ORGANIC CORROSION INHIBITOR EFFECT ON CONCRETE PROPERTIES

Suhayb.H. Altushani [1*], Hamza.A. Benomran [2], Almabruk Alhadad [3]

[1*]altshani.sohaib@gmail.coma, [2]benomranham3a@gmail.com

[2] associate professor, head civil engineering department, faculty of engineering, University of Omar Almukhtar University, Derne branch.

[1*] post graduate student of civil engineering, University of Omar Almukhtar, Albida.

[3] under graduate of civil engineering, University of Omar Almukhtar, Derne.

ABSTRACT

The mechanism of Organic Corrosion Inhibitors increases the service life of reinforced concrete by protecting concrete steel from chloride and water attack. Many studies have proven the efficiency of inhibitors. However, some studies showed that inhibitors could have an effect on the properties of concrete. In this paper, the effect of corrosion inhibitors admixture on the properties of fresh and hard concrete with different water to cement ratio was studied. Ferrogard®-901 was used as an organic corrosion inhibitor with a ratio of 12.5 kg/ m^3. Three water to cement ratios were used, which are 0.4, 0.5 and, 0.6 for each of the reference concrete and the organic inhibitor concrete. Mechanical properties of fresh and hard concrete have been studied. It includes workability, air content, permeability and, both compression and tensile strength of concrete. The effect of the organic inhibitor was clear on the properties of fresh concrete. The workability is increased with the addition of Organic Corrosion Inhibitor. The specimen with Ferrogard®-901 shows a decrease in the compressive strength of concrete for w/c of both 0.4 and 0.5. However, with w/c of 0.6 the strength of both control specimen and that with Ferrogard®-901, were very close. The tensile strength of the control specimen was higher than that with Ferrogard®-901. In general, the permeability of concrete with organic corrosion inhibitor was less than that of the reference concrete.

Keywords: Corrosion Inhibitor Admixture - Strength Properties – concrete –sustainable technology -corrosion

تأثير مثبط التآكل العضوي على خصائص الخرسانة

الملخص

تعمل آلية مثبطات التآكل العضوية على زيادة العمر التشغيلي للخرسانة المسلحة من خلال حماية حديد التسليح من هجوم الكلوريد. لقد أثبتت العديد من الدراسات كفاءة المثبطات. ومع ذلك، أظهرت بعض الدراسات أن المثبطات يمكن أن يكون لها تأثير على خصائص الخرسانة. في هذه الورقة تمت دراسة تأثير اضافة مثبط التآكل العضوي على خصائص الخرسانة الطازجة والصلبة باختلاف نسبة الماء إلى الاسمنت (W/C). بحيث تم استخدام Ferrogard®-901 كمثبط للتآكل العضوي بنسبة 12.5 كجم /م^3 ، وتمت مقارنتها مع الخرسانة المرجعية. تم استخدام ثلاث نسب ماء إلى أسمنت وهي 0.4 و0.5 و0.6 لكل من الخرسانة المرجعية وخرسانة المثبط العضوي. تمت دراسة الخواص الميكانيكية للخرسانة الطازجة والصلبة. وهي تشمل قابلية التشغيل، ومحتوى الهواء، والنفاذية، وقوة الضغط والشد للخرسانة. كان تأثير المانع العضوي واضحا على خواص الخرسانة الطازجة. تزداد قابلية التشغيل مع إضافة مثبط التآكل العضوي. تُظهر العينة باستخدام Ferrogard®-901 انخفاضًا في مقاومة الضغط للخرسانة لكل من (W/C) 0.4 و0.5. بينما نسبة الماء الي الاسمنت 0.6 للعينة Ferrogard®-901 كانت قريبة جدا مقارنة مع نفس النسبة من العينة المرجعية .كانت قوة الشد لعينة التحكم أعلى من تلك الموجودة في Ferrogard®-901 بشكل عام، كانت نفاذية الخرسانة مع مثبط التآكل العضوي أقل من الخرسانة المرجعية.

INTRODUCTION

Researches on organic inhibitors focus on the efficiency of inhibitors in protecting steel reinforcement from corrosion. Therefore, research on the effect of organic corrosion inhibitors on the properties of fresh and hard concrete has not received proper attention, and this field includes many questions, especially the difference in the chemical composition of the inhibitor according to the manufacture. The study aims to determine the effect of organic retarder on concrete by different ratios of water to cement in the concrete mix. Corrosive inhibitors are divided into organic and inorganic inhibitors. They are classified according to the type of reactions that form a layer on the surface of steel-reinforcement to protect it from chlorides attack, oxygen and, water[1]. The corrosion of concrete steels exposed to the marine environment depends on environmental, physical, and chemical factors. Organic Corrosion Inhibitor (OCI) depends on its composition (Amine, Carboxylate) in reinforcement protection. Its mechanism of action depends on the interaction with the attacking materials and steel reinforcement. The medium through which the inhibitor travels is by diffusion and penetration through micro-cracks in the concrete[2]. An alkaline layer of $Ca(OH)_2$ is formed to protect the reinforcing steel from rust when the concrete is exposed to carbon dioxide and chloride ions. This layer breaks down and the reinforcing steel starts to rust. The life of the concrete is prolonged when corrosion inhibitors are added, where the service life is divided into the initiation and the propagation phase. The action mechanism of corrosion inhibitor increased the initiation stage.

