -23.81% for SCC continuously immersed in crude oil, motor oil, fuel oil and gas oil respectively.
- The modulus of rupture is reduced in the range of 3.74 -24.01%, 4-25.98% , 3.6-24.67% and 0.4 -21.92% after exposing to crude oil, motor oil , fuel oil and gas oil respectively for exposure period of 60 - 180 days.
- The total absorption for SCC specimens continuous immersion in different oil products increases as the time of continuously immersed increases. The percentage increase in exposure period of 180 days is 1.9%, 2.64%, 2.91%, 3.06% for SCC continuously immersed in crude oil ,gas oil ,motor oil and fuel oil respectively.

**, Abed Al-Ameer, 2011.** studied the influence of oil products (kerosene and diesel oil) on the mechanical properties of steel fiber reinforced concrete. The compressive strength of concrete decreases as the exposure period to oil products increases. At 120 days of exposure, the compressive strength of concrete cubes (with and without SF) decreases. The decrease occure in compressive strength for plain and for steel fiber reinforced concrete exposed to kerosene or diesel.

## 3. MATERIALS AND EXPERIMENTAL WORK

### 3.1 Materials

Ordinary Portland cement type (I) was used. **Tables 1** and **2** show the physical and chemical composition properties of the cement used in this investigation respectively. Natural sand from Al-Ukhaider region was used and crashed gravel with nominal maximum size of 14 mm from Al-Niba'ee region was used.

### 3.2: Admixture:

3.2.1: High range water reducing admixture(superplasticiser)

Superplasticizer used throughout this study is known commercially as Glenium 51.

Glenium 51 is differentiated from conventional superplasticisers in that it is based on a unique carboxylic ether polymer with long lateral chains. This greatly improves cement dispersion. At the start of the mixing process the same electrostatic dispersion occurs but the presence of the lateral chains, linked to the polymer backbone, generates a steric hindrance which stabilizes the cement particles capacity to separate and disperse. Glenium 51 is free from chlorides and complies with ASTM C494 Types A and F. Glenium 51 is compatible with all Portland cements that meet recognized international standards**, Degussa, 2002. Table 3** lists the properties of this product.

3.2.2 Polymer

Styrene-butadiene copolymer latex (SBR) which is commercially named "Rheomix 141" was used as a polymer modifier in this research. Rheomix 141 is a milky, white liquid, produced from styrene and butadiene by high pressure emulsion polymerization. The latex consists of microscopic particles of synthetic rubber dispersed in an aqueous solution. Rheomix 141 modified mixes may be slightly darker than corresponding unmodified mixes.

All cementitious mixes stated shall be modified with Rheomix 141, styrene butadiene copolymer Latex, manufactured by Basf or similarly approved supplier has the following specification shown in **Table 4**.

3.2.3 Fly Ash

Fly ash class F was used in this research according to **ASTM C618-03**, the chemical and physical properties of fly ash are given in **Table 5** and **Table 6**, respectively.

### 3.3 Oil Product

kerosene and Gas oil were used in this investigation. They were brought from AL – Daura Refinery and stored in airtight steel and plastic containers to avoid any losses.

### 3.4 Concrete Mixtures

Four types of concrete mixtures (R, P1, P2 and P3) were made with respect to the ratio of polymer (SBR) in concrete, mix design of SCC and PMSCC must satisfy the criteria of filling ability, passing ability and segregation resistance. The mix design method used in the present study is according to, **ERMCO, 2005**, then the proportions of materials were modified after obtaining a satisfactory self-compactability by evaluating fresh concrete tests. Several trial mixes were carried out to determine the suitable dosage of superplasticizer, with compressive strength of about 40 MPa at 28 days. Types of Mixture and its proportions shown in **Table 7**.

### 3.5 Casting and Curing of Specimens

The molds were cleaned and the internal surface was oiled to prevent adhesion of concrete after hardening. Then the specimens were covered with polyethylene sheet in the laboratory for about 24 hrs and then the specimens were remolded carefully and immersed in curing water for two days and for 26 days in air for PMSCC specimens, while the SCC was immersed in curing water for 28 days.

### 3.6 Type of Exposure to Oil Products

After curing, some of these specimens were taken out to dry in the air for one week under laboratory environment. After drying, some of these specimens were exposed to kerosene and the others were exposed to gas oil for different periods (30, 60, 90 and 180 days).

### 3.7 Tests of Fresh Concrete

The workability of self-compacting concrete is high, so the conventional methods for testing the workability cannot be used. Slump flow test, T50 cm test, V-Funnel test, L-Box test, and U-Box test were used as test methods for workability properties of SCC by many researchers and agencies. These methods are given in the European Federation dedicated to specialist construction chemicals and concrete systems SCC Guidelines**, ERMCO, 2005.**

### 3.8 Hardened Concrete Test

3.8.1 Compressive strength test

The compressive strength was determined by using cubes tests according to British Standard **B.S 1881: part 116, 1989**. Each concrete cube was taken out of the curing tank and placed in the compression device on one of its sides (after cleaning the faces of the cube) so that the compressive load is applied perpendicularly to the direction of concrete placement in the moulds at a constant rate.

3.8.2 Modulus of rupture

Prismatic specimens of (100*100*400) were used in the Modulus of Rupture (flexural strength) test and cured as those of compressive strength, according to **ASTM C78-02**, with clear span supported by 300 mm. The average of the two specimens was recorded.

3.8.3 Total water absorption

Total absorption in hardened concrete was determined according to **ASTM C642–06** [(74)]. This test method is useful in developing the data required for conversion between mass and volume for concrete. It can be used to determine conformance with specifications for concrete and to show differences from place to place within a mass of concrete.

## 4. RESULTS AND DISCUSSIONS

### 4.1 Fresh Properties of SCC and PMSCC

The four mixes (R, P1, P2 and P3 ) were prepared, then the fresh properties of each of them were evaluated by four tests, which were, Slump Flow and T50 test, V-Funnel test, L-Box test, and U-Box test. **Table 8** shows the results of these tests for all mixes.

4.1.1: High range water reducing admixture dosages

Dosages of superplasticizer were adjusted to give the required flow. The effect of polymer/cement ratio (p/c) content on the dosage of chemical admixture (superplasticizer) is shown in **Table 9**. From this Table, it is clearly that the increase in polymer/cement ratio content is lead to decrease in the dosage of required superplasticizer. This effect may be due to the plasticizing effect of polymers. The reduction in a dosage of superplasticizer is 15%, 25% and 35% for polymer modified self-compacting concrete with 5.0%, 10.0% and 15.0% styrene butadiene rubber, respectively compared with that of self-compacting concrete. From this table, it is seen water content is constant.

