Treatment of Sulfate in Sand by Using Magnetic Water Process

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Abstract

One of the most important problems in concrete production in Iraq and other country is the high sulfate content in sand that led to damage of concrete and hence reduces its compressive strength and may leads to cracking due to internal sulfate attack and delay ettringite formation.

The magnetic water treatment process is adopted in this study. Many samples with different SO_3 content are treated with magnetic water (12, 8, 4 and 2)L that needed for each 1kg of sand with the magnetic intensity (9000 and 5000) Gaus. The magnetic water needed is reduced with less SO_3 content in sand.

The ACI 211.1-91 concrete mix design was used in this research with slump range (75-100) mm and the specified compressive strength (35MPa).

The compressive strength was studied for the concrete mixes containing sand before and after treatment, such as the concrete mix containing the treated sand (SO_3% = 0.25) showed an increase in compressive strength up to (7.14, 10.69 and 32.87) at (28, 90 and 180 days) respectively compared to concrete mix containing sand before treatment(SO_3% = 3.0).

1. INTRODUCTION

The magnetized water had been used in several applications like environment, health, and construction industry. The main target of this instigation was to study the ability of using magnetic water to treat sand from sulfate.

The main cause of failure of concrete structures in Iraq and Middle East was the impurity of sand with sulfate [1].

Calcium sulfates in the sand approximately 95% and the rest consists of sodium, magnesium and potassium sulfate [2].

Al-Obaidi studied the concrete mixes with SO_3 content of (1.5 and 3.0)% in fine aggregate, the result of compressive strength appears to increase in early age and then decrease at later age; the result percentage is (2.53,-6,-9.09) at (7, 28, 90) days respectively for SO_3=1.5content and (0.6,-13.3,-16.1) at (7, 28, 90) days respectively for SO_3=1.5content compared to reference mix with SO_3=0.11[3].

The previous studied showed that it is very important to find a solution to the sulfate in fine aggregate, so our study is a new technology to treat the sand with an easy process with low cost.

Ahmed [4] studied the effect of magnetic water on compressive strength and slump test of concrete. The percentage increase of compressive strength about 10-20% for the concrete specimens prepared with magnetic water compered to tap water specimens when the magnetic intensity of water is 1.2 T with improvement of workability.

Wang and Zhao's study showed the improvement of cement characteristics which made with magnetic water. Also magnetic treatment had given positive results in compressive strength [7].

Concrete mixes were prepared by Karam and Al-Shamali using both Tap and magnetic water. They concluded that the strength of concrete prepared with magnetic water increased by (10 – 15) % and the tensile strength and flexural increased by (7 – 28) %. The use of magnetic water led to better workability of concrete mix [5].

Nadem et al studied the effect of magnetized water in concrete mix with (400,600 and 1200) kg/$m^3$of (cement, sand and gravel) respectively. The experimental work using two kind of water magnetized water and ordinary water. The magnetic water prepared by passing the tap water through the systems of different magnetic strength of (6000 and 9000) Gauss with magnetic intensity up to 1m/sec. The compressive strength results of concrete mixture with magnetic water showed an increase 24% compared to the results of the control mix [6].

2. AIM OF THE RESEARCH

The study produce a technology technic to treat the sand from the sulfate by using an easy process with a low cost which is the magnetic water process.

3. EXPERIMENTAL PROGRAM

3.1 Material

Cement: Ordinary Portland cement (OPC)-Tasloja, conforming to the IQS 5/1984 and ASTM C150 were used. The chemical and physical properties are presented in **Tables. 1 and 2** respectively.

Fine Aggregate (sand): Fine aggregate-(natural sand) from Al-Ukhaider region with different SO_3 content was used. The grading satisfies the Iraqi specification IQS 45/1984-zone two and ASTM C33.

Table 1. Chemical composition of OPC cement.

Abbreviation	Percentage by weight	Limit of Iraqi Specification No. 5/1984	Limit of ASTM Specification C150-12
CaO	60.5	-	
SiO_2	20.2	-	
Al_2O_3	5.1	-	
Fe_2O_3	3.5	-	
SO_3	2.2	≤ 2.8 % if $C_3A \geq 5\%$	≤ 3.0 if $C_3A \leq 8\%$ ≤ 3.5 if $C_3A \leq 8\%$
MgO	3.5	≤ 5.0 %	≤ 6.0 %
L.O.I.	2.3	≤ 4.0 %	≤ 3.0 %
I.R.	0.6	≤ 1.5 %	≤ 0.75 %
L.S.F		0.66-1.02	
Main Compounds (Bogue′s equations)			
C_3S	47.16	-	-
C_2S	22.41	-	-
C_3A	7.6	-	-
C_4AF	10.64	-	-

* The test was carried out in Building Research Center/ ministry of construction and Housing

Table 2. Physical properties of OPC cements.

Physical properties	Test results	Limits of Iraqi Specification No. 5/1984	Limits of ASTM Specification C150-12
Specific surface area (Blaine method) (m^2/ kg)	310	≥ 230	≥ 280
Soundness by Autoclave Method (%)	0.6	≤ 0.8	-
Setting time (Vicat′s method) Initial setting (hrs. : min) Final setting (hrs. : min)	1:25 5:30	≥ 45 min ≤ 10 hrs.	≥ 45 min ≤ 375min
Compressive strength (MPa) 3 days 7 days	20 26	$\geq$ 15 $\geq$ 23	$\geq$ 12 $\geq$ 19

* The test was carried out in Building Research Center/ ministry of construction and Housing

The sieve analysis, sulfate content and the physical properties are shown in **Table. 3**.

Coarse Aggregate: Natural crushed coarse aggregate (gravel) from Al-Niba`ee quarry was used with maximum size equal to 20mm. The aggregate conforms to the Iraqi specification IQS 45/1984. The sieve analysis, sulfate content and the physical properties are presented in **Table. 4.**

Mixing Water: Ordinary tap water is used for mixing and curing of the concrete, confirming to the IQS 1703/1992.

Table 3. Physical tests and sulfate content of fine aggregate.

Sieve size (mm)	% passing by weight (Sample 1)	% passing by weight (Sample 2)	% passing by weight (Sample 3)	Iraqi specifications No.45/1984 (Zone 2)	ASTM specification C33-
10	100	100	100	100	100
4.75	92	90	92	90-100	95 -100
2.36	78	80	80	75-100	80 – 100
1.18	65	62	68	55-90	50 – 85
0.6	40	45	50	35-59	25 – 60
0.3	12	10	10	8-30	5 – 30
0.15	3	2	1	0-10	0 – 10
Fineness modulus	3.1	3.11	2.99	Max. 0.5	-
Sulfate content (%)	0.3	3.0	0.8	Max. 0.5	-
Specific gravity	2.58	2.59	2.58	Max. 0.5	-
Absorption (%)	0.8	0.75	0.82	-	-

*The test was carried out in Building Research Center/ ministry of construction and Housing

Table 4. Physical tests and sulfate content of coarse aggregate.

Sieve size (mm)	Passing by weight (%)	Iraqi specification No. 45/1984 (5-20)mm	ASTM specification C33-
37.5	100	100	-
25	100	-	100
20	96	95-100	90-100
10	35	30-60	20-55
5	2	0-10	0-10
Material finer than 0.075 mm	1.2	Max. 3	-
Sulfate content (%)	0.01	Max. 0.1	-
Specific gravity	2.6	-	-
Absorption %	0.2	-	-

* The test was carried out in Building Research Center/ ministry of construction and Housing

3.2 Mix Design Proportion

The ACI 211.1-91 concrete mix design was adopted in this research. The slump range is (75-100) mm and the specified compressive strength (35MPa). The cement content, fine aggregate and coarse aggregate are 455, 635 and 1000kg/m^3respectively with w/c= 0.45 ratio.

3.3 Mixing and Curing of Concrete

The mixing of the material is done by using a rotary mixer. The cube molds, with dimensions of (100x100x100)mm are arranged (cleaned and oiled). The compaction of concrete was done by a vibrating **Table for (12 -14)** second for the tow layer. Then the molds were covered with nylon bag for just about 24hr. The specimens were placed in the curing tank filled with water till the time of testing at 7, 28, 90 and 180- days.

3.4 Tests Performed

Part one: Using magnetic water process as shown in **Fig. 1** by using magnetic water device **Fig. 2** as shown in **Fig. 1.** The research includes trying to use 2- intensity (5000 and 9000) Gaus with different water content (4, 8, 12 and 20) L for intensity 9000 Gaus and (20)L for 5000 Gaus. The lab test program is done in Ministry of science and technology.

Part two: The tests for fresh and hardened properties of concrete with different content of SO_3 in sand to study the effect of magnetic water process on treatment sand.

Fresh Concrete: The slump test of fresh concrete (workability) is adopted according to the ASTM C143M– 00A.

Compressive Strength Test: The BS 1881: Part 116: 1983 for compressive strength test is adopted with a cube of (100) mm at 7, 28, 90 and 180-days.

4. RESULTS AND DISCUSSION

4.1 Treatment Process

Table. 5 present the SO_3 content of sand before and after magnetic water process. The samples 1, 2 and 3 with SO_3 content (0.3, 0.8 and 3.0)% respectively as a reference sand treated with water (12L) and the magnetic intensity 9000 Gaus. The SO_3 content reduced to (0.0, 0.017 and 0.25)% respectively which is within the Iraqi specification limits (0.5)%.

When reducing the used water that needed for each 1kg sand from 12L to 8L for sample 3, the treated sand results still within the Iraqi specification (0.42)%, while when reduced the water in the process to (4 and 2)L the treated sand-sample 3 fail with the requirement.

Then we try to use 20L of water with the magnetic intensity 5000 Gaus, the treated sand-sample 3 fail in Iraqi requirement.

Table 5. The magnetic water process.

Test No.	Samples	SO_3 content (%)	Magnetic intensity (Gaus)	Water needed for each 1kg sand(L)	SO_3 content (%) after washing with magnetic water
1	Sample 1	0.3	9000	12	0.0
2	Sample 2	0.8	9000	12	0.017
3	Sample 3	3.0	9000	12	0.25
4	Sample 3	3.0	9000	8	0.42
5	Sample 3	3.0	9000	4	0.6
6	Sample 3	3.0	9000	2	0.68
7	Sample 3	3.0	5000	20	0.6

* The test was carried out in Ministry of science and technology

4.2 Effect of Sand on Concrete Properties Before and After Treatment

Table 6. presents the compressive strength results for concrete mixes with different SO_3 content before and after treated with magnetic water process.

Fig. 3 showed the development compressive strength with age (7,28,90 and 180 days) for concrete mixes M1, M2 and M3 using sand before treatment with SO_3 content (0.3, 0.8 and 3.0)% respectively. The percentage decrease in compressive strength (-1.35 and-5.41)% for 28-day , (-3.85 and -9.05)% for 90 day and (-15.98 and -25.20)% for 180-days for concrete mixes M2 and M3 compared to M1 respectively. The decrease in compressive strength is increased with increased of sulfate in sand due to higher exposure to sulfate so more significant effect of internal sulfate attack and delay ettringite formation and that is conformed to literatures.

The concrete mix (M2-ms) containing treated sand of sample 2 showed an increase in compressive strength as shown in **Fig. 4**. The percentage increase equal to (+1.36, +5.88 and +18.29) for (28, 90 and 180 days) respectively compared to M2 concrete mix, that means that the concrete mix compressive strength development approximately same as M1. The concrete mix (M3-ms) containing treated sand of sample 3 showed an increase in compressive strength as shown in **Fig. 5**. The percentage increase equal to (+7.14, +10.69 and +32.87) for (28, 90 and 180 days) respectively compared to M3 concrete mix, that means that the concrete mix compressive strength development approximately same as M1.

Table 6. The slump and compressive strength results.

Mix symbol	SO_3 content in sand (%)	Slump (mm)	Compressive strength (MPa)			
			7-days	28-days	90-days	180-days
M1	0.3	80	29.5	37	44.2	48.8
M2	0.8	82	29	36.5	42.5	41.0
M3	3.0	70	27.6	35	40.2	36.5
M1-ms*	0.0	80	30	37	45.5	49.2
M2-ms*	0.017	80	29.8	37	45.0	48.5
M3-ms*	0.25	79	30	37.5	44.5	48.5

Mixes M1, M2 and M3 using treated sand (magnetic water process)

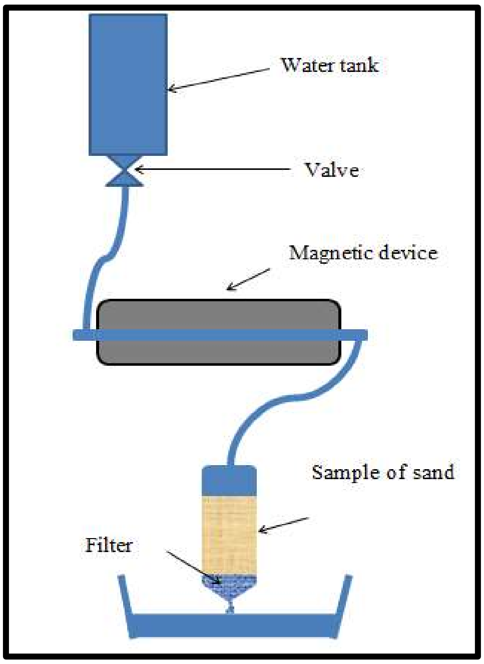

Fig. 1. Washing process by magnetic water

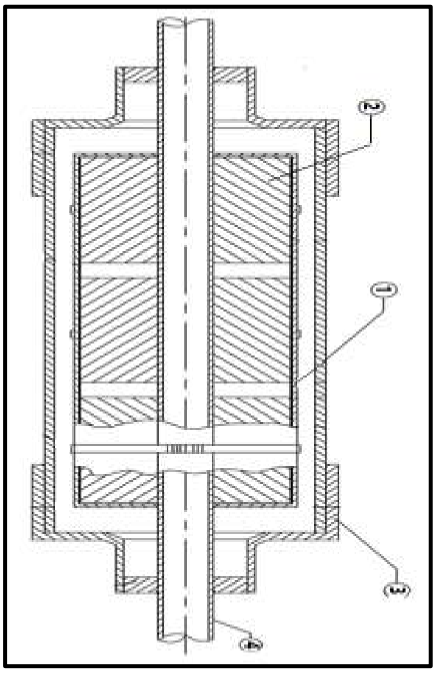

Fig. 2. Magnetic device, 1-magnetic container, 2-magnetic pieces, 3-cover, 4- tube

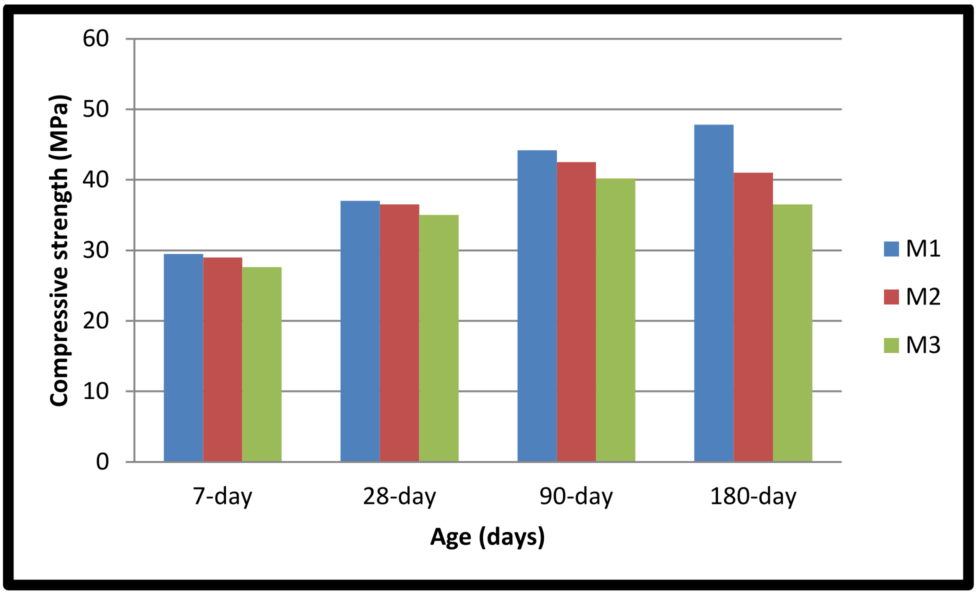

Fig. 3. The compressive strength with age for concrete mixes (M1, M2 and M3)

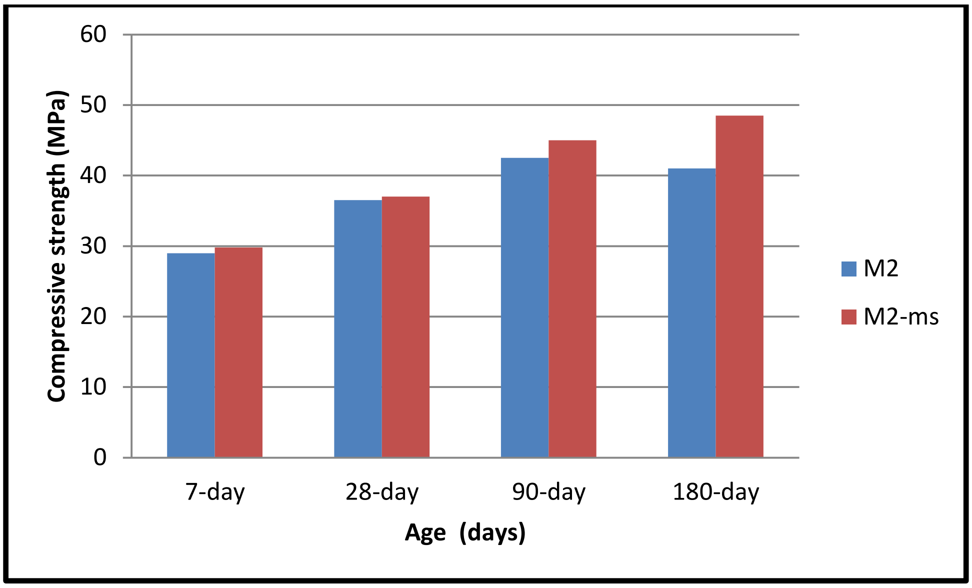

Fig. 4. The compressive strength with age for concrete mixes M2(SO_3=0.8) and M2-ms (SO_3=0.017).

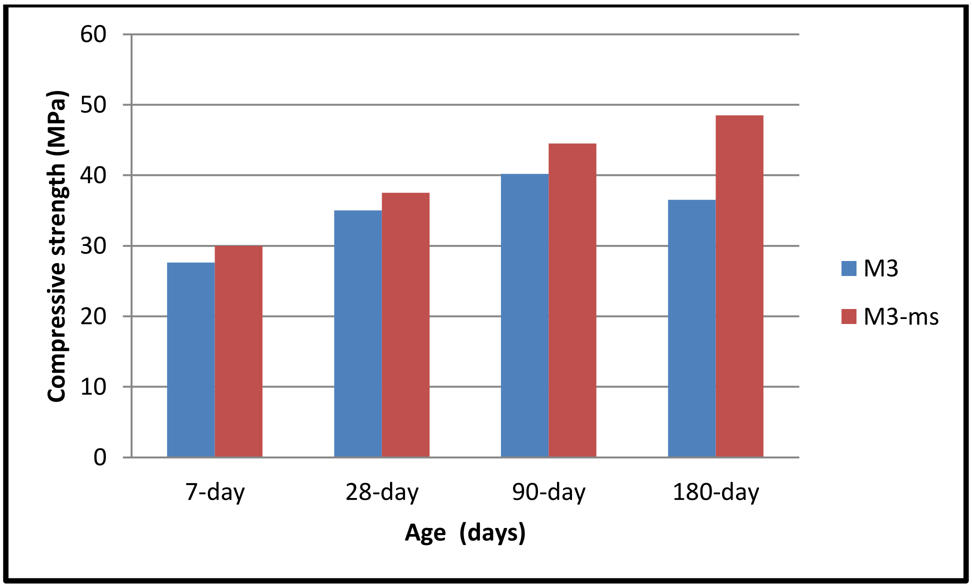

Fig. 5. The compressive strength with age for concrete mixes M2(SO_3=3.0) and M2-ms (SO_3=0.25).

5. CONCLOUSHONS

1. The ability of using the magnetic water process to overcome the problem of high SO_3 content in sand.
2. The treatment of 1kg sand containing (SO_3%=3.0) needs (8L) of magnetic water using magnetic intensity 9000 Gaus and the required magnetic

water reduced with les SO_3 content in sand.

3. The concrete mix containing (SO_3% =0.8) in sand showed a reduction in compressive strength up to (15.98%) at 180-days while it showed an increase up to (1.36, 5.88 and 18.29)% compared to reference mix at (28, 90 and 180 days) respectively after treatment of sand.
4. The concrete mix containing (SO_3% =3.0)in sand showed a reduction in compressive strength up to (25.2%) at 180-days while it showed an increase up to (1.36, 5.88 and 18.29)% compared to reference mix at (28, 90 and 180 days) respectively after treatment of sand.

6. REFRENCE

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معالجة الاملاح في الرمال بأستخدام تقنية المياه الممغنطة

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الخلاصة

واحدة من اهم المشاكل التي تصادف انتاج الخرسانة في العراق و بلدان أخرى هو المحتوى العالي من الاملاح في الرمال و التي تؤدي الى ضرر الخرسانة و تناقص مقاومة الانضغاط و التي قد تؤدي الى التشققات بسبب مهاجمة الاملاح الداخلية .

في هذة الدراسة تم تبني معالجة ملوحة الرمال باستخدام تقنية المياة المغنطه. تم معالