Properties of Self Compacted Concrete Modified with Epoxy and Exposed to Sewerage Environment

خواص الخرسانة الذاتية الرص المطورة بالايبوكسي والمعرضة الى بيئة الصرف الصحي

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Abstract

Recently, there has been a lot of research that is concerned with developing the durability of concrete exposed to a sever environment in order to reduce the cost of maintenance, by making the maintenance in interval spacede specially in strategic projects that serve many people such as sewage and sewerage projects. In this study, the properties of the epoxy modified self compacted concrete were studied after being placed in a sever environment (partially submerged in septic tank) for different periods of 30, 90 and 180 days. Epoxy material was added to the self compacted concrete (SCC) in three different ratios 5, 7.5 and 10% of the cement weight. The properties studied in this work were compressive, splitting tensile strength, change in weight and total absorption. In general, and through the results of the tests, a deterioration in the reference SCC was observed due to exposure to extreme conditions. At 180 days of exposure it was observed that there was a noticeable decrease in compressive and tensile strength of 20.8% and 46.5%, for the reference SCC, respectively, compared to the same concrete prior to exposure. The exposure of the reference SCC to the sewerage environment led to a significant deterioration in the percentage of weight loss and absorption after 180 days of partial immersion in septic tank. The modification of SCC by the addition of epoxy resin resulted in a clear improvement in all properties examined and was the greatest improvement when using 10% of the epoxy. After 180 days of exposure to the sewerage environment, the increase in compressive and tensile strength of 10% epoxy SCC were 87% and 142%, respectively, compared to the reference SCC without epoxy resin.

Keywords: Self Compacted Concrete, Compressive Strength, Weight Change, Total Absorption, Sewerage, Epoxy Resin .

الخلاصة

حديثا هناك عدد قليل من البحوث التي تهتم بتطوير ديمومة الخرسانة المعرضة الى بيئة قاسية وذلك لتقليل كلفة الصيانة وخصوصا في المشاريع الستراتيجية التي تخدم الكثير من السكان مثل مشاريع المجاري والصرف الصحي. في هذا البحث تم دراسة خواص الخرسانة الذاتية الرص والمطورة بالايبوكسي بعد وضعها في بيئة قاسية (غمرها جزئيا في حوض التعفين المنزلي) لفترات مختلفة 30 ، 90 و 180 يوم. تم اضافة مادة الايبوكسي الى الخرسانة ذاتية الرص بثلاث نسب مختلفة 5، 7.5 و 10% من وزن السمنت. الخواص التي تم دراستها في هذا البحث هي مقاومة الانضغاط والشد والتغير بالوزن والامتصاص الكلي. بصورة عامة ومن خلال نتائج الفحص لوحظ حدوث تدهور في الخرسانة ذاتية الرص المرجعية نتيجة التعرض للظروف القاسية. بعمر ١٨٠ يوم من التعرض لوحظ ان هناك نقصان واضح في مقاومة الانضغاط والشد 20.8% و 46.5% على التوالي للخرسانة الذاتية الرص المرجعية مقارنة مع نفس الخرسانة قبل التعرض. ان تعرض النماذج للخرسانة المرجعية الى بيئة الصرف الصحي ادى الى حدوث تدهور واضح في نسبة النقصان بالوزن والامتصاص بعد 180 يوم من الغمر الجزئي في خزان التعفين. ان تطوير الخرسانة بواسطة اضافة راتنج الايبوكسي ادى الى حدوث تحسن واضح في جميع الخواص المفحوصة وكان التحسن الاكبر عند استخدام نسبة 10% من الايبوكسي. بعد 180 يوم من التعرض لبيئة الظرف الصحي كانت نسبة الزيادة في مقاومة الانضغاط والشد 87% و 142% للخرسانة ذاتية الرص والحاوية على 10% من الراتنج الايبوكسي على التوالي مقارنة مع الخرسانة الذاتية الرص المرجعية والغير حاوية على راتنج الايبوكسي.

الكلمات المفتاحية : خرسانة ذاتية الرص ، مقاومة الانضغاط ، التغيير بالوزن ، الامتصاص الكلي ، الصرف الصحي ، راتنج الايبوكسي .

1. Introduction

Sewage projects are one of the most important elements of infrastructure for the construction and development of cities. Concrete in sewerage environment, where numerous types of chemical and biotic destructive constituents exist, is prone to different forms of attack. These constituents react with concrete through different mechanisms that lead to the deterioration of concrete and corrosion of its buried reinforcement. Most aggressive events focus on the attack of sulfuric acid, dispersing chloride and carbonate in a sewage environment. **Parande A. K. [1]** described that the biological deterioration of concrete which is very well known in the sewage system and sewage treatment plant. Typically, the process can be clarified by the following two events:

1- Biochemical reactions creating biogenic hostile type in biofilms which are dispersed on the surface area of concrete. Sulfuric acid (H_2SO_4) formed by sulphur oxiding bacteria (SOB) is considered to be the most important biogenic acid in sewerage environment (sewer concrete pipes, manholes and septic tanks).

2- Chemical reactions between biogenic hostile type and cement hydration products which is accountable for concrete degradation

In Iraq, most of the sewage networks are old and have not been regularly maintained. This has led to the deterioration of these networks, especially the concrete parts such as treatment plants, pumping stations or manholes and other concrete parts exposed to sewerage water. After 2003, new sewerage networks were started in most Iraqi cities, but it was noticed that the concrete parts of these projects were not implemented in a manner that would provide them with long-term durability. Most of the concrete parts were exposed to harsh water painted with cool tar epoxy. However, can be noticed that after a short period of time the deterioration of concrete parts began. The main reason for this deterioration is not to use concrete with good quality (low absorption ,low permeability and high resistance to aggressive conditions). Of axioms in civil engineering are all type of concrete declines over time. The rate at which concrete declines is a function of two aspects: the quality of the concrete and the environment to which the concrete is exposed. Many problems may be affected on the durability of concrete in sewerage projects , the most important is the chemical attack. This harsh force can considerably reduce the service life of the structure. The quality of concrete mentions to the properties combined into the novel concrete mix design such as water/cement ratio, cement type, size and rigidity of the aggregate and air entrainment. Quality is also reliant on the construction performs used to place the concrete such as suitable consolidation, cover and curing. If the designer funded attention to these details, then expectantly your concrete is impenetrable, has low penetrability, is resistant to freeze-thaw harm, and is fairly crack-free. Self compacted concrete (SCC) is one of the most significant advances in concrete and construction technology at present-day. The ability of self compacted concrete to regulator the free flow of forms and compact itself by itself and to dismiss confined air without use vibrators. An important advantage in the use of SCC related to old-style concrete is compact itself in a complete and uniformity manner leading to the formation of smooth and condensed concrete surfaces with high segregation resistance **EFNARC (2002) [2]**. The ability of SCC to withstand durability is due to high density, high workability and reduction the pores are excellent as well as reduce the phenomenon of bleeding in addition to growing the strength of adhesion between concrete and reinforcing steel. The tests proved that the SCC gives adhesive 50-70% higher than the concrete which are fully compacted by vibrator in addition to high segregation resistance **Zeeshan and Mahure [3]**. On the other hand, the concrete is self compacted is characterized by compressive, splitting tensile and flexural strength, and high ultrasonic velocity. In order to improve the properties of SCC and make it better in terms of durability, attention is directed to the use of polymer materials. Adding of polymer to concrete leads to the manufacture of polymer modified concrete. One of the most newly used polymer materials is epoxy resin. Epoxy modified concrete is one of the acceptable solutions to improve the mechanical properties of concrete and rise concrete durability to aggressive environment particularly sewerage.

2. Significant and outline of research

The use of epoxy modified concrete is producing an equilibrium in strength, durability, and cost. Numerous researches have been prepared about the effect of sewerage water on the properties of epoxy modified self compacted concrete. The main objective of this study is to find out the properties of the epoxy modified SCC submerged in sewerage water. The influence of sewerage environment on epoxy modified self compacted concrete was examined in this research. An optimum design mix using locally obtainable materials are studied to produce of self compacted concrete. The SCC was also modified by adding different percentages of epoxy resin to make SCC best acceptable durability criteria when exposed to sewerage environment. The criteria are the physical changes in weight and water/sewerage absorption percentages. Compressive and splitting tensile strength for 30, 90 and 180 days were also calculated. Results were related with control mix of SCC (having 0% epoxy in the mix).

3. Mechanism of bio degradation of concrete sewerage structures

Concrete in the sewage projects is usually subjected to harsh conditions and these conditions vary from severe to very severe and lead to a deterioration in the concrete, which eventually leads to a collapse in the construction. The understanding of the mechanisms of deterioration of cementitious materials by these hostile media is an necessary step toward the growth of concrete that accomplishes well in these environments and toward the rise of the facility life or the safety of this type of structures and services **Sambhav and Raksha [4]**. There are many bio-organic acids such as acetic, lactic, butyric, etc. In addition to carbon dioxide, created by different microorganisms, these acids make concrete susceptible to corrosion. This has been demonstrated by researchers **Beata [5]**. In normal household pH phases, from 25% to 33% of soluble solids existing in molecular H_2S, which are not restricted in the air and located on the wall of the wet structure. Bacteria on the wall convert H_2S to H_2SO_4, which reduces the pH numbers of the wall moisture to one-two range, and the acid oxidization the structure wall above the flow line. Oxidative bacteria present sulfur oxidation of H_2S dissolved in moisture to sulfuric acid H_2SO_4, mentioned to as bio sulfuric acid, which is thought to be answerable for biodegradation. This biodegradation of acids leads to degradation of constituents in concrete, thus creating gypsum ($CaSO_4$ for different hydration phases) and etringite ($3CaO \cdot Al_2O_3 \cdot CaSO_4 \cdot 12H_2O$) with expansionary properties. As a protective layer for concrete gypsum may be act in the same manner that the initial layer of defense against metal corrosion. If this "defense" layer is removed from the gypsum, the acid attack can accelerate the harm to the surface. In addition, a mixture of $CaSO_4$ and C_3A in concrete produces etringite, which rises the internal stresses caused by its somewhat big size and quickly to the formation of cracks. With the elimination of degraded substances through sewage flow, concrete corrosion accelerated as new surfaces area were exposed to these procedures. **Table 1** demonstrate all these chemicals of biological origin interact easily with concrete components and reason its deterioration.

Table 1 : Biogenic substances and chemical reactions essential for the microbiologically influenced deterioration of concrete

Biogenic organic acids	
$Ca(OH)_2 + 2\ \underset{\text{lactic acid}}{C_2H_4(OH)COOH} + 3\ H_2O \rightarrow \underset{\text{calcium lactate}}{Ca[C_2H_4(OH)COO]_2 \cdot 5\ H_2O}$	............................Eq.1
$Ca(OH)_2 + 2\ \underset{\text{acetic acid}}{CH_3COOH} \rightarrow \underset{\text{calcium acetate}}{Ca(CH_3COO)_2.H_2O} + H_2O.$	...........................Eq. 2
Biogenic carbon dioxide	
$Ca(OH)_2 + 2\ CO_2 \rightarrow Ca(HCO_3)_2$	............................Eq. 3
$CaCO_3 + CO_2 + H_2O \rightarrow Ca(HCO_3)_2.$	............................Eq. 4
Biogenic nitric acid	
$2\ NH_4^+ + 3\ O_2 \xrightarrow{Nitrosomonas} 2\ NO_2^- + 2\ H_2O + 4\ H^+$	............................Eq. 5
$2\ NO_2^- + O_2 \xrightarrow{Nitrobacter} 2\ NO_3^-$	

$Ca(OH)_2 + 2\,HNO_3 \rightarrow Ca(NO_3)_2 + 2\,H_2O$ ....Eq. 6

Biogenic hydrogen sulfide and sulfuric acid

$SO_4^{2-} + 2\,H^+ + 4\,H_2 \xrightarrow{SRB} H_2S \uparrow + 4\,H_2O$ ....Eq. 7

SRB – sulfate reducing bacteria

$H_2S + 2O_2 \xrightarrow{SOB} H_2SO_4$ ....Eq. 8

SOB – sulfur oxidizing bacteria

$Ca(OH)_2 + H_2SO_4 \rightarrow \underbrace{CaSO_4.2\,H_2O}_{\text{gypsum}}$. ....Eq. 9

$3CaO{\cdot}Al_2O_3.3CaSO_4{\cdot}nH_2O + 3\underbrace{(CaSO_4{\cdot}2H_2O)}_{\text{gypsum}} + H_2O \rightarrow \underbrace{3CaO{\cdot}Al_2O_3{\cdot}3CaSO_4{\cdot}32H_2O}_{\text{ettringite}}$ ....Eq. 10

Microorganisms can enter into the concrete surface even if it does not contain cracks in the concrete **Sanchez and Rossowski [6]**. The mechanism for their entry is through microcracks or through the capillary pores in the concrete. The significances of microscopic microorganisms are different. Although there is unsatisfactory investigational evidence, it was observed that the work of microorganisms on the concrete matrix rises concrete porosity, which in turn can alter the diffusivity of concrete. High values for porosity can also result in higher surface wear, which reduces the depth of the concrete defense cover on reinforcement.

4. Materials and Method

4.1 Materials

4.1.1 Cement

Sulphate Resistance Cement (Type V) from a cement plant Tasluja. Conforming to Iraqi specifications No. 5/1984 [7].

4.1.2 Aggregates

Locally available natural sand from of Al-Najaf quarries with 4.75 mm maximum size was used as fine aggregate and crushed stone from Al-Nabaey region with 20 mm maximum size was used as coarse aggregate having sieve analysis, finer materials and sulphate content corresponding with Iraqi specifications No. 45/1984 [8] as given in Table 2 and 3.

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	98.5	90 – 100
2.36	95.2	85 – 100
1.18	91.8	75 – 100
0.6	77.8	60 – 79
0.3	20.6	12 – 40
0.15	5.1	0.0 – 10
materials less than 75 micron %	1.45	5% upper limit
Sulphate content %	0.24	0.5% upper limit

Table 3 : Sieve analysis of coarse aggregate*

Sieve size (5-20) mm	Passing%	Requirements according IQ.S No.45/1984
37.5	100	100
20	98.7	95 – 100
10	21.6	30 – 60
5	2.7	0 – 10
materials less than 75 μ %	1.08	3% upper limit
Sulphate content %	0.033	0.1% upper limit

* Fine and coarse aggregate tests were conducted by Faculty Engineering Laboratories/Kufa University

4.1.3 Fly Ash

A finely divided powder fly ash known commercially as (Admix FLY ASH) was used in this study. Admix FLY ASH is of grayish white color which is a pozzolanic material used in the production of high strength concrete. This material is obtained by the processing of FLY ASH produced by the combustion of coal in power stations and its complies with ASTM C 618-03 [9] . 20% Fly ash was replaced by weight of cement [3] . The main characteristics are showed in Table 4

Table 4 : Physical and chemical characteristics of Admix FLY ASH*

Physical characteristics	
Color	Greyish white
Fitness (retained on 235 mesh sieve)	Maximum 34%
Moisture	Maximum 2%
Loss on Ignition	Maximum 2%
Chemical characteristics	
SiO_2+Al_2O_3+Fe_2O_3	Minimum 20%
SO_3	Maximum 2%
Na_2O	Maximum 2%

* Admix FLY ASH brought from SODAMCO for chemical admixtures

4.1.4 Admixture / Hyperplasticizer

High performance superplasticising was used in this study. Hyperplast PC 711 is admixture based on polycarboxylic polymers with long chains specially designed to enable the water content of the concrete to perform more effectively. Its complies with ASTM C 494 Type F [10]. Characteristics of Hyperplast PC 711 are illustrated in Table 5.