Studies have demonstrated the efficacy of Amino Alcohols (AMAS) from the use of Sika Ferrogard®-903 and their interaction with iron. Penetration depends on porosity of concrete and moisture, and does not affecte by water through sprinkling and puddles on the concrete structure.[3] The effectiveness of AMAS was verified in terms of their interaction with rebar and formation of a layer on the reinforcement surface so that a simulation of concrete conditions was used. The mechanism of action of Sika Ferrogard®-901 is primarily anodic protection. It must be added in the appropriate amount so that corrosion acceleration does not occur.[4] The components of organic corrosion inhibitors (OCI) are rarely identified from the manufacturer, Material Safety Data Sheet (MSDS). However, some of them were examined for the safety and security requirements of some countries. Where the great difference in the composition of the same product for different factories. The Table 1 show the composition of the same product for different factories Material Safety Data Sheet (MSDS)[5].

Table 1:composition of the same product for different factories Material Safety Data Sheet (MSDS)[5].

Country	***Product***	***Method of use***	***Type of ingredient***	***Chemical ingredients disclosed in the MSDS***
Norway	Sika Ferrogard®-901	Mixed into concrete	2-dimethylaminoethanol (DMEA)	5 – 10
			Organic/inorganic nitrogen compounds	Not given
Canadian	Sika Ferrogard®-901	Mixed into concrete	Salt of alkanolamine	15 – 40

There are five common types of primarily Organic Alcohol Amines, including Diethylenetriamine (C4H13N3), Aminoethylethanolamine (C4H12N2O), Triethanolamine (C6H15NO3), Triisopropanolamine (C9H21NO3) and, Polyvinyl Ammonium phosphate (C9H21NO3) (C2H4NO3). Several studies indicate that compressive strength is affected by the increase in the Inhibitor content according to the type of Inhibitor, while resistance decreases with increasing the content of Diethylenetriamine (C4H13N3)[6]. Determining the efficiency of inhibitors type Amines and Alkanolamines (organic basic nitrogen compounds) is difficult. Most commercial Inhibitors are made from a mixture of chemicals whose composition is unknown to the researcher and is not disclosed by the manufacturer. Therefore, commercial inhibitors are called (Amino-Alcohol Based Mixed Corrosion Inhibitor).[7, 8]

The efficiency of corrosion inhibitor differs by the manufacturer from company to another [9]. The effect of Amine was tested on concrete properties and it was observed that it reduces the compressive strength of the concrete by (10-20)%[10]. Corrosion inhibitors have been applied to many buildings and towers. The age of the treated buildings has increased and decreased the cost of maintenance, which is of great importance in the use of concrete [11]. The Organic Inhibitors were applied to the Princess Tower Building, Dubai, UAE, and the life of the tower was estimated by a program LIFE-365[12]. The results showed that the building life was increased from 42 years to 100 years.

The Amine group is a mixed (anodic/cathode) inhibitor that is based on nitrogen, that can bonded and be absorbed by metal (including steel reinforcement)[13]. Transport of Organic Corrosion Inhibitors (OCI) from concrete to the reinforcement by diffusion as liquid and/or vapor. The strength of the bond between the OCI molecule and the steel-reinforced is what delays the initial period of the service life of reinforcement concrete. Amine alcohol based gives double the life span of the reinforced concrete. The effect of chloride ion concentration on steel corrosion and the alkalinity of concrete is not fully understood. Chloride ions can initiate active corrosion because they break down the negative oxide layer on the reinforcement embedded into the concrete[14].

Sika Ferrogard®-901 was added in amounts of 0.1, 0.2, and 0.3% the weight of cement in the concrete mix, and the w/c ratio of 0.52. The results were Slight increase in compressive and Splitting tensile strength when the percentage of Sika Ferrogard®-901 corrosion inhibitor increased[15]. The addition of Sika Ferrogard®-901 to concrete at a percentage of 5% of the weight of cement affects the properties of concrete, the compressive strength decreased by 10% compared with the reference sample[16]. Amino-Alcohol Base Mixed Corrosion Inhibitor experienced a decrease in the diffusion coefficient of approximately 30% in chloride migration testing in compared to the reference sample. also, the capillary absorption was decreased by 56% [17].

There is an insufficiency understanding of the effect of organic corrosion inhibitors on the mechanical properties of concrete. In addition, every company has a chemical composition that may differ from other companies that manufacture the same type of inhibitor. Therefore, in this study, sika Ferrogard®-901 available in the local market was used. The influence of organic corrosion inhibitors on the mechanical properties of concrete remains unclear.