## 4.2 Hardened Properties of SCC and PMSCC

4.2.1 Compressive strength

The results of compressive strength tests on reference concrete (SCC) and the polymer modified self-compacting concrete (PMSCC) exposed to oil products up to 180 days of exposure are given in **Tables 10**. The graphical representations of these relations are shown in **Figs. 1 to 4.**

The compressive strength of Polymer modified self-compacting concrete immersed in water is higher than that of reference concrete (SCC) at all test periods and the percentages of increasing rise with the increase in P/C ratio. This behavior may be due to the addition of polymers (SBR) which leads to form a continuous three dimensional polymer network which interpenetrates the cement paste, and the partial filling of the pores with the polymer particles reduces the porosity of the polymer modified self compacting concrete.

The test results showed that there's no difference in compressive strength for specimens which exposed to kerosene and gas oil for 30 days, in comparison with the same mixes immersed in water and at the same age. This is due to the pores inside the SCC and PMSCC which were still partially filled with water leading to further hydration that delays, the deterioration of concrete**, Al-Hadithi, 2005**. Also, it may be due to the low permeability of SCC and PMSCC mix produced in this investigation since the presence of flyash leads to a modification in the microstructure of concrete. This will delay the deterioration of all mixes subjected to oil products.

The compressive strength for all mixes exposed to oil products decreases moderately with time in comparison with the same mixes immersed in water at the same age. The deterioration in compressive strength may be due to the extension of gel pores and spreading solid hydration components due to penetration of oil products into the microstructure of SCC and PMSCC leading to weak adhesion and cohesion forces in cement in addition to the effects of oil products on the SCC surface interactions. After exposure to the oil products, reference SCC indicates that the maximum percentages reduction values in compressive strength were up to 21.2% for the specimens exposed to kerosene and 25.2% for the specimens exposed to gas oil for 180 days respectively in comparison with the same mixes immersed in water at the same age. While the percentages of reduction in compressive strength for concrete mixes P1, P2, and P3 were 13.7%, 9.2%,and 6% for the specimens exposed to kerosene, and 14.8%, 11%,and 9.6% for the specimens exposed to gas oil for exposure periods of 180 days respectively, and when compared with the reference concrete it can be seen that the rate of deterioration decreased with the increase in P/C ratio at all test ages. The reasons for this behavior is the good compatibility for styrene butadiene rubber (SBR) Latex and bond strength, low porosity, in addition to the excellent strength and durability properties of the SBR itself, and the other reason for this behavior is the reference mixes enables them to gain a reasonable strength by the hydration operation only, whereas, for concrete mixes containing polymer (SBR) both the cement hydration and production of polymer film by polymerization are responsible for strength gain. In addition, the secondary hydration products around the pozzolan particles tend to fill the capacity void and reduce their size**, Mehta, 2002.**

4.2.2 Modulus of Rupture

The results of modulus of rupture tests on reference concrete (SCC) and the polymer modified self compacting concrete (PMSCC) exposed to oil products are given in **Table 11.** The graphical representations of these relations are shown plotted in **Figs. 5 to 8.**

The results of modulus of rupture of Polymer modified self-compacting concrete exposed to water is higher than that of reference concrete (SCC) at all test periods . Also this increase arises with the increase in P/C ratio at all ages. The reasons for this behavior in addition the reasons aforementioned in the compression are a considerable increase in the strength characteristics of the flexural section especially at tension side, because the transition zone elasticity will be utilized to large degree as compared with that of reference concrete.

The modulus of rupture for all mixes exposed to oil products decreases moderately with time. The reduction in modulus of rupture may be due to the extension of gel pores and spreading solid hydration components due to penetration of oil products into the microstructure of SCC and PMSCC leading to weak adhesion and cohesion forces in cement in addition to the effects of oil products on the SCC surface interactions.

For the reference concrete (SCC) exposed to the oil products, the maximum reduction values were up to 23.3% for the specimens exposed to kerosene and 27.6% for the specimens exposed to gas oil for 180 days respectively in comparison with the same mixes immersed in water. While the reduction in modulus of rupture for concrete mixes,P1, P2, P3 was 20.1%, 17.3%, 13.7% for the specimens exposed to kerosene, and 23.9%, 18.7%, 15.6% for the specimens exposed to gas oil for exposure periods of 180 days respectively in comparison with the same mixes immersed in water, and when compared with the reference concrete it can be seen that the rate of reduction in modulus of rupture is improved with the increase in P/C ratio at all test ages. The reasons for this behavior is the good compatibility between Styrene butadiene rubber (SBR) Latex and bond strength, low porosity, in addition to the excellent strength and durability properties of the SBR itself. The other reason for this behavior is the reference mixes make them gain a reasonable strength at early ages, as the hydration operation responsible for this strength, whereas, for concrete mixes containing polymer (SBR) both the cement hydration and production of polymer film by polymerization are responsible for strength gain. In addition, the secondary hydration products around the pozzolan particles tend to fill the capacity void and reduce their size.

4.2.3 Total Water Absorption

The results of total absorption tests for reference concrete (SCC) and the polymer modified self-compacting concrete (PMSCC) exposed to oil products are given in **Tables 12**. The graphical representations of these relations are shown plotted in **Figs. 9 to 12**.

Test results indicate that the total absorption of all specimens immersed in water decreases continuously with the progress of age. This is because of the partial filling of pores by the hydration and polymerization reaction which reduces capillary porosity, which is confirmed by other investigations.