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

* Hyperplast PC 711 brought from Don Construction Products (DCP)

4.1.5 Epoxy Resin

Quickmast 108 is a two component, solvent free epoxy resin bonding agent, supplied in pre-weighed packs containing base and hardener. Quickmast 108 is a permanent epoxy adhesive for bonding fresh wet concrete/cementitious material to old concrete which is suitable for internal and external application. Quickmast 108 complies with ASTM C881/C881M-15, Type II, Grade 2, Class C [11] Characteristics of Quickmast 108 are shown in Table 6.

Table 6 : Characteristics of Quickmast 108

Color	Green for mixed material
Mixed density	1.2 ± 0.1 g/cm^3
Compressive yield Strength: ASTM D695	≥ 50 MPa @ 7 days
Water absorption: ASTM D570	≤ 0.2%

* Quickmast 108 brought from Don Construction Products (DCP)

4.2 Mixes, Mixing and Preparation of Specimens

In this research, the Self Compacted Concrete (SCC) mixture was designed according to Krishna, Narasimha, and Ramana [12] . SCC is made in accordance with [2] "Specification and Guidelines for Self-Compacting Concrete". Reference SCC mixture is designed to provide at 28 days (100X100X100) mm specific compressive strength of 40 MPa . The mix proportion for epoxy modified SCC is similar to that of reference SCC excepting the W/C ratio, were renewed to keep the same workability requirements for all epoxy/cement ratio. The Epoxy/Cement ratio for epoxy which used are 5, 7.5, 10%. The use of epoxy resin in modification SCC can be difficult because the compound begins to set once the hardener and resin mix together. Therefore, other materials are pre-prepared and thoroughly mixed before adding the epoxy compound as shown in the following manner. After the cement, fly ash and aggregate are mixed with water for 2 minutes up to the uniformity of mix, then the epoxy modifier is added throughout a mix period about 60 seconds and mixed for roughly 30 seconds, with stop period of 1 minute rest to avoid the air bubbles as recommended by ACI committee 548-1999 [13]. After casting the samples, they were placed in curing water tank for 28 days, after which the samples were extracted and covered with nylon sheets for a period of 3 days to evaporate the water located in the surface area or the samples . After that the specimens, labeled and then were enfolded with plastic nets and placed in the inside of household septic tank and partially submerged. One-third to half of the specimens were immersed with sewage water and two-thirds were not submerged. Specimens were removed from the sewerage septic tank for laboratory testing after 30, 90 and 180 days of the exposure. Table 7 and Fig. 1 showed compressive strength of various types of self compacted concrete mixes at 28 days of curing in water

Table 7 : Mix proportion and compressive strength of reference SCC and various types of epoxy modified SCC mixes at 28 days of curing in water.

Mix.	Cement kg/m^3	Fly ash kg/m^3	Fine agg. kg/m^3	Coarse agg. kg/m^3	Hyper plasticizer PC 711 l/m^3	Epoxy resin %	w/b	Compressive strength N/mm^2 at 28 days
SCC- EP 0*	408	102	810	980	4	0.0	0.38	42.3
SCC-EP 5*	408	102	810	980	4	5.0	0.35	61.4
SCC-EP 7.5*	408	102	810	980	4	7.5	0.33	65.3
SCC-EP 10*	408	102	810	980	4	10.0	0.30	66.8

*EP represent epoxy/cement ratio (0, 5, 7.5, 10)%

4.3 Tests of Fresh SCC.

Self compacted concrete mixtures were assessed in its fresh state by specified tests conducted for this purpose to make certain concrete performance being self compacted. There are many suggested methods to ensure that they comply with the self-compacted requirements of dielectric resistance, filling ability and passing ability between reinforcing steel bars for self compacted concrete mixtures. Details have been mentioned and the method of conducting these tests in many research [2]. The acceptance criteria for SCC and results of workability tests on SCC are shown in Tables 8 and 9 , respectively.

Table 8: Acceptance criteria of SCC according to European requirements (EFNARC)

Test method	Range of value
Slump Flow	650 – 800 mm (Average flow Diameter)
T_{50cm}	2 – 5 sec (Time to flow 500 mm)
V – Funnel	6 – 12 sec (Time for emptying of funnel)
L – Box (H_2 / H_1)	0.8 – 1 (Ratio of heights at beginning and end of flow)
U – Box (H_2 – H_1)	0 – 30 mm (Difference in heights in two limbs)

Table 9 : Flow characteristics of reference SCC and various types of EM-SCC mixes

Mix.	Slump Flow (mm)	T_{50cm} (sec)	V – Funnel (sec)	L – Box (H2 / H1)	U – Box (H2 – H1)
SCC- EP 0	730	3.2	9.2	0.89	7.6
SCC-EP 5	760	2.8	8.3	0.92	4.3
SCC-EP 7.5	780	2.4	7.9	0.96	3.2
SCC-EP 10	790	2.1	7.6	0.98	2.8

