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The effect of sea water (sulfates and chlorides) on concrete with varying levels of silica fume

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Abstract

Concrete is most versatile construction material widely used for. It is considered a very strong and durable material that does not require maintenance or may require minor maintenance. However, the compounds present in cement concrete are attacked by many salt solutions and acids. The present study aims to investigate the effect of sea water (attack of sulfates and chlorides) present with varying severity on compressive strength, durability and workability of concrete with silica fume as partial replacement of cement. The results showed that the lowest penetration rate was obtained from samples S. F10 (silica fume =10%). Thus, the durability and strength of concrete improve when silica fume is added as partial replacement of cement in comparison to conventional concrete when exposed to aggressive environment. And by improving the durability of concrete structures, it will direct climate change, achieve sustainable development, and give more life to these structures. These results indicated that the higher the percentage of

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silica fume, the greater the strength, resistance of concrete to the attack of sulphates and chlorides, the lower the workability.

Key words: Chlorides, Silica fume, Sulfates, Concrete.

دراسة تأثير ماء البحر (الكلوريداتوالكبريتات) على الخرسانة بنسب مختلفة من دخان السيليكا

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الملخص

الخرسانة هي مواد البناء الأكثر استخدامًا على نطاق واسع. تعتبر مادة قوية ومتينة للغاية ولا تتطلب صيانة أو قد تتطلب صيانة بسيطة. ومع ذلك، فإن المركبات الموجودة في الخرسانة الأسمنتية تتعرض للهجوم من قبل العديد من المحاليل والأحماض الملحية. تهدف الدراسة الحالية إلى معرفة تأثير مياه البحر (هجوم الكبريتات والكلوريدات) الموجودة بدرجات متفاوتة من الشدة على مقاومة الانضغاط والمتانة وقابلية التشغيل للخرسانة بدخان السيليكا كبديل جزئي للأسمنت. أظهرت النتائج أن أقل معدل اختراق تم الحصول عليه من عينات S.F10 (دخان السيليكا = 10٪). وبالتالي، تتحسن متانة ومقاومة الخرسانة عند إضافة دخان السيليكا كبديل جزئي للأسمنت مقارنة بالخرسانة التقليدية عند تعرضها لبيئة عدوانية. ومن خلال تحسين متانة الهياكل الخرسانية، فإنه سيوجه تغير

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المناخ، ويحقق التنمية المستدامة، ويعطي المزيد من الحياة لهذه الهياكل. أشارت هذه النتائج إلى أنه كلما زادت نسبة دخان السيليكا، كلما زادت قوة ومقاومة الخرسانة لهجوم الكبريتات والكلوريدات، انخفضت قابلية التشغيل.

الكلمات الدالة: الكلوريدات، دخان السيليكا، الكبريتات، الخرسانة.

1. Introduction

Hardened concrete has two properties, durability and Strength. The ability of concrete to withstand the conditions it is exposed to is durability. The resistance of concrete to the pressures imposed, due to external load, temperature effect…. etc is the strength. These conditions may be internal causes within the concrete itself, such as or may be external causes such as attack by aggressive agents such as sulfate sand chlorides present in soilor water. Assuming usage of good quality aggregates in concrete, should be taken against the external causes that might impair the concrete. Design requires certain provisions to achieve good durability for concrete. The Institution of Structural Engineering **[**1**]** for example requires that there be should:

1. Good compaction of concrete during casting
2. A lower limit of concrete cover to reinforcement.
3. Adequate curing of hardening concrete.
4. A lower limit of cement content.
5. An upper limit of water/cement ratio.

There are a lot of damages to structures in the marine environment. Marine environment is very aggressive, since sea water contains a

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lot of sulfate sand chlorides. Sulfate attack on concrete takes different forms depending on the atmospheric environment and the chemical form of the sulfate [2]. Sulfates affect strength through the deterioration of concrete itself and chlorides influence strength by initiating corrosion of reinforcing steel [3, 4].

Carbondioxide in the environment penetrates the concrete to react with calcium hydroxide to form calcium carbonate, this process is called carbonization [2]. The penetration of chloride into reinforced concrete is a major threat to it, especially those structures in marine environments [5].

In this paper, the focus is on the effect of sulfate and chloride penetration into concrete from sea water.

Since aggregate particles in the concrete are coatedwith cement mortar, the permeability of the cement paste has the greatest impact on the permeability of the concrete [2]. Accordingly, reducing the permeability by reducing the size of the capillary pores (or porosity) in the cement paste responsible for transporting water to the reinforced concrete, especially if the pores are continuous, is considered the key to the durability of the concrete [2].