Organic corrosion inhibitors are commonly used in structures such as bridges and towers that require high compressive strength and long service life. It can also be used in structures that require a long service life and low compressive strength. In addition, the effect of organic corrosion inhibitors may change with the difference of water to cement ratios. Furthermore, earlier research did not describe the influence of organic inhibitors on concrete properties in a straightforward and clear explanation.

EXPERIMENTAL INVESTIGATION.

MATERIAL

The real challenge at this stage is to match the materials with the standards. River sand and coarse aggregate that conform to standard are not available therefore certain measures were taken such as washing both local sand and coarse aggregate. nominal maximum size of coarse aggregate was 12.5 mm fineness module of sand was 2.4.the specific gravities of cement, sand and coarse aggregate were 3.15, 2.74, and 2.61 respectively. The admixture used in this study was Sika Ferrogard®-901. Table 2 shows the material's chemical compositions tested by X-ray fluorescence analysis.

Table 2: materials chemical compositions tested by X-ray fluorescence analysis.

Chemical composition%	*Sand (S)*	*CEMENT (OPC)*
Silicon dioxide(SIO_2)	0.110	20.90
Aluminum oxide (AL_2O_3)	0.222	6.06
Iron oxide (Fe_2O_3)	0.159	3.68
Calcium oxide (CaO)	51.850	64.56
Magnesium oxide (MgO)	3.136	2.55
Sodium oxide (Na2O)	0.105	0.24
Potassium oxide (K2O)	0.000	0.98
Chloride (CI)	0.01	0.007
Sulfur trioxide (SO3)	0.25	2.53

Sand contains chloride in addition to its granular irregularity, so it was important to take samples from different places and to adopt the one that conforms to standards. Several tests were conducted, such as chloride content in the sand.

CORROSION INHIBITING CONCRETE ADMIXTURE (SIKA® FERROGARD®-901) .

It is a liquid concrete mixture based on Sika Ferrogard® technology for use in reinforced concrete and mortars. It acts as an inhibitor to protect steel reinforcement from corrosion. Designed for reinforced concrete especially the building exposed to chloride environment. Such that provides protection against corrosion caused by chloride. It is often used in structures that have a long service life such as concrete roads, bridges, tunnels and, retaining walls. Mechanism of Sika® Ferrogard®-901 mixes the anodic and cathodic reactions of the electrochemical corrosion process. The product forms a film on the steel surface which delays the damage of corrosion and also reduces the degree of corrosion. Sika® Ferrogard®-901 was mixed with water. The quantity of Sika® Ferrogard®-901 in the mix design was taken into consideration when determined the quantity of water for a specific W/C ratio. Chemical composition of Sika® Ferrogard®-901 is shown in Table 3.

Table 3:Chemical composition of Sika® Ferrogard®-901.

Chemical name	Concentration (% w/w)
2-dimethylaminoethanol	%10
2,2'-(methylimino)diethanol	%10

MIX PROPORTIONS OF CONCRETE.

The mixed proportions of concrete are summarized in Table 4. The concrete mix is designed according to the ACI code-211. The amount of ordinary portland cement type I (OPC) of 398 kg/m3 was used in all mixes. Ratio of gravel to sand (G/S) was obtained from ASTM 29. The concrete mixtures had a water-to-cement ratio of 0.4,0.5 and, 0.6. The slump of fresh concrete had been estimated at 50 mm. Control specimen (C) with no admixture. specimens (OA) uses Ferrogard®-901 as corrosion inhibitors. Ferrogard®-901 was added to the concrete at a ratio of 12.5 kg / m^3.

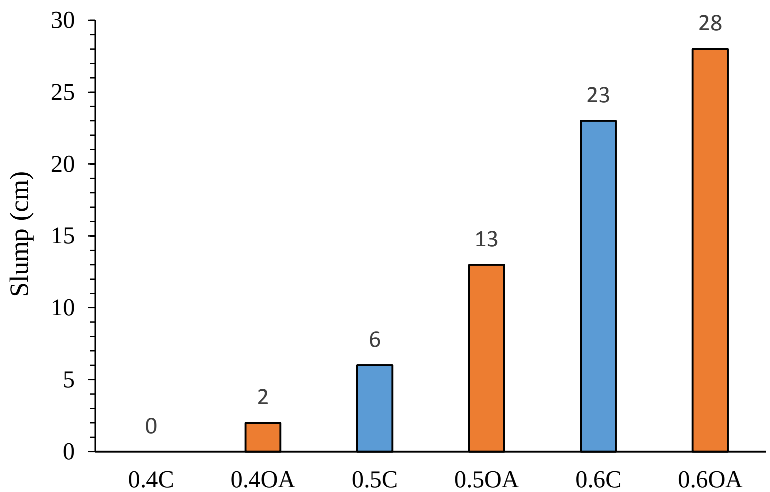
Table 4: The mix proportions of concretes.