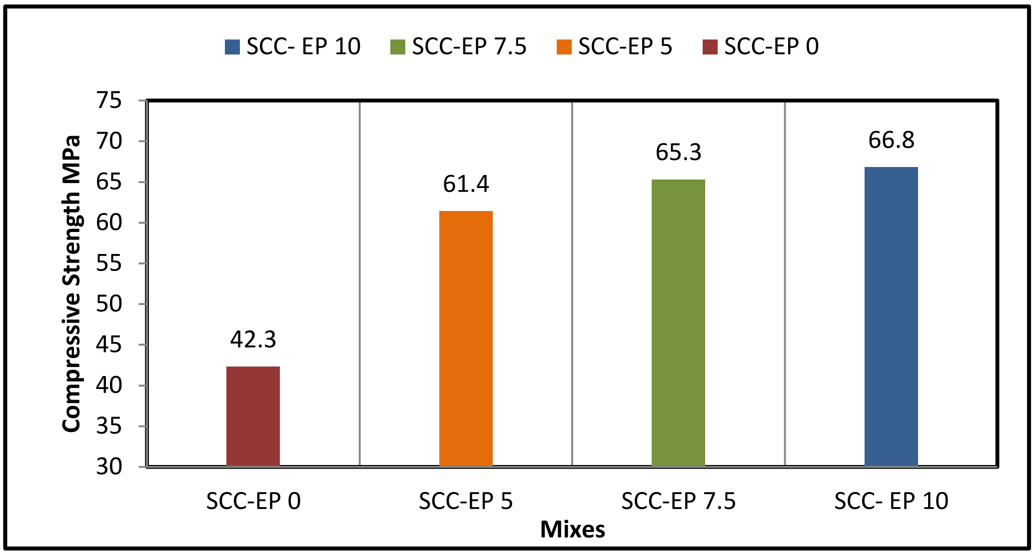

Fig. 1 Compressive strength of various types of SCC-EP at 28 days water curing

4.4 Laboratory Testing Techniques

4.4.1 Compressive Strength Test

The compressive strength test was evaluated according to **B.S.1881, part 116 [14]**. This test was made on 100 mm cubes using an electrical testing machine with 2000 kN capacity. The test was conducted at ages of 30, 90 and 180 days of exposure to sewerage environment after 28 days water curing.

4.4.2 Splitting Tensile Strength Test

The splitting tensile strength test was done giving to **ASTM C496-86 [15]** requirement. Cylinders of 100×200 mm were used and load was applied unceasingly up to failure using the same machine in computing compressive strength value. The test was performed at ages of 30, 90 and 180 days of exposure after 28 days water curing.

4.4.3 Weight Change Test (Method C)

After 28 days of curing, the first weight of the cylinder specimens of 100 x 200 mm was founded before submerging in the septic tanks. Then, the specimens were kept continuously immersed in these tanks for the time of test as recommended by **ASTM C267-01 [16]**. Throughout the test period, the cylinder specimens were removed weekly from septic tanks, washed with tap water, without brushing, and left to dry for 30 min before weighing and visual inspection. Cumulative weight change (WC) for each specimen was determined as follows:

$$\text{Weight change, \%} = [(W - C) / C] \times 100 \qquad \text{Eq. 11}$$

Where:
C : Conditioned weight of specimen, g, and
W : Weight of specimen after immersion, g.

4.4.4 Water Absorption Test

After 28 days water curing water absorption test were conducted for self compacted concretes with and without epoxy resin after 30, 90 and 180 days of exposure to sewerage environment. Water absorption test of concrete is based on **ASTM C 642-97 [17]**. ASTM C642 defines water absorption as a ratio of the water absorbed to dry weight of test specimen.

Water Absorption = [(B-A)/A]×100 ……………….Eq. 12
where,
A = Dry weight of test specimen
B = Wet weight of test specimen after immersion in water for 48 hrs

5. Results and Discussion

5.1 Compressive Strength

Table 10 and Fig. 2 reviews the results of compressive strength values for epoxy modified SCC at various periods of partial immersion in sewage environment relative to reference SCC without epoxy resin. Results showed that at 180 days of exposure the highest decrease in compressive strength for reference self compacted concrete (SCC-EP 0) was 20.8% compared to the reference SCC before exposure. This is due to the biodegradation that affects the physical and mechanical properties of concrete. During the process of the biologic attack it is often observed that a layer of high porosity is produced. This high porosity layer leads to increased permeability in the concrete, resulting in a decrease in concrete compressive strength. The results of compressive strength for SCC-EP specimens (with 5, 7.5 and 10% epoxy) showed an increasing compared to reference SCC (having 0% of epoxy). The results also illustrated that after 180 days of partial immersion in septic tank the compressive strength was still exceeds the control mix SCC by 48.2% for SCC-EP10. This may be due three evidences. First evidence, is that the use of resin pointers to the formation of thin membrane under the surrounding conditions to covering cement matrix and total particles of aggregate leading to a tough bond between the cement matrix and aggregates. Second evidence, is that filling most pores with epoxy would decrease the porosity and thus rise the compressive strength. Third evidence, is that, resin leads to formation a nonstop three-dimensional structure of the micro network of epoxy particles inside the pores of concrete, which affect as a binder structure because of the excellent binding of epoxy resins [13]. Fig. 2 showed that there was a noticeable deterioration in compressive strength for all self compacted concretes with the time of exposure to the harsh environment conditions compared to self compacted concretes before exposure.

Table 10 : *Compressive strength of epoxy modified SCC mixes exposed to sewerage

Mix.	Compressive Strength N/mm^2			
	Before exposure	Sewerage Exposure		
	28 days of curing	30 days	90 days	180 days
SCC- EP 0	42.3	38.4	35.2	33.5
SCC-EP 5	61.4	56.6	54.7	51.8
SCC-EP 7.5	65.3	62.5	60.3	58.6
SCC-EP 10	66.8	65.2	64.0	62.7

*Number of samples were used in this work 48 cubes.