The total water absorption decreases with the increase in P/C ratio of all specimens immersed in water at all test periods. This behavior is because of the low porosity of polymer modified self-compacting concrete compared with reference concrete and the dispersion of polymer particles (which fill or envelope the large pores) which create a tight membrane around these pores causing discontinuity of capillary pores**, Bolton, 1998. And, Mangat, 1978.** This polymeric system controls the water movement through the concrete structure. It is clear that the addition of polymer leads to decrease the absorption ratio in all conditions, where the percentage of decrease in absorption at the age of 28 day is (22.86, 28.31, 32.73 )% for P1 , P2, P3 respectively, in comparison with the reference mixes

The total absorption of all mixes exposed to oil products increases with time. The total absorption for reference concrete increases gradually (2.43%, 2.71%, 2.86% and 3.34%) after exposure to kerosene, and (1.93%, 2.29%, 2.47% and 3.16%) after exposure to gas oil ,for soaking periods of 30,60, 90 and 180 days respectively, whereas, for concrete mixes P1, the total absorption increases gradually (2.18%, 2.47%, 2.51% and 2.94%) after exposure to kerosene, and (1.81%, 2.12%, 2.25% and 2.89%) after exposure to gas oil ,for soaking periods of 30,60, 90 and 180 days respectively , whereas, for concrete mixes P2, the total absorption increases gradually (2.02%, 2.31%, 2.43% and 2.77%) after exposure to kerosene, and (1.74%, 1.96%, 2.03% and 2.43%) after exposure to gas oil, for soaking periods of 30,60, 90 and 180 days respectively, whereas, for concrete mixes P3, the total absorption increases gradually (1.84 %, 1.94 %, 2.08 % and 2.21 %) after exposure to kerosene, and (1.68%, 1.84%, 1.89% and 2.17 %) after exposure to gas oil ,for soaking periods of 30,60, 90 and 180 days respectively. This is due to the harmful effects of oil products on the microstructure of the concrete(microstructure of cement paste) and the bond between aggregate and cement paste formation of micro crack in the interfacial transition zone which leads to increase the porosity and then increase the absorption of concrete**, Matti, 1976.**

Polymer modified self-compacting concrete mixtures (P1, P2 and P3) exposed to the oil products showed significant reduction in total absorption when compared with the reference concrete exposed to the oil products, and the rate of reduction in total absorption was raised with the increase in P/C ratio at all test ages. The percentages of reduction in mixes P1 compared to Reference concrete were (13.61%) and (9.34%) up to 180 days for specimens exposed to kerosene and gas oil respectively, whereas, for concrete mixes P2, the percentages of reduction in mixes P2 compared to Reference concrete were (17.07%) and (23.1%) up to 180 days for specimens exposed to kerosene and gas oil respectively, whereas, for concrete mixes P3, the percentages of reduction in mixes P3 compared to Reference concrete were (33.83%) and (31.33%) up to 180 days for specimens exposed to kerosene and gas oil respectively. This is due to the fact that polymer modified concrete has a structure in which the larger pores can be filled with polymers or sealed with continuous polymer films. In general, the effect of polymer filling or sealing increases with a rise in the polymer content or polymer-cement ratio. These features are reflected in reduced water absorption, **Ohama, 1998.**

## 5. CONCLUSIONS

Based on the experimental results of this research, the following conclusions can be drawn:

1. For constant water content, the polymer content (SBR) reduces the dosage of superplasticizer when added to the concrete mixes and the percentage of reduction increases with the increase in the P/C ratio.
2. The compressive strength and modulus of rupture, for SCC and PMSCC specimens continuously immersed in water after curing increase with age, while the total absorption and voids for SCC and PMSCC specimens continuously immersed in water after curing decrease with age.
3. The effect of polymer on modulus of rupture is higher than that on compressive strength in specimens immersed in water after curing. For modulus of rupture, the percentage of

increase in mix P3 up to 180 days is (43.61%), whereas, for compressive strength is (17.18%) in comparison with the reference concrete.

4. The test results for the compressive strength and modulus of rupture of all mixes exposed to kerosene and gas oil for 30 days showed that there's no difference in values when comparison with the same mixes immersed in water at the same age, then they drop continuously up to 180 days exposure.
5. The compressive strength of all mixes deteriorated as the exposure period to oil products increases. The percentage of reduction in reference concrete for exposure period at 180 days is (21.2%, and 25.2%), whereas, for concrete mixes P1 it is (13.7%, 14.8%). For concrete mixes P2 it is (9.2%, and 11%). For concrete mixes P3 it is (6%, and 9.6%). After exposure to kerosene, and gas oil ,respectively in comparison with the same mixes immersed in water at the same age.
6. The modulus of rupture of all mixes deteriorated as the exposure period to oil products increases. The percentage of reduction in reference concrete for exposure period at 180 days is (23.3 %, and 27.6%), whereas, for concrete mixes P1 it is (20.1%, 23.9%), whereas, for concrete mixes P2 it is (17.3%, and 18.7%). For concrete mixes P3 it is (13.7%, and 15.6%). After exposure to kerosene, and gas oil, respectively in comparison with the same mixes immersed in water at the same age.
7. The total absorption of all mixes increases as the exposure period to oil products increases. The percentage of increase in reference concrete for exposure period of 180 days is (89.77%, and 79.55%), whereas, for concrete mixes P1 it is (78.18%, 75.15%), and for concrete mixes P2 it is (85.91%, and 63.09%). For concrete mixes P3 it is (64.93%, and 61.94%). After exposure to kerosene, and gas oil, respectively in comparison with the same mixes immersed in water at the same age.
8. The development of strength with age for mix P3, when exposed to oil products is larger than that obtained for reference concrete specimens immersed in water at the same age. The compressive strength up to 180 days for mix P3 was (57.7 and 55.5) MPa after exposed to kerosene and gas oil, while it was (52.4) MPa for reference concrete.

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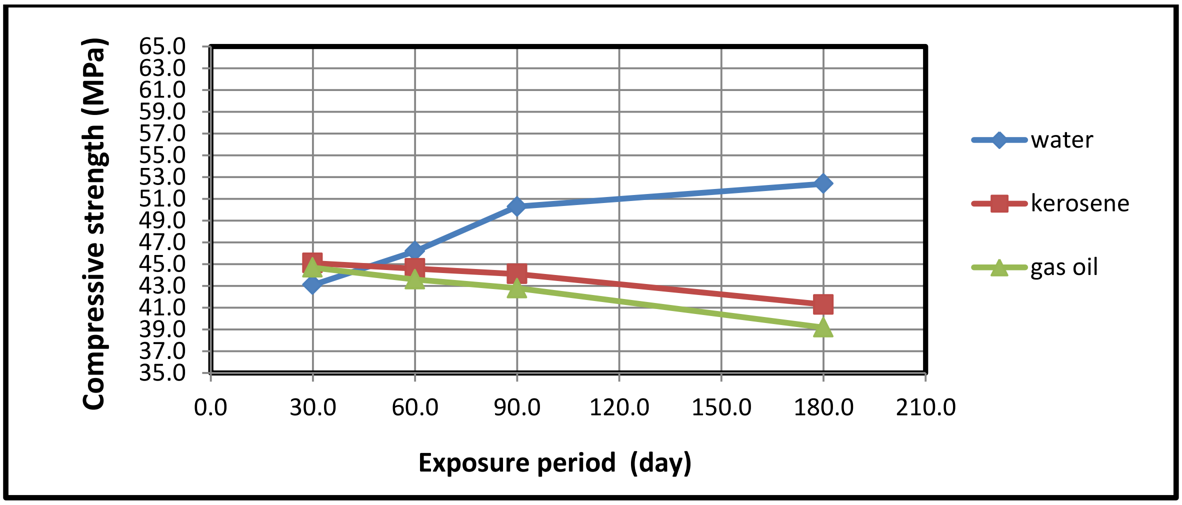


**Figure 1.** Relationship between compressive strength for mix R and durations of immersion in water, kerosene and gas oil.