MIX ID	*BINDER + Admixture*	*PER WEIGHT CEMENT %*				*ACI Kg/m³*
		Cement	*Aggregate*	*Sand*	*water*	
0.4-C	OPC	398	1061.685	774.52	159.2	-
0.4-OA	OPC+ ACI	398	1043.526	761.28	159.2	12.5
0.5-C	OPC	398	1000.397	729.81	199	-
0.5-OA	OPC+ ACI	398	982.238	716.57	199	12.5
0.6-C	OPC	398	939.1092	685.10	238.8	-
0.6-OA	OPC+ ACI	398	920.95	659.59	238.8	12.5

RESULTS AND DISCUSSION

WORKABILITY.

Workability was examining by the slump test in accordance with ASTM C143. Figure 1, show the addition of Organic Corrosion Inhibitors materials affects the workability of the mixture in which the water to cement ratio is 0.4. The workability of the reference mixture was 0, while



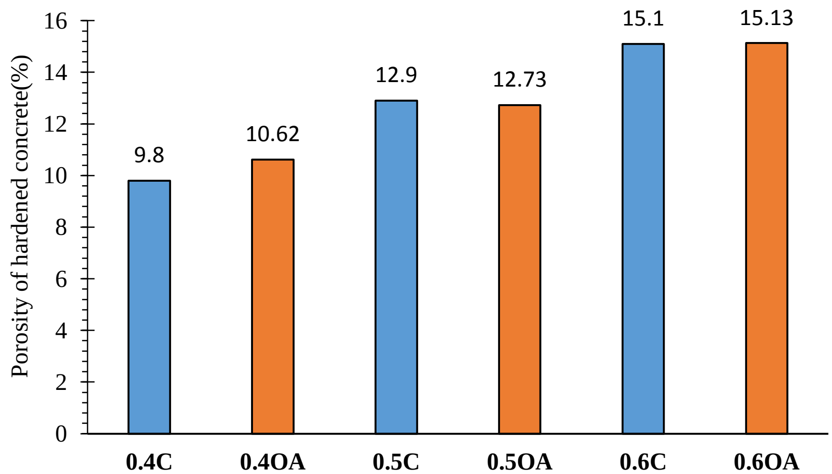
the workability of the mixture contains Ferrogard®-901 increased to 2 cm.

Figure 1:Effect s of w/c with Ferrogard®-901 addition on the slump.

As for the water to cement ratio of 0.5, The Workability of the mixture containing Ferrogard®-901 was doubled, so that the Workability of the sample 0.5C, 0.5OA was 6 cm and 13 cm, respectively. As for the water to cement ratio of 0.6, The Workability of the mixture containing Ferrogard®-901 was increased, so that the Workability of the mix of 0.6-C, 0.6OA was 23 cm and 35 cm, respectively. In general, the Workability of concrete containing Ferrogard®-901 was affected, so that the Workability of the concrete mix with a water-cement ratio equal to 0.4 and containing Ferrogard®-901 (0.4 OA) was very small. And the mix 0.6OA was Too high and rejected according to the specification.

THE POROSITY OF HARDENED CONCRETE.

The cement used is Ordinary Portland Cement (OPC) ASTM C150. Mix proportions of concretes are summarized in Table 4. The raw materials were mixed with tap water and compacted into moulds (50mm×50mm×200mm) and placed in a curing tank, until the ages of days,28 days. The samples are first oven-dried at 60℃ for 4 days and then be weighted. The air



was withdrawn from the dry samples by placing the dry samples in a vacuum machine for 1 hour. Then the samples were soaked in the water while continuing to withdraw air from the samples for two hours. The ratio of weight difference before and after soaking in water divided by the concrete volume is considered as porosity.

Figure 2:Effects of W/C with Ferrogard®-901 addition on the porosity.

The results are shown in Figure 2 at 28 days of age for all samples. The effect of Ferrogard®-901 OA sample on the porosity of concrete with a water-cement ratio of 0.4 was clear compared to the control sample with the same water-cement ratio. However, the corrosion inhibitor Ferrogard®-901 did not significantly affect the porosity of concrete samples with a water-cement ratio of 0.5and 0.6 compared to the control sample with the same water-cement ratio. The correlation between compressive strength and porosity of Ferrogard®-901 on concrete

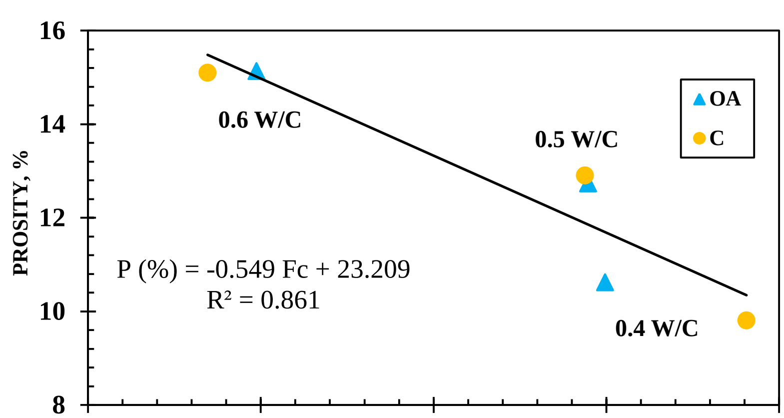


Figure 3:relationship between the porosity and the compressive strength at 28 days of curing.

is shown in Figure 3 It can be seen that with the correlation coefficient of R2 = 0.861.