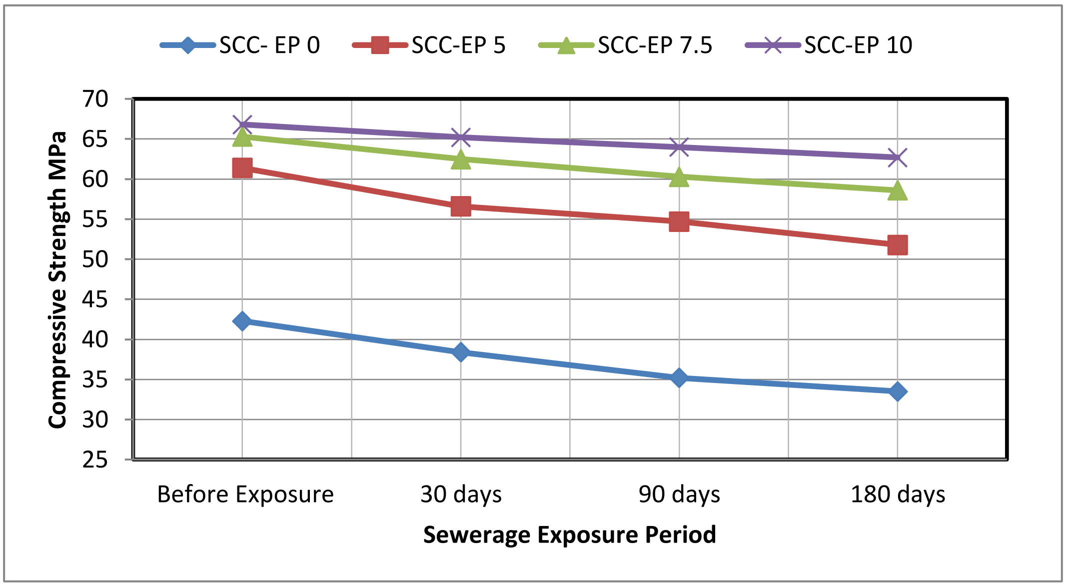

Fig. 2 Compressive strength of epoxy modified SCC mixes exposed to sewerage

5.2 Splitting Tensile Strength

The results illustrated in Table 11 and Fig. 3 showed that there is a decrease ratio in splitting tensile strength for all self compacted concretes exposed to sewerage environmental correspondingly with the increase in exposure period. As expected, low reduction in splitting tensile strength of SCC immersed partially in sewerage tank was observed. This may be caused by the formation of extensive salts such as gypsum and ettringite which resulted in damage of bonding characteristics and of weight. An rise in the mass of salt crystals in the pores nearby the vaporizing surface resulted in fast cracking and scaling. Unceasing reaction leads to the concrete structure to increasingly lose its mechanical strength. However, higher decreasing ratios were noted for reference SCC (46.5 % after 180 days of exposure) relative to reference SCC before exposure. The results also showed that there was a marked improvement in splitting tensile strength when epoxy resin was added to SCC compared with non-epoxy reference SCC. The best behavior for all tested concrete mixes were found for the SCC-EP10 with a lowest percentage of splitting strength of 29.5% after 180 days immersion compared with the control mix SCC-EP0. This is due to the addition of epoxy to the concrete leads to the formation of a lattice of fine linear tubes connected in all directions. In addition, the epoxy material fills all the fine spaces within the structure of the concrete and the epoxy acts as a lubricant material helps reduce friction between the aggregates particles thus increase the density and improve the splitting tensile strength.

Table 11 : *Splitting tensile strength of epoxy modified SCC mixes exposed to sewerage

Mix.	Splitting Tensile Strength N/mm^2			
	Before exposure	Sewerage Exposure		
	28 days of curing	30 days	90 days	180 days
SCC- EP 0	3.55	2.7	2.5	1.9
SCC-EP 5	4.86	4.2	3.8	3.4
SCC-EP 7.5	5.22	4.8	4.5	4.3
SCC-EP 10	5.35	5.1	4.8	4.6

*Number of samples were used in this work 48 cylinders.