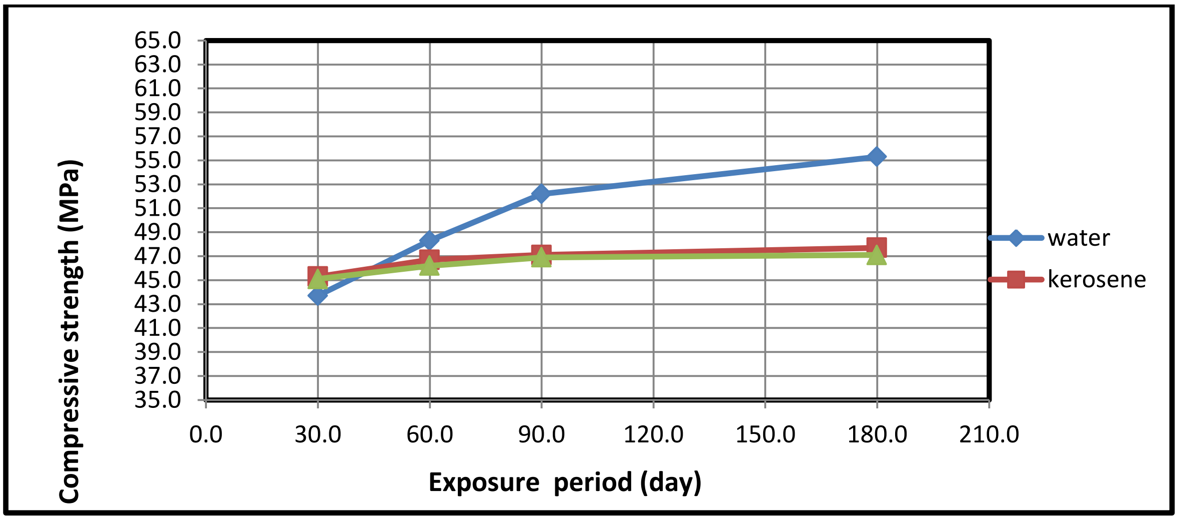


**Figure 2.** Relationship between compressive strength for mix P1 and durations of immersion in water, kerosene and gas oil.

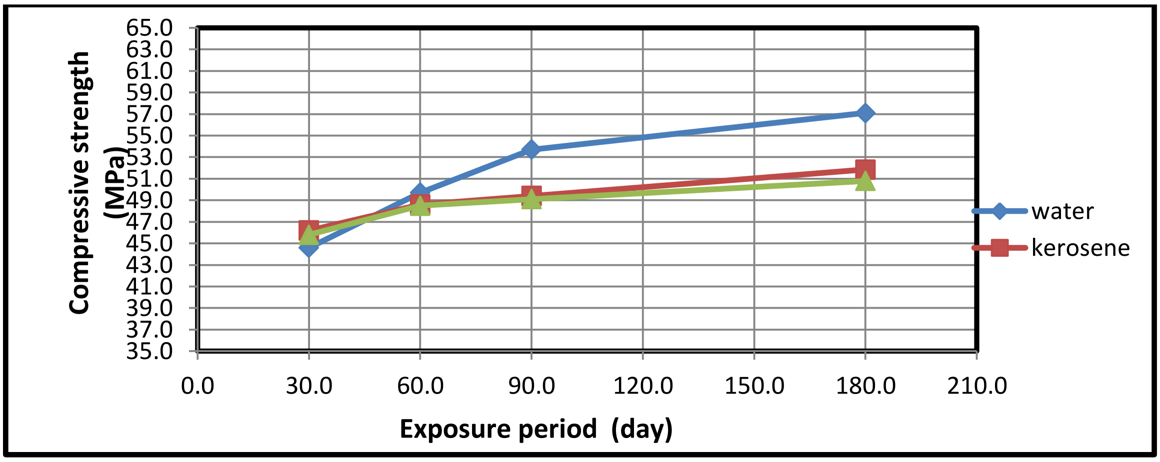


**Figure 3.** Relationship between compressive strength for mix P2 and durations of immersion in water, kerosene and gas oil.

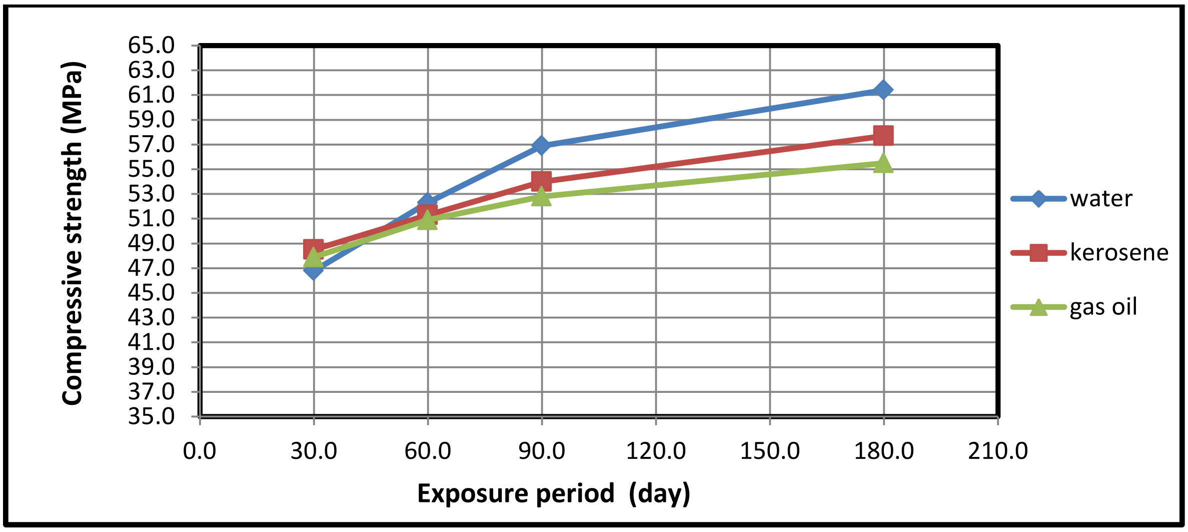


**Figure 4.** Relationship between compressive strength for mix P3 and durations of immersion in water, kerosene and gas oil.