COMPRESSIVE STRENGTH TEST OF CONCRETE.

Concrete cylinder specimens of (70*140) mm were cast according to ASTM-C39 and were allowed to set for 24 h. Concrete specimens C, OA were cured in water until the date of testing to determine the compressive strength at age of 1,3, 7, 28, and 90 days. The cylinder was filled with freshly mixed concrete in two layers of approximately equal volume. Each layer was tamped 25 times. The mixes were then covered with a non-absorptive, non-reactive sheet of tough, durable impervious plastic for 24 ± 2 hours, after which they were de-molded and moist cured in a curing tank for 90 days.

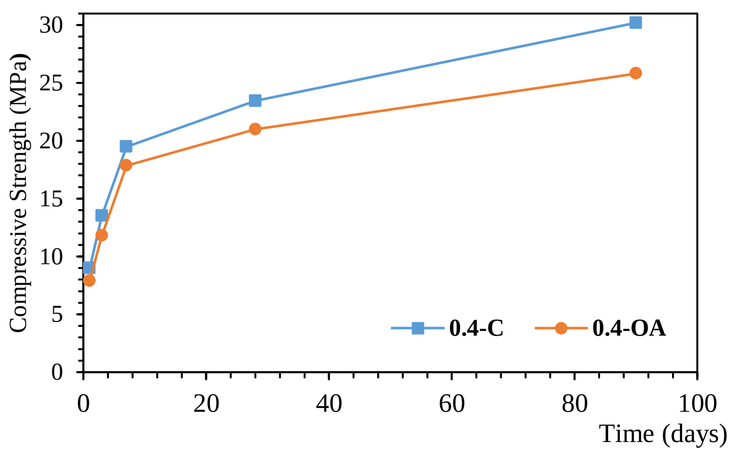


Figure 4:compressive strength of samples with (w/c) equal 0.4.

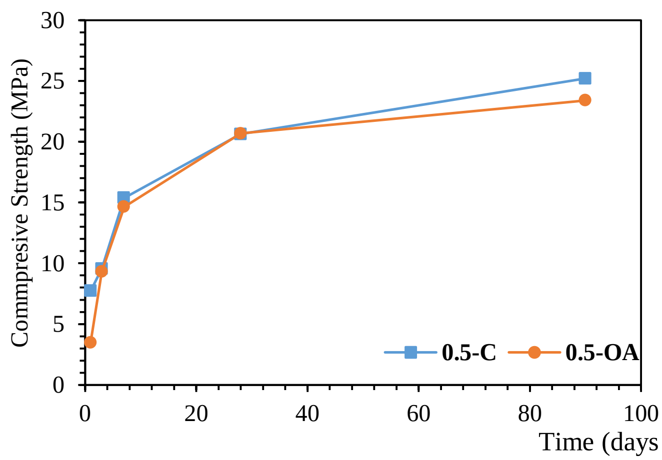


Figure 6:compressive strength of samples with (w/c) equal 0.5.

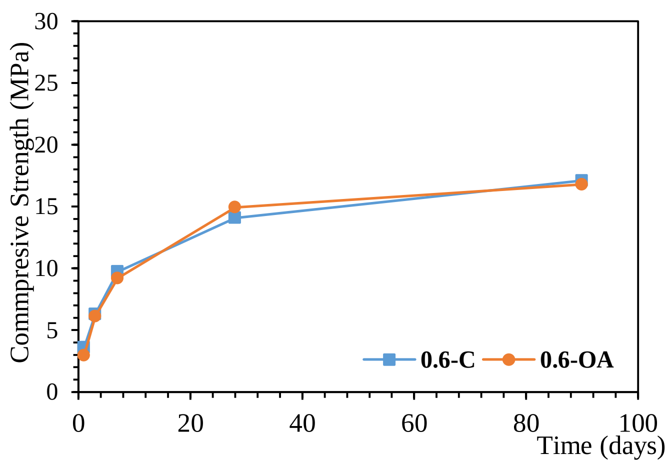


Figure 5:compressive strength of samples with (w/c) equal 0.6.

The effect of compressive strength of concrete varies with the change of water-cement ratio and with the addition of organic corrosion inhibitors. In concrete with a water-cement ratio of 0.4, the compressive strength of the OA samples was less than the compressive strength of the reference sample as shown in Figure 4. The compressive strength of the OA samples was close to the compressive strength of the reference sample at the young ages of 1 and 3 days. As The published literature indicates that the chemical compound Dimethylaminoethanol in Sika Ferrogard®-901 leads to a decrease in the compressive strength of concrete.

In concrete with a water-cement ratio of 0.5, the compressive strength of the OA samples was close to the compressive strength of the reference sample as shown in Figure 6. The compressive strength of the OA samples was less than the compressive strength of the control sample at the early ages of 1 and 3 days. This is attributed to the increase in porosity and the distribution of the pores within the sample, so the material was able to enter it before affecting the hydration of the concrete.