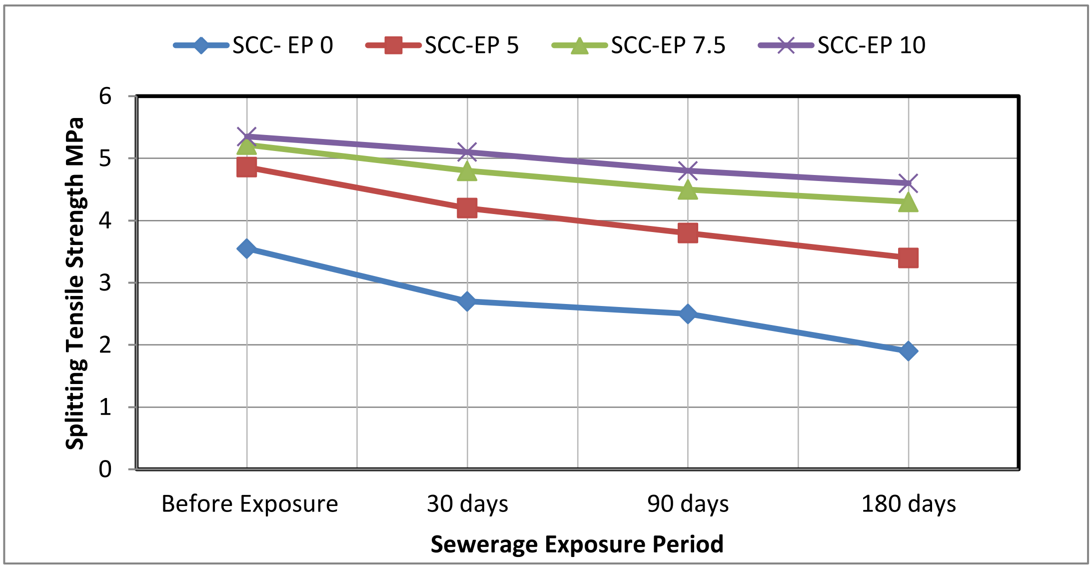

Fig. 3 : Splitting tensile strength of epoxy modified SCC mixes exposed to sewerage

5.3 Weight Change

The test results for weight change of reference SCC and SCC modified by epoxy exposed to aggressive environmental up to age of 180 days exposure are given in Table 12, while the increament in weight loss due to the effect of sewerage of epoxy modified SCC compared to reference SCC are plotted in Fig. 4. Test results showed that the weight increased strongly with time for all SCC specimens partially immersed in septic tank. For the reference SCC specimens exposed to the sewerage, the highest increase in weight loss value were about 8.8% after 180 days of exposure. The highest increment percentage weight loss in 10% epoxy modified SCC was 2.8% at 180 days of exposure. On the other hand, at 180 days of exposure the maximum improvement value in the weight loss of SCC-EP (having 10% epoxy) specimens was 68.2% relative to mix SCC-EP0 . This may be due to several causes such as high density, less porosity, good diffusion of epoxy resin within the pore volume, removal of the big pores, and good compatibility with aggregate.

Table 12 : Weight change of epoxy modified SCC mixes exposed to sewerage

Mix.	Weight Change (%)		
	Sewerage Exposure		
	30 days	90 days	180 days
SCC- EP 0	5.2	6.2	8.8
SCC-EP 5	4.7	5.2	6.2
SCC-EP 7.5	2.9	3.3	4.2
SCC-EP 10	2.1	2.4	2.8

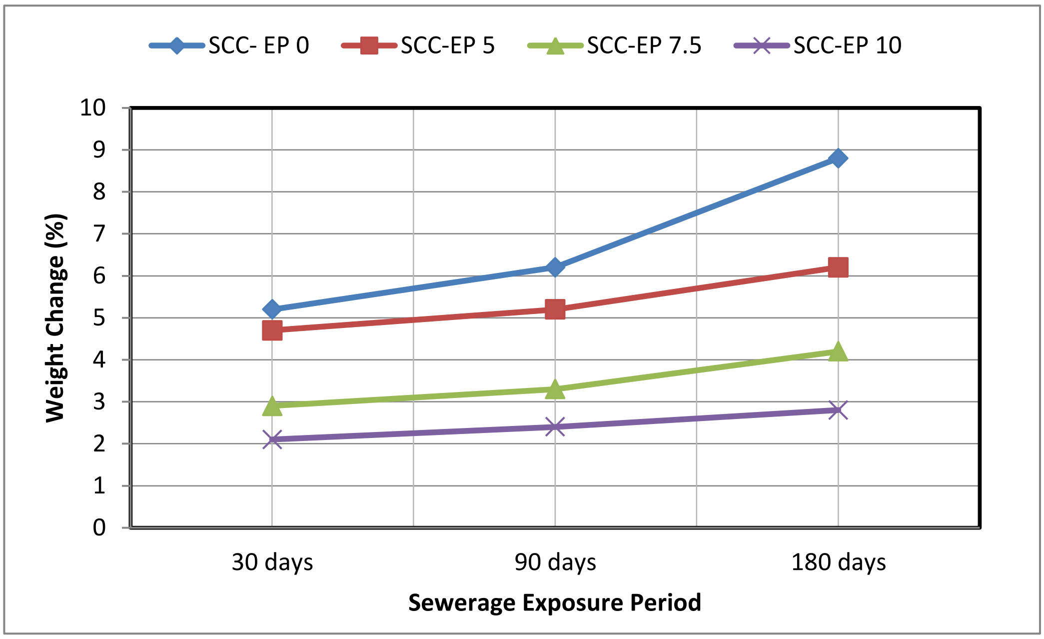

Fig. 4 : Weight change of epoxy modified SCC mixes exposed to sewerage

5.4 Absorption

Table 13 and Fig. 5 showed that there is an increase in the absorption value while increasing the exposure time of the sewerage. This is expected because longer exposure time allows more penetration of aggressive sewer water and makes the concrete more porous due to biological reactions. However, Absorption rate was range (after 180 days of exposure) from 5.54% for SCC with 0% epoxy resin to only 2.91% for SCC with 10% epoxy resin. The above discussion indicates the high density and less porosity of SCC modified by epoxy resin.

Table 13 : Absorption of epoxy modified SCC mixes exposed to sewerage

Mix.	Absorption (%)		
	Sewerage Exposure		
	30 days	90 days	180 days
SCC- EP 0	4.15	4.87	5.54
SCC-EP 5	3.34	3.76	4.15
SCC-EP 7.5	2.85	3.32	3.74
SCC-EP 10	2.32	2.58	2.91

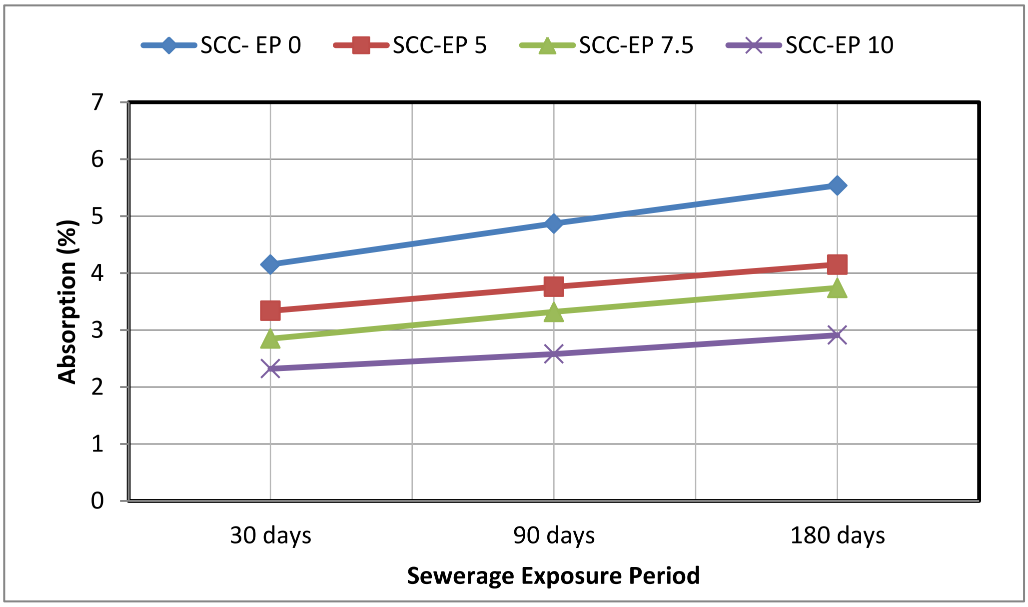

Fig. 5 : Absorption of epoxy modified SCC mixes exposed to sewerage

6. Conclusion

Based on the investigational results in this study, numerous conclusions can be drawn :

1- For the mix SCC-EP0 specimens exposed sewerage environment, a decrease in compressive and splitting tensile strength occurred as the time of exposure increases. The decreasing ratio were 20.8 % and 46.5%, respectively at 180 days of exposure compared to reference SCC.

2- The compressive and splitting tensile strength of all epoxy modified SCC specimens exposed to sewerage showed significant improvement relative to reference SCC without epoxy. This is due to the role of epoxy in reducing and eliminating pores and thus reducing the permeability of harmful substances to concrete and subsequently increasing the strength of concrete.

3- Modification of SCC with epoxy resin causes the reduction of weight loss and absorption values regardless of the time of exposure compared to the SCC without epoxy resin. The better results were at the ratio 10% of epoxy resin.

References :

1- Parande A. K., (2006), " Deterioration of reinforced concrete in sewer environments ", Proceedings of the Institution of Civil Engineers, pp. 11-20.

2- EFNARC (2002) . “Specification and guidelines for self-compacting concrete". European Federation of Producers and Applicators of Specialist Products for Structures.

3- Zeeshan A. A., and S. H. Mahure, (2016), " High Strength Self-Compacting Concrete Using Fly Ash" , International Journal for Research in Applied Science & Engineering Technology (IJRASET), Volume 4 Issue VIII, August, pp. 489-497.

4- Sambhav G., and Raksha P., (2015), " Studies on Effect of Sewage Water on Natural Concrete and Recycled Concrete", International Journal of Engineering Science & Research Technology, ISSN: 2277-9655, February, pp. 581-585.

5- Beata Cwalina, (2008)," Biodeterioration of concrete" Architecture Civil Engineering Environment, Vol. No. 4, pp. 130-144.

6- Sanchez S., and Rossowski, (2008)," Biodeterioration of Construction Materials ", State of the Art and Future Challenges. J Mater Civil Eng., Vol. 20, pp.352-365.

7- Iraqi specification No.5 (1984) "Portland Cement".

8- Iraqi specification No.45 (1984) "Aggregate from Natural Sources for Concrete and Construction".

9- ASTM C618, (2003),"Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete".
10- ASTM C494/C494M, (2008),"Standared Specification for Chemical Admixtures for Concrete".
11- ASTM C881/C881M, (2015) " Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete".
12- Krishna M. N., Narasimha R. A., and Ramana R. I, (2012), "Mix Design Procedure for Self Compacting Concrete", IOSR Journal of Engineering (IOSRJEN), Vol, 2, Issue 9, September, PP 33-41.
13- ACI Committee 548 (1999), "Polymer Modified Concrete", ACI Manual of Concrete Practice, Part 5, 548-3R, 1999.
14- B.S. 1881, Part 116,"Method for Determination of Compressive Strength of Concrete Cubes", British Standard Institute, pp. 1-3.
15- ASTM C496, (2003),"Standard Test Methods for Splitting Tensile Strength of Cylindrical".
16- ASTM C267-03, "Standard Test Methods for Chemical Resistance of Mortars, Grouts, and Monolithic Surfacings and Polymer Concretes".
17- ASTM C 642, (1997), " Standard Test Method for Density, Absorption, and Voids in Hardened Concrete".