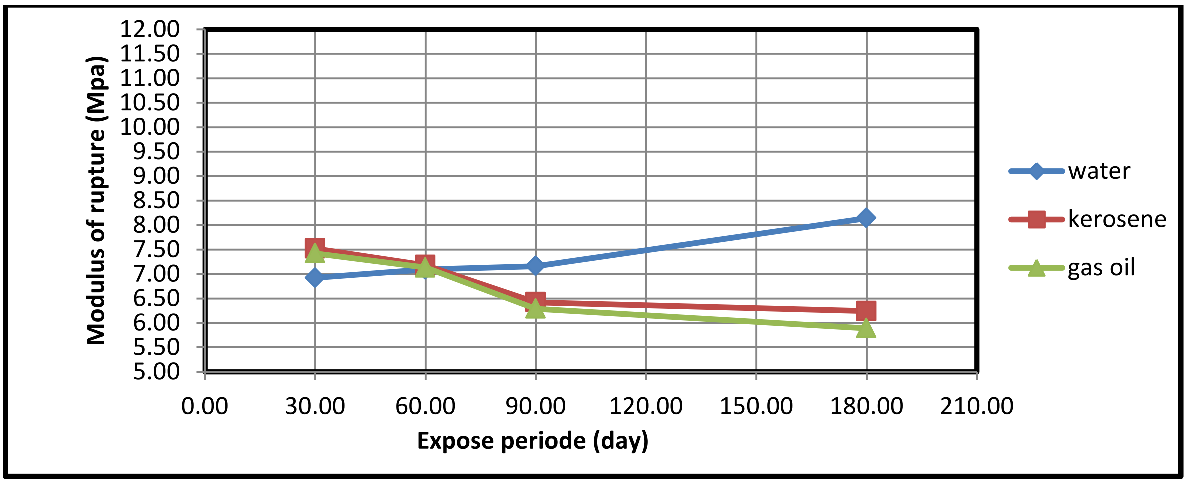


**Figure 5.** Relationship between modulus of rupture for mix R and durations of immersion in water, kerosene and gas oil.

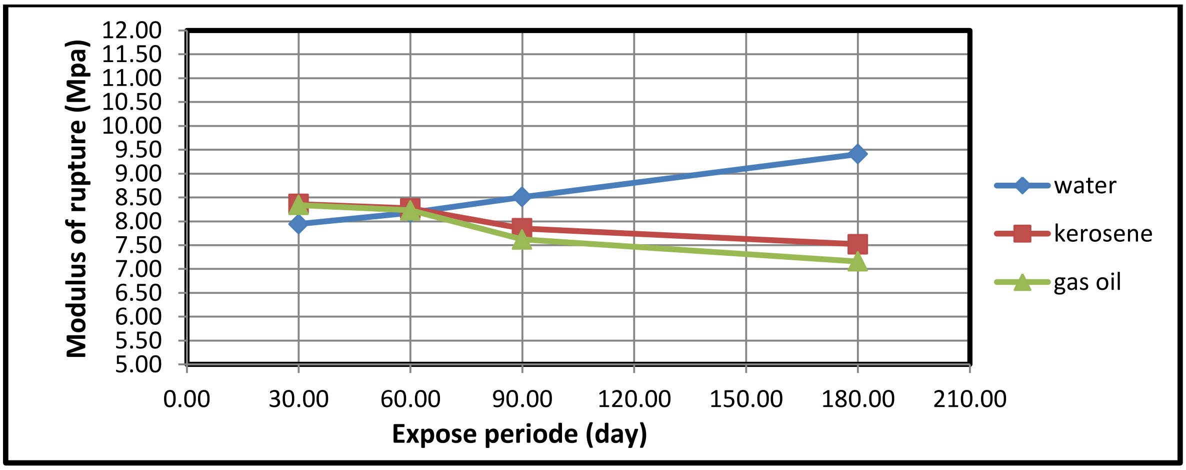


**Figure 6.** Relationship between modulus of rupture for mix P1 and durations of immersion in water, kerosene and gas oil.

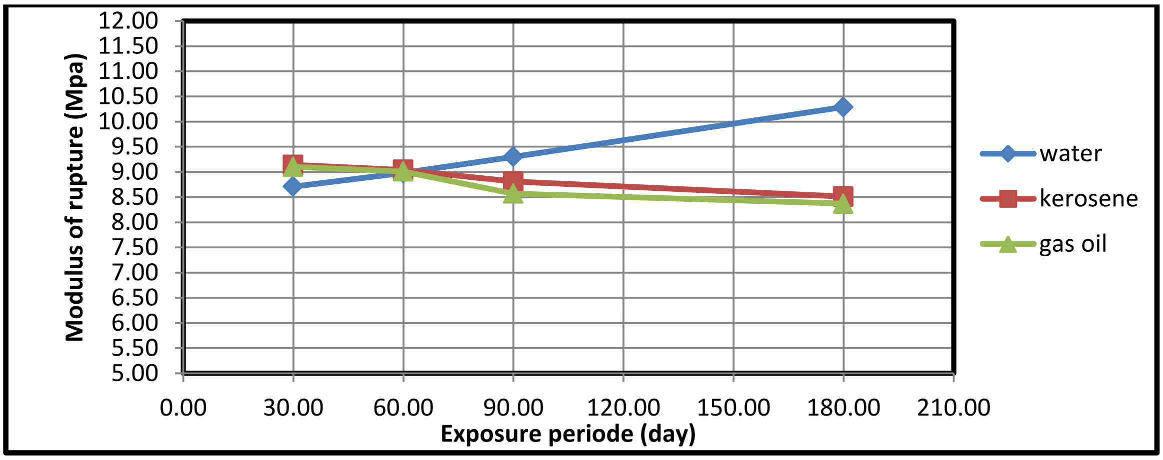


**Figure 7.** Relationship between modulus of rupture for mix P2 and durations of immersion in water, kerosene and gas oil.