The use of pozzolanic materials such as silica fume with cement in this concrete mixture reduces the pores in the concrete. The mechanism of this is by reaction of silicon dioxide [Sio_2] present in silica fume with [$Ca(OH)_2$] to form calcium silicate hydrate [C.S.H] which fills up the pores. Besides, some silica fume particles will increase the packing of cement particles by interlocking with them in the paste.

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For a givenw/ cratio of rebar, are usually protected against corrosion by good compaction of concrete and applying suitable concrete cover to steel bars. Unsuitable cover to steel bars and/or bad compacted concrete will permit passage of soluble chlorides to steel and initiate electrochemical corrosion through the shown mechanism; Figure 1.

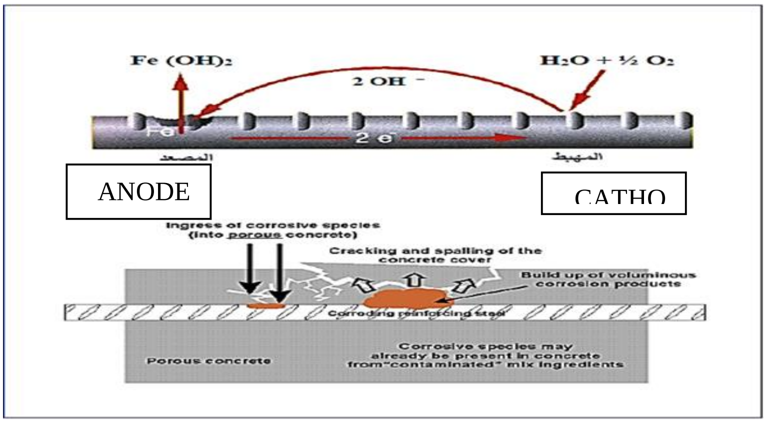

Figure1. Mechanism of electrochemical corrosion **[**6**]**

2. Material properties

Materials used in concrete mix were crushed coarse aggregate, Ordinary Portland Cement**,** silica fume, potable water and natural sand (as fine aggregate).

2.1 Cement

Ordinary Portland Cement (Zliten) CEM I 42.5 N was used, which conforms to the Libyan Standard Specifications **[**7**]**.

2.2 Fine aggregate

The sand used was locally available from the Sirte region, and the sieve analysis test was carried out according to the British Standard. The physical tests were carried out in accordance with the British Standard **[**8**]**.

Specific gravity was 2.78 and the absorption capacity was 0.644%, which was to found conforms to the British Standard Specifications **[**9**]**.

2.3 Coarse aggregate

Two types of local coarse aggregates were used, (the nominal maximum size of 20mmandthe nominal maximum size of 10mm) which are crushed stone aggregate. The physical and mechanical tests were also carried out according to the British Specifications shown in Table 1 **[**10**]**. It is clear that the used aggregate conforms to the British Standard Specifications **[**8**]**.

TABLE 1. Coarse aggregate physical test results

Nominal Maximum Size	Test	results
10mm	specific gravity	2.45
20mm		2.43
10mm	absorption capacity	1.87%
20mm		1.55%

2.4 Water

Potable water free from impurities was used in the mixture.

2.5 Silica fume

Silica fume is generally used as an additive in the production of high strength concrete. Silica fume mainly consists of fine spherical

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particles of silicon dioxide (SiO_2). It is a pozzolanic material resulting as a by-product from the use of high-purity quartz with coal in the electric arc furnace in productions of silicon alloys **[**11**]**. Mentioned earlier of about 1/100 of cement particles in size.
In this paper, silica fume produced by sika company, packed in 15kg bags was used for the tested specimens.

3. Concrete mix design

The mix used to cast the specimens was developed by Department OF Environment (DOE) by trial batching in the concrete laboratory of Sirte University. The mix was designed to develop compressive target strength of 48 N/mm^2 for concrete with no silica fume. All concrete mixtures are designed with water / binder ratio (W/B) = 0.51. Should show that there are 4 types of mixes S.F.0%, S.F.5%, S.F.7% and S.F.10%for silica fume. Table 2 shows the weights of the materials used in these mixtures.

TABLE 2. Mixing ratios quantities of the materials used in the mix.

Mix Designation	Cement (kg/m³)	silica fume (kg/m³)	fine agg (kg/m³)	coarse agg 10 mm (kg/m³)	coarse agg 20 mm (kg/m³)	water (kg/m³)
S.F0%	390	0	435	600	600	200
S.F5%	370.5	19.5	435	600	600	200
S.F7%	362.7	27.3	435	600	600	200
S.F10%	351	39	435	600	600	200

4. Results and Discussions

4.1 Slump test results

Table 3 shows the results of the slump test for the reference mixture (S.F0) and the mixtures that contain silica fume at percentages of 5%, 7%, 10%, and the results showed that when adding silica fume at these percentages of the value of the slump on the reference mixture decreased, because of the fine composition of silica fume which means high surface area. consequently, reduces the workability. We also note from the results that the higher the percentage of silica fume, the lower the workability.

TABLE 3. Slump test results

Mix Designation	slump (mm)
S.F0%	45
S.F5%	25
S.F7%	15
S.F10%	10

4.2 Compression Test results

Table 4 shows the results of the compressive strength test for the reference mixture (S.F0) and for mixtures containing silica fume in the percentages of (5%, 7%, 10%), at ages (7, 28, 90 and 180 days). The values given are the average of 3 compressive strength results of 3 cubes for each ordered pair (mix, age). Results indicated

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increase in the compressive strength as the percentage of silica fume increased in the mix at all ages. These results are consistent with the results of (T.M. EL Sokkary , H.H. Assal, A.M. Kandeel 2004) **[**12**]**. The compressive strength increased with the silica fume up to 25.5% at all immersing times, these results are also in agreement with the results of (Seung-Tae Lee, Dae-Wook Park, and Ki-Yong Ann 2008) **[**13**]**. Figure 2 shows graphically the effect of adding silica fume percentages on the compressive strength of concrete.

TABLE 4. Compressive strength test results

Mix Designation	compressive strength (Mpa)			
	7 days	28 days	90 days	180 days
S.F0%	36.93	46.28	49.24	57.78
S.F5%	39.75	49.82	53	60.15
S.F7%	43.5	54.52	58	60.67
S.F10%	46.33	58.07	61.78	61

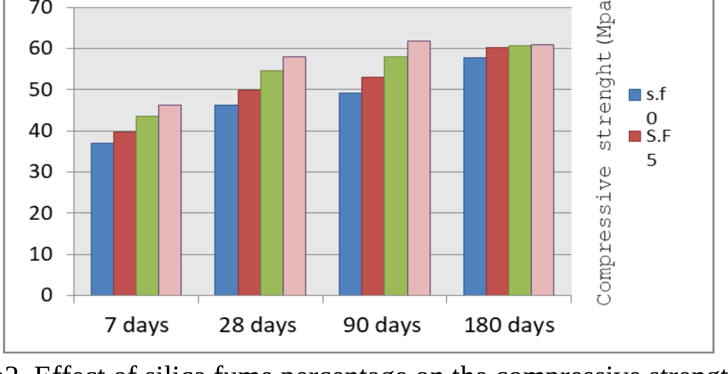

Figure2. Effect of silica fume percentage on the compressive strength

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4.3 Sulfates and Chlorides Test results

The results of the percentage of sulfates and chlorides for the reference mixture (S.F0) and for mixtures containing silica fume in the proportion of (5, 7, 10%), at age (180 days). Results indicated decrease in the percentage of sulfates and chlorides on the reference mixture. The lowest percentage of sulfates and chlorides was found when silica fume is 10% of the weight of the cement. These results are consistent with results of (I.M.Helmy , H.EI-Didamony , A.H.Ali & T.M. EL Sokkary 2001) **[**14**]**. These results are also in agreement with the results of (Dr. Ihab Sabri Saleh 2017) **[**15**]**, Figure3 and 4 shows the positive effect of silica fume percentages in concrete on the attack of sulfates and chlorides.

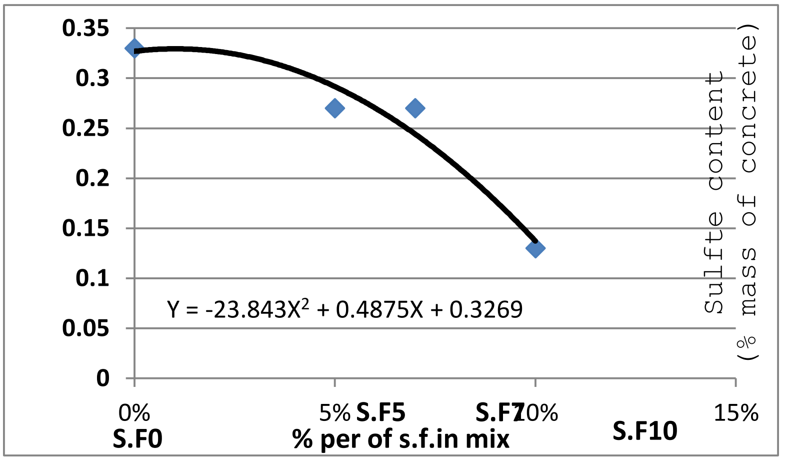

Figure 3. Effect of silica fume % per on the attack of chloride

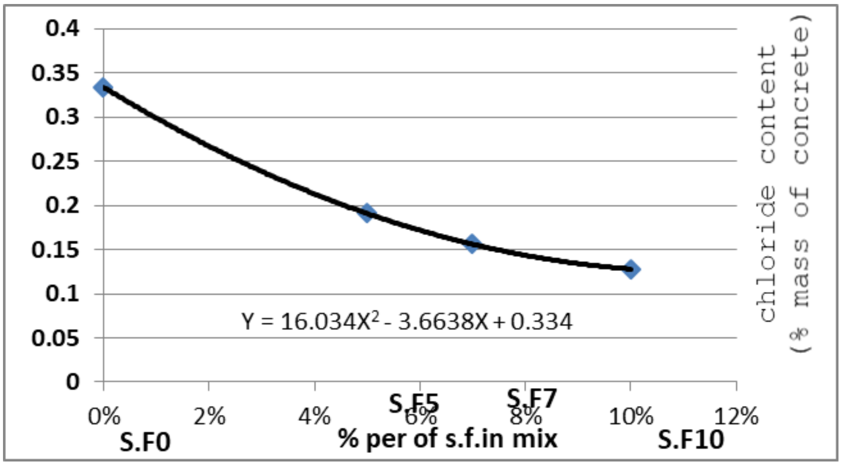

Figure 4. Effect of silica fume % per on the attack of sulfate

5. Conclusions

Based on the experimental findings of paper, the following conclusions can be withdrawn with respect to compressive strength, durability and workability:

1. Compressive strength: As the percentage of silica fume increases, the compressive strength increases accordingly.
2. Durability: Results of chloride and sulfate penetration show decrease of their content in concrete by increase of S.F percentage, hence durability increase.
3. Workability: It is found that workability decreases with increase of silica fume percentage in concrete.

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6. Recommendations

1. It is recommended to perform more studies regarding the effect of higher percentages of silica fume in concrete, (say 15% and higher).
2. It is recommended to use silica fume with suitable percentages in concretes for resisting the harmful effects of chloride and sulfates.

References

[1].I.Struct.E/ICE Joint Committee, Manual for the Design of Reinforced Concrete Building Structures, Institution of structural Engineering, London (1985).

[2]. A.M. Neville,properties of concrete, 4th edition, London Longman (1994).

[3].Tang, L, Chloride transport in concrete-measurement and prediction, Chalmers University of Technology, Sweden, Doctor Thesis (1996).

[4].Shi. C, Yuan. Q, Deng. D, & Zheng. K, Test methods for the transport of chloride ion in concrete, Journal-Chinese ceramic society (2007), 35(4), 522.

[5].Ndahirwa. D, Qiao. H., & Mahame. C, Effect of Carbonation, Chloride and Sulphate Attacks on Reinforced Concrete: A Review. International Journal of Civil Engineering, Construction and Estate Management (2018), 6(2), 59-64.

[6] A. M. Neville,"Corrosion of Reinforcement", Concrete Society Publication on "Concrete Repairs", London(1984).

تم استلام الورقة بتاريخ:23 /2023/12م وتم نشرها على الموقع بتاريخ: 30/ 1 /2024م

[7].LNCSM, Libyan National Center for Standardization and Metrology(2009), 340.

[8].BS.812 Part 103:. British Standard, Method for sampling and testing of mineral aggregates, sands and fillers, Part 103 Method for determination of particle size distribution (1985).

[9].BS.812 Part 2. EN 12390-7, British Standard, Method for sampling and testing of mineral aggregates, sands and fillers, Part 2 Test Method for Density, Relative Density (Specific Gravity) and absorption of fine aggregate.

[10].BS.812: British Standard test for the apparent specific gravity and absorption of coarse aggregate (1951).

[11].Edward G. Nawy, Reinforced concrete, Fourth Edition, prentice Hall International series.

[12].El Sokkary, T. M, Assal, H. H, & Kandeel, A. M, Effect of silica fume or granulated slag on sulphate attack of ordinary Portland and alumina cement blend, Ceramics international (2004), 30(2), 133-138.

[13].Lee, S. T, Park, D. W, & Ann, K. Y, Mitigating effect of chloride ions on sulfate attack of cement mortars with or without silica fume, Canadian Journal of Civil Engineering (2008)., 35(11), 1210-1220.

[14].Helmy, I. M, El-Didamony, H, Ali, A. H, & El-Sokkary, T. M, Effect of silica fume on the chloride and sulphate attack of sulphate resisting and high alumina cement composite(2001).

[15].Saleh, I. S, Effect of external and internal sulphate on compressive strength of concrete. Int. J. App. Eng. Res (2017), 12, 10324-10333..