In concrete with a water-cement ratio of 0.6, the compressive strength of the OA samples was the closest to the compressive strength of the reference sample as showed in Figure 5 compared to samples with a water-cement ratio of 0.4 and 0.5 at all ages. This is attributed to two reasons. One is the additional amount of water contributed to reducing the concentration of the chemical compound dimethylaminoethanol in of Sika Ferrogard®-901. high porosity the second reason is the increase in porosity attributed to the amount of water at w/c equal 0.6.

PERMEABILITY TEST OF CONCRETE

Concrete cubes specimens of (150*150*150) mm were cast in accordance with EN12390-8 and were allowed to set for 24h concrete specimen C, OA concretes were cured in water until the date of testing to determine the permeability at 28 days. The average of three concrete samples were taken as the permeability of concrete.

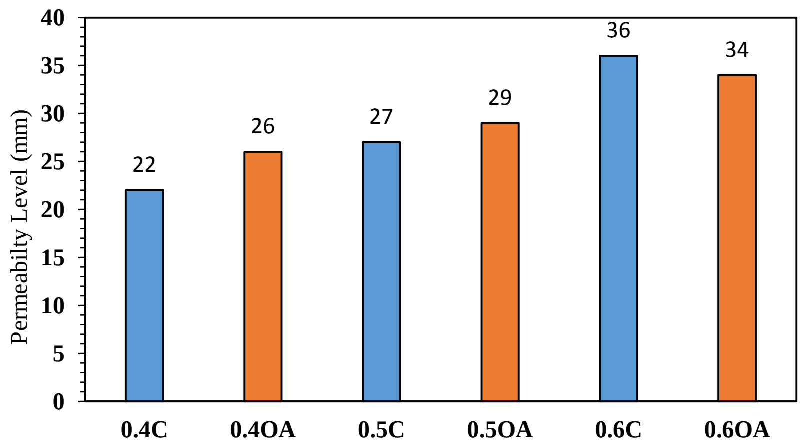


Figure 7:water permeability of concrete samples

The water permeability penetration under pressure 5 bar on C and OA concrete is given in Figure 7, where the level of permeability is represented at the age of 28 days. It can be observed that all the OA samples give a permeability level higher than the C sample. With the exception of the sample 0.6.OA, it gave a level of permeability less than 0.6.C. This can be explained by the presence of Sika Ferrogard®-901 inside the voids and the resistance to water entering through the concrete. As for 0.5.OA and 0.4.OA, it gave a higher level of permeability than that of the reference samples. This explains by the lack of enough pores inside the concrete to contain Sika Ferrogard®-901 due to the presence of water in a small amount, and as result the concentration of Dimethylaminoethanol was not diluted.

SPLIT CYLINDER TEST.

The split tensile strength test according to ASTM C496 - 96 was carried out on a Universal

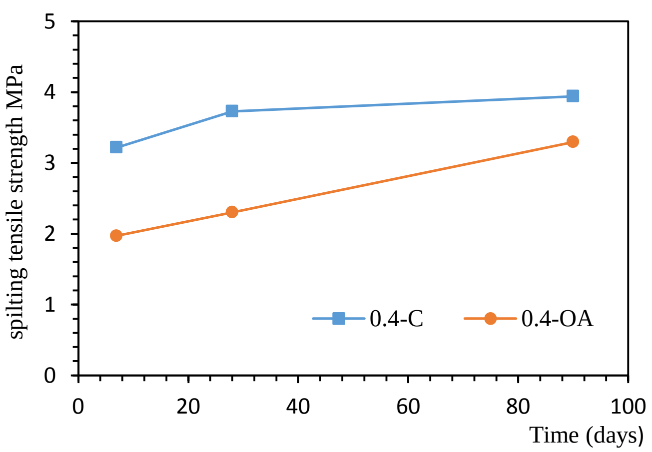


Figure (7-A) the splitting tensile for sample with W/C=0.4

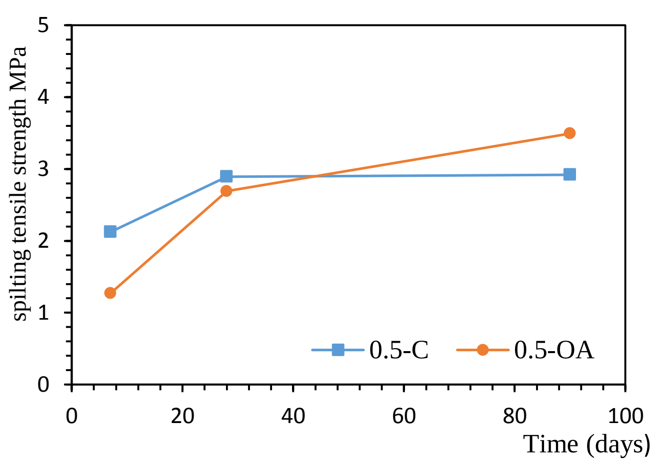


Figure (7-B) the splitting tensile for sample with

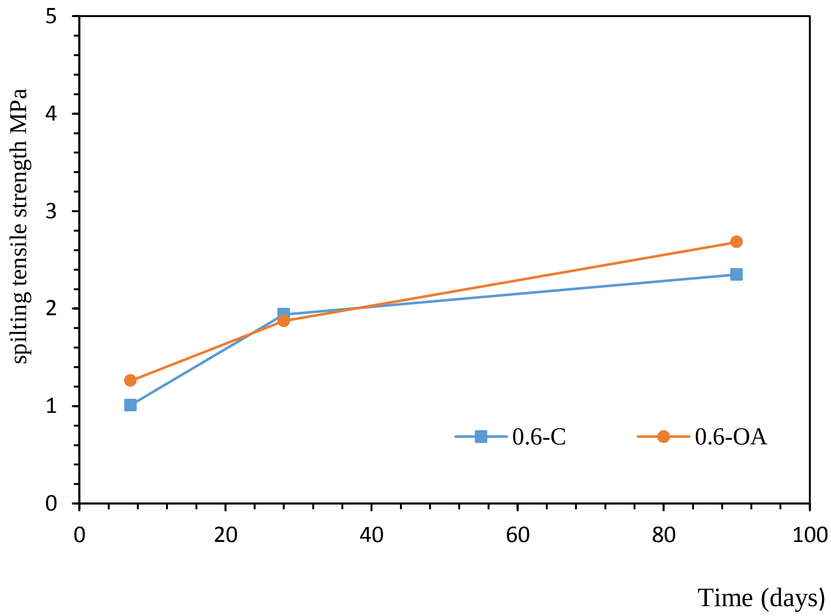


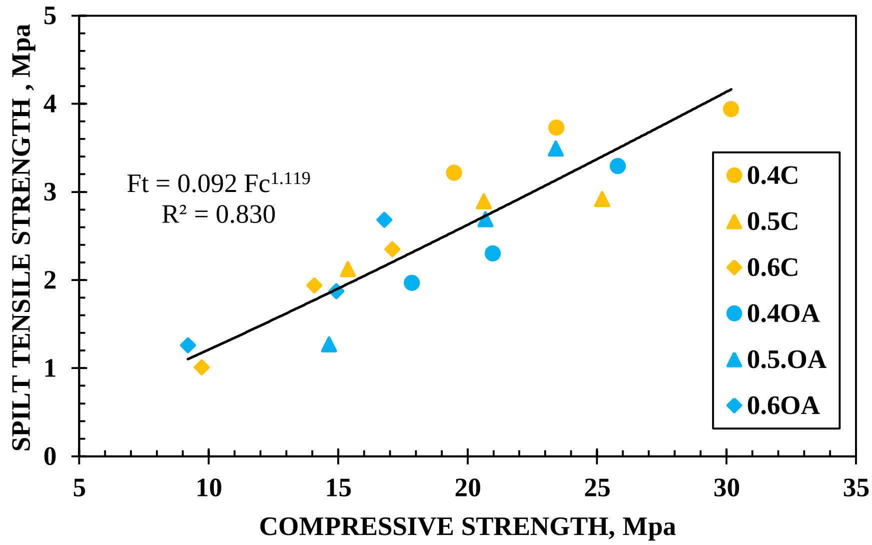
Figure (7-C) the splitting tensile for sample with

Testing Machine (UTM). The sample used was a cylinder with a diameter of 70×140 mm in

according to ASTM C39. The test was performed at 7, 28 and, 90 days curing before Samples were tested. The cylinders were tested in a dry, surface condition.

The effect of adding organic corrosion inhibitors to concrete (Ferrogard®-901) on the tensile strength of concrete with the different water to cement ratios. In concrete with a water-cement ratio of 0.4 as shown in Figure (7-A), the tensile strength of the OA samples was less than the tensile strength of the reference sample for all ages. Previous studies indicate that the chemical compound Dimethylaminoethanol in Sika Ferrogard®-901effect on both the compressive and tensile strength of concrete. In concrete with a water-cement ratio of 0.5 as shown in Figure (7-B), The tensile strength of the OA samples increased compared the reference sample at 90 days. The tensile strength of the OA samples was less than the control sample at the early ages of 7 and28 days. In concrete with a water-cement ratio of 0.6 as shown in Figure (7-C), the tensile strength of the OA samples was close to the reference sample compere to the concrete with a water-cement ratio of 0.4 and 0.5 for all ages. Besides the porosity, the Ferrogard®-901 influence compressive strength. The correlation between compressive strength and split tensile strength of Ferrogard®-901 on concrete is shown in Figure 8. It can be seen that with the correlation coefficient of R2 = 0.83.

Figure 8:relationship between the spilt tensile test and the compressive strength.



CONCLUSIONS.

1 The organic corrosion inhibitor (Sika Ferrogard®-901) clearly affect the workability of concrete. The value of slump increase when (Sika Ferrogard® 901) added to all mixes.

2 The effect of the organic corrosion inhibitor (Sika Ferrogard® 901) on the compressive strength of concrete decreases with increasing w/c. So that, in concrete with a water-cement ratio (w/c = 0.6), the compressive strength was closest to The reference concrete, while the effect of (Sika Ferrogard®-901) was more evident on the specimens with decreasing the water to cement ratio.

3 The organic corrosion inhibitor (Sika Ferrogard®-901) reduces the tensile strength of concrete at ages 7 and 28, however, it increases the tensile strength at the age of 90 days for concrete that water-cement ratio of 0.4 and 0.5. The tensile strength increased at all ages for concrete with a water-cement ratio of 0.6.

4 The effect of the organic corrosion inhibitor (Sika Ferrogard®-901) on the porosity is small and decreases with increasing water to cement ratio.

5 The permeability decreased with (Sika Ferrogard®-901) when w/c=0.6. However, it increased when w/c=0.4 and 0.5. This could have an effect on corrosion protection.

REFRENCES

[1]M. L. S. Rivetti, J. Netto, M. A. Junior, and D. V. Ribeiro, "Corrosion inhibitors for reinforced concrete," *Corrosion inhibitors, principles and recent applications*, pp. 35-58, 2018.
[2]B. Bavarian and L. Reiner, "Corrosion protection of steel rebar in concrete using migrating corrosion inhibitors," *Corrosion of Reinforcement in Concrete: Monitoring, Prevention and Rehabilitation Techniques*, vol. 38, p. 239, 2014.
[3]F. Wombacher, U. Maeder, and B. Marazzani, "Aminoalcohol based mixed corrosion inhibitors," *Cement and Concrete Composites*, vol. 26, no. 3, pp. 209-216, 2004.
[4]H. E. Jamil, M. Montemor, R. Boulif, A. Shriri, and M. Ferreira, "An electrochemical and analytical approach to the inhibition mechanism of an amino-alcohol-based corrosion inhibitor for reinforced concrete," *Electrochimica acta*, vol. 48, no. 23, pp. 3509-3518, 2003.
[5]M. Jang, C. Yoon, J. Park, and O. Kwon, "Evaluation of hazardous chemicals with material safety data sheet and by-products of a photoresist used in the semiconductor-manufacturing industry," *Safety and health at work*, vol. 10, no. 1, pp. 114-121, 2019.
[6]J. Li, J. Guo, and Q. Ma, "A Study on the Effects of Chemical Admixtures on the Strength of Portland Cement," *Chemical Engineering Transactions*, vol. 59, pp. 343-348, 2017.
[7]T. A. Söylev and M. Richardson, "Corrosion inhibitors for steel in concrete: State-of-the-art report," *Construction and Building Materials*, vol. 22, no. 4, pp. 609-622, 2008.
[8]M. Ormellese, L. Lazzari, S. Goidanich, G. Fumagalli, and A. Brenna, "A study of organic substances as inhibitors for chloride-induced corrosion in concrete," *Corrosion Science*, vol. 51, no. 12, pp. 2959-2968, 2009.
[9]B. Elsener and U. Angst, "Corrosion inhibitors for reinforced concrete," in *Science and Technology of Concrete Admixtures*: Elsevier, 2016, pp. 321-339.
[10]S. A. Civjan, J. M. LaFave, J. Trybulski, D. Lovett, J. Lima, and D. W. Pfeifer, "Effectiveness of corrosion inhibiting admixture combinations in structural concrete," *Cement and Concrete composites*, vol. 27, no. 6, pp. 688-703, 2005.
[11]S. P. J. Meyer Cortec Corporation, Minnesota, US, "ORGANIC CORROSION INHIBITORS – NEW BUILD AND EXISTING STRUCTURES PERFORMANCE," *Brian Cherry International Concrete Symposium*, p. page 12, 2012.
[12]M. Ehlen, Kojundic, "A. Life-365™ v2.2. Amer Conc I. 2014," ed, 2014 May.
[13]B. Miksic, "Improving the durability of infrastructure with migratory corrosion inhibitors (MCI) handbook," *Cortec Corporation, St Paul*, 2014.
[14]J. H. Ideker and S. H. Smith, "ACI CRC 117," 2020.
[15]H. M. Oleiwi, "Durability of Concrete Incorporating Corrosion Inhibitors Exposed to a Salt Solution of CL-+ SO 4-2," *University of Thi-Qar Journal for Engineering Sciences*, vol. 6, no. 1, pp. 71-86, 2015.
[16]M. A. Imam, A. H. El-Agamy, M. I. Mahdy, and A. I. Abdel-Fattah, "Effect of Corrosion Inhibitors Admixtures on Corrosion Rate of Steel Reinforcement in Concrete (Dept. C)," *MEJ. Mansoura Engineering Journal*, vol. 35, no. 1, pp. 27-43, 2020.
[17]J. Buffenbarger, M. Miltenberger, B. Miller, and H. Casal, "Long-Term performance of organic inhibitors," in *Proceedings of the International Congress on Advanced Materials, Their Processes and Applications, Munich, Germany*, 2000.