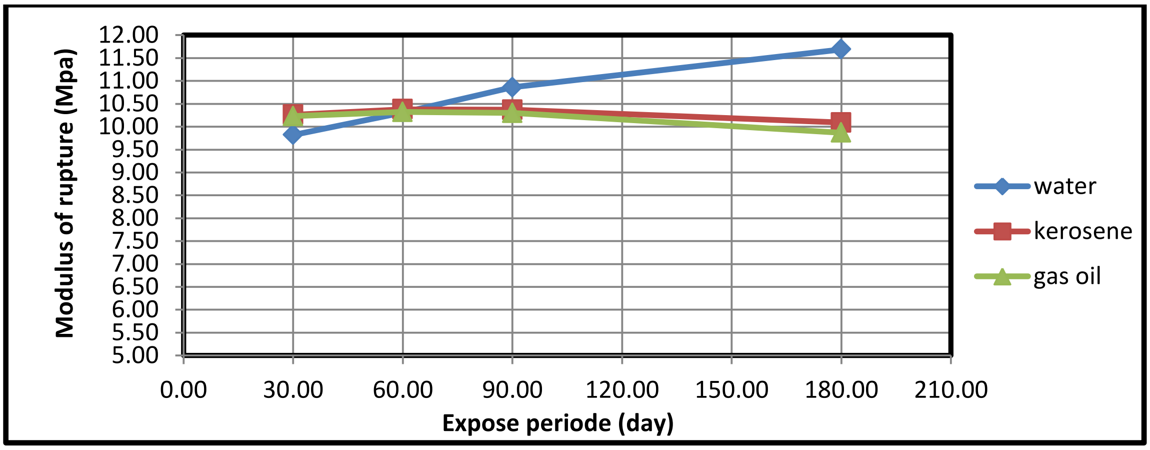


**Figure 8.** Relationship between modulus of rupture for mix P3 and durations of immersion in water, kerosene and gas oil.

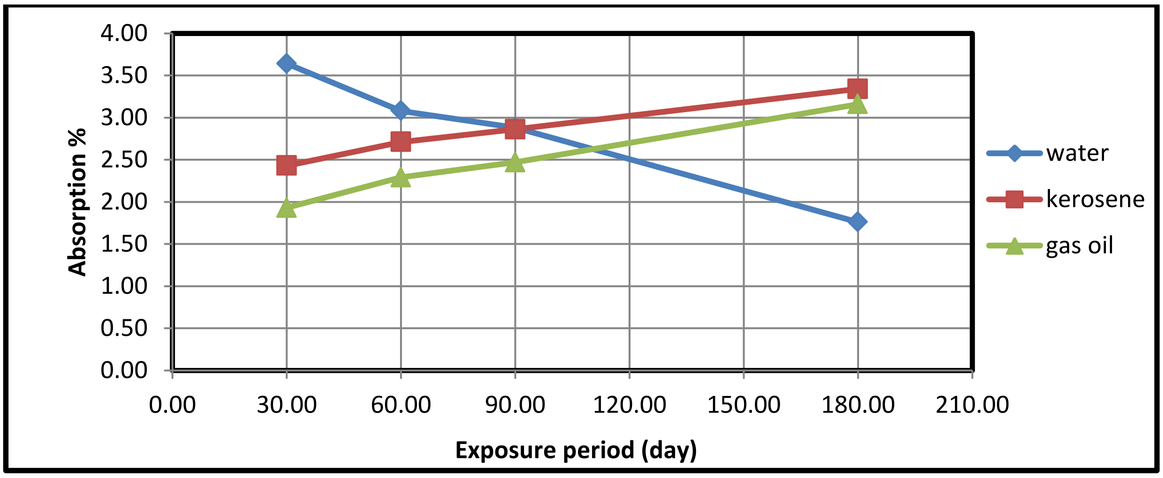


**Figure 9.** Relationship between total absorption for Reference concrete (R1) and durations of immersion in water, kerosene and gas

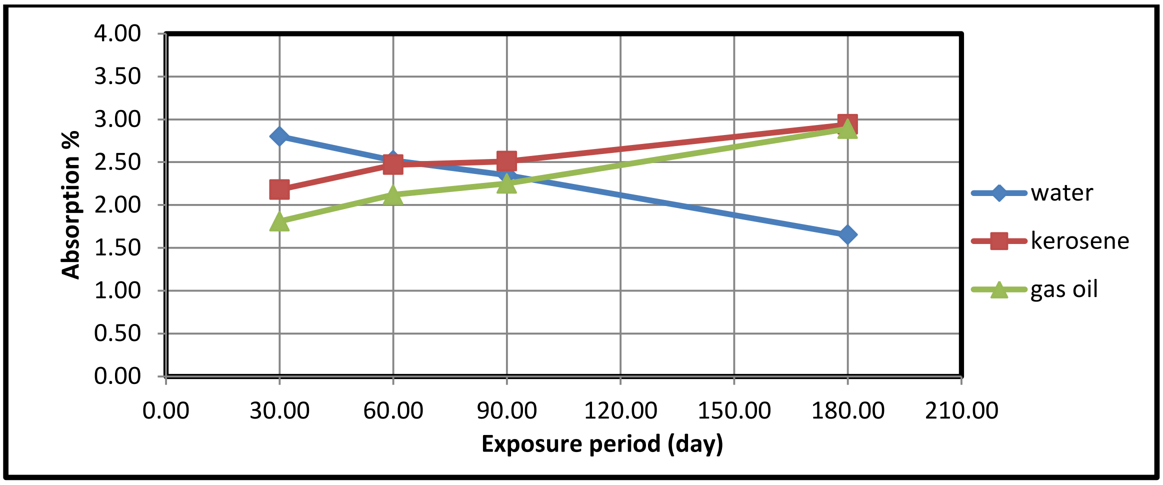


**Figure 10.** Relationship between total absorption for mix P1 and durations of immersion in water, kerosene and gas oil.

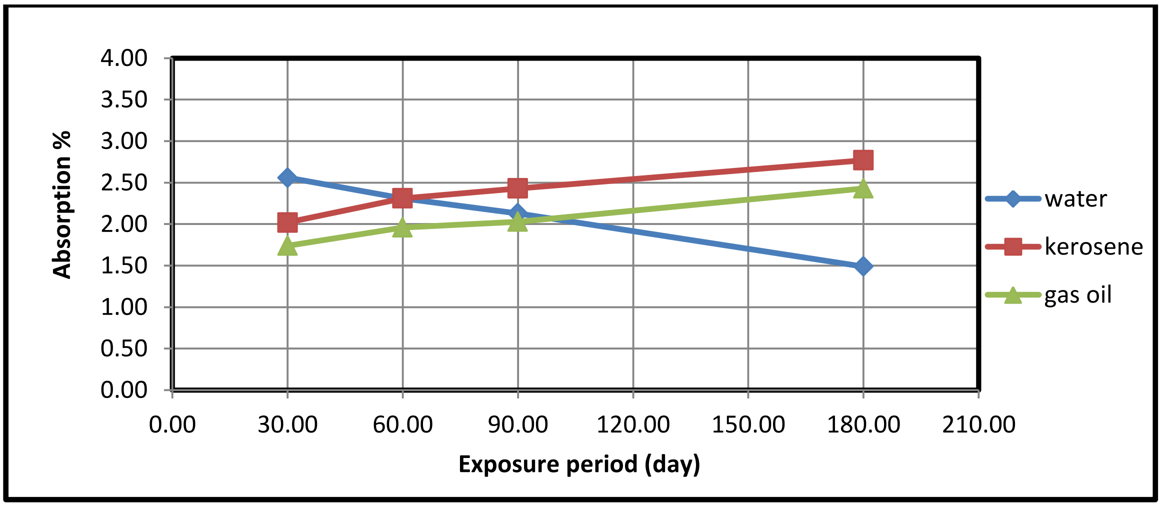


**Figure 11.** Relationship between total absorption for mix P2 and durations of immersion in water, kerosene and gas oil.

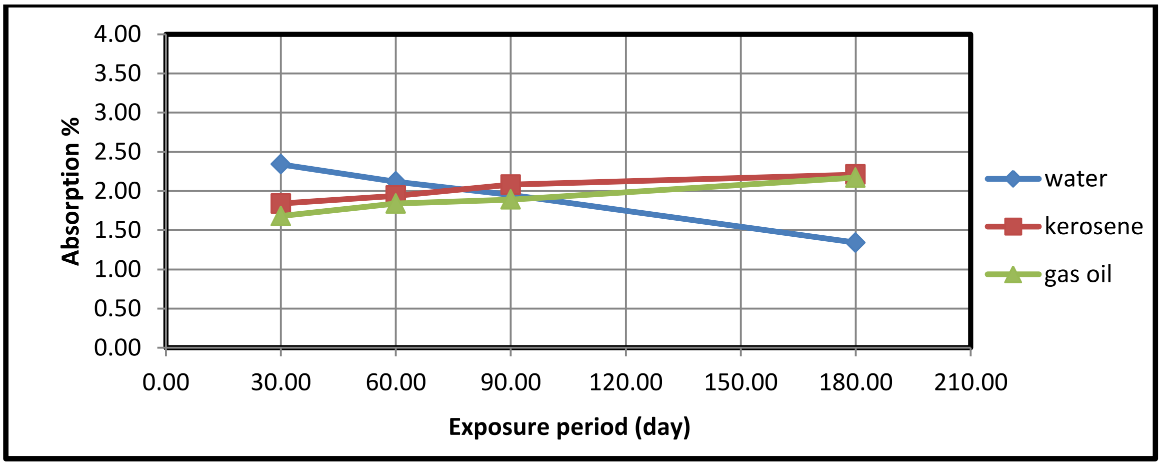


**Figure 12.** Relationship between total absorption for mix P3 and durations of immersion in water, kerosene and gas oil.

**Table 1.** Physical properties of cement.

| Physical properties | Test result | Limit of Iraqi Specification No. 5/1984 |
|---|---|---|
| Specific surface area (Blaine method), $cm^2/gm$ | 2900 | ≥2300 |
| Setting time (Vicat's apparatus)<br>Initial setting time, hrs: min.<br>Final setting, hrs: min. | <br>1:50<br>4:29 | <br>≥ 0:45<br>≤10:0 |
| Compressive strength<br>3days, $N/mm^2$<br>7days, $N/mm^2$ | <br>20.4<br>31.6 | <br>≥15<br>≥23 |

**Table 2.** Chemical composition and main compounds of cement.

| Oxide Composition | Abbreviation | Content (%) | Limit of Iraqi Specification NO. 5/1984 |
|---|---|---|---|
| Lime | $CaO$ | 58.98 | - |
| Silica | $SiO_2$ | 19.74 | - |
| Alumina | $Al_2O_3$ | 3.72 | - |
| Iron Oxide | $Fe_2O_3$ | 3.54 | - |
| Magnesia | $MgO$ | 3.78 | ≤5.0% |
| Sulfate | $SO_3$ | 2.73 | ≤2.8% |
| Loss on Ignition | L.O.I. | 3.46 | ≤4.0% |
| Insoluble residue | I.R. | 0.74 | ≤1.5% |
| Lime saturation Factor | L.S.F. | 0.92 | 0.66-1.02 |
| **Main Compounds (Bogue's equations)** | | | |
| Tricalcium Silicate | $C_3S$ | 52.26 | - |
| Dicalcium Silicate | $C_2S$ | 17.17 | - |
| Tricalcium Aluminate | $C_3A$ | 3.87 | - |
| Tetracalcium alumino-ferrite | $C_4AF$ | 10.77 | - |

**Table 3.** Typical properties of (Glenium 51).

| NO. | Main action | Concrete super plasticizer |
|---|---|---|
| 1 | Form | Viscous liquid |
| 2 | Color | Light brown |
| 3 | Relative density | 1.1 at 20°C |
| 4 | pH value | 6.6 |
| 5 | Viscosity | 128 +/ - 30 cps at 20°C |

**Table 4.** Typical properties of styrene butadiene copolymer Latex.

| **Properties** | **Description** |
|---|---|
| Composition | A milky, white styrene butadiene copolymer latex, specifically made for use with Portland cement. |
| Ph | 10.5. |
| Specific gravity | 1.00 – 1.03 |
| Mean particle size | 0.17 micron. |
| Butadiene content | 40% by weight of Rheomix 141 polymer. |
| Styrene | 60 (% by weight) |

**Table 5.** Chemical properties of Fly Ash.

| **Chemical Properties** | **Oxide content %** | **ASTM C 618-03** |
|---|---|---|
| Silica ($SiO_2$) | 54.7 | |
| Alumina ($Al_2O_3$) | 31.91 | |
| Iron Oxide ($Fe_2O_3$) | 8.79 | |
| Calcium Oxide (CaO) | 1.5 | |
| Magnesia Oxide (MgO) | 0.21 | |
| Sulfate ($SO_3$) | 0.06 | $\leq$ 5 % |
| Loss on Ignition | 2.05 | $\leq$ 6 % |
| $SiO_2$+$Al_2O_3$+$Fe_2O_3$ | 95.4 | $\geq$ 70 |

**Table 6**. Physical properties of Fly Ash.

| **Physical Properties** | **Test Results** |
|---|---|
| Colour | Grey |
| Specific gravity | 2.15 |
| Strength Activity Index | 93% |

**Table 7.** Types of concrete mixtures and Mix proportions.

| Type of Mixing | Mix proportions (Kg/m3) | | | | | | | w/b | plasticize/C | Polymer/C | Reduction S.P. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | cement | water | F.A. | C.A. | Fly Ash | Polymer | Plasticize (S.P) | | | | |
| R | 410 | 175 | 840 | 850 | 41 | 0 | 5.33 | 0.38 | 1.3 | 0% | 0% |
| P1 | 396.8 | 175 | 840 | 850 | 41 | 13.2 | 4.53 | 0.4 | 1.14 | 5% | 15% |
| P2 | 383.6 | 175 | 840 | 850 | 41 | 26.4 | 4 | 0.41 | 1.04 | 10% | 25% |
| P3 | 370.5 | 175 | 840 | 850 | 41 | 39.5 | 3.46 | 0.43 | 0.93 | 15% | 35% |

**Table 8.** Results of fresh properties tests for all mixes.

| Set No. | Dosage of S.P $l/m^3$ | Slump flow (mm) | T50 (Sec.) | L-Box blocking ratio (H2/H1) | U-Box filling height (H2-H1) Mm | V-Funnel Time (Sec.) | Segregation Index (visual) |
|---|---|---|---|---|---|---|---|
| R | 5.33 | 720 | 4 | 0.90 | 12 | 10 | homogeneous |
| P1 | 4.53 | 710 | 5 | 0.85 | 15 | 11 | homogeneous |
| P2 | 4 | 725 | 3.5 | 0.91 | 10 | 9 | homogeneous |
| P3 | 3.46 | 715 | 5 | 0.88 | 13 | 10 | homogeneous |

**Table 9.** Average compressive strength results of all mixes at various periods of immersion in water and oil products.

| **Set no.** | **Compressive strength (MPa) after 28 days curing** | Compressive strength of all mixes after different exposure periods (MPa) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Duration of exposure (Age) day | | | | | | | | | | | |
| | | 30(65) | | | 60(95) | | | 90(125) | | | 180(215) | | |
| | | Water | Kerosene | gas oil | water | Kerosene | gas oil | Water | kerosene | gas oil | water | Kerosene | gas oil |
| R | 40.6 | 43.1 | 45.1 | 44.7 | 46.2 | 44.6 | 43.6 | 50.3 | 44.1 | 42.8 | 52.4 | 41.3 | 39.2 |
| P1 | 40.8 | 43.7 | 45.3 | 45.1 | 48.3 | 46.7 | 46.2 | 52.2 | 47.1 | 46.9 | 55.3 | 47.7 | 47.1 |
| P2 | 41.5 | 44.6 | 46.2 | 45.8 | 49.7 | 48.6 | 48.5 | 53.7 | 49.4 | 49.1 | 57.1 | 51.9 | 50.8 |
| P3 | 42.8 | 46.8 | 48.5 | 47.9 | 52.3 | 51.3 | 50.9 | 56.9 | 54.0 | 52.8 | 61.4 | 57.7 | 55.5 |

**Table 10.** Modulus of rupture results of all mixes at various periods of immersion in water or oil products.

| Set no. | Modulus of rupture (MPa) after 28 days curing | Modulus of rupture of all mixes at different exposure periods (MPa) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Duration of exposure (Age) day | | | | | | | | | | | |
| | | 30(65) | | | 60(95) | | | 90(125) | | | 180(215) | | |
| | | Water | Kerosene | gas oil | water | Kerosene | gas oil | Water | Kerosene | gas oil | water | Kerosene | gas oil |
| R | 6.85 | 6.92 | 7.52 | 7.42 | 7.09 | 7.18 | 7.13 | 7.16 | 6.42 | 6.29 | 8.14 | 6.24 | 5.89 |
| P1 | 7.35 | 7.94 | 8.36 | 8.34 | 8.18 | 8.27 | 8.23 | 8.51 | 7.85 | 7.62 | 9.41 | 7.52 | 7.16 |
| P2 | 7.77 | 8.71 | 9.14 | 9.10 | 8.98 | 9.04 | 9.01 | 9.30 | 8.81 | 8.57 | 10.29 | 8.51 | 8.37 |
| P3 | 8.65 | 9.82 | 10.26 | 10.23 | 10.31 | 10.38 | 10.32 | 10.86 | 10.37 | 10.30 | 11.69 | 10.09 | 9.87 |

**Table 11.** Total water absorption results of all mixes at various periods of immersion in water or oil products.

| Set no. | Total absorption (%) after 28 days curing | Total absorption of all mixes at different exposure periods (%) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Duration of exposure (Age) day | | | | | | | | | | | |
| | | 30(65) | | | 60(95) | | | 90(125) | | | 180(215) | | |
| | | Water | Kerosene | gas oil | water | Kerosene | gas oil | Water | Kerosene | gas oil | water | Kerosene | gas oil |
| R | 3.85 | 3.64 | 2.43 | 1.93 | 3.08 | 2.71 | 2.29 | 2.88 | 2.86 | 2.47 | 1.76 | 3.34 | 3.16 |
| P1 | 2.97 | 2.80 | 2.18 | 1.81 | 2.52 | 2.47 | 2.12 | 2.35 | 2.51 | 2.25 | 1.65 | 2.94 | 2.89 |
| P2 | 2.76 | 2.56 | 2.02 | 1.74 | 2.31 | 2.31 | 1.96 | 2.13 | 2.43 | 2.03 | 1.49 | 2.77 | 2.43 |
| P3 | 2.59 | 2.34 | 1.84 | 1.68 | 2.12 | 1.94 | 1.84 | 1.95 | 2.08 | 1.89 | 1.34 | 2.21 | 2.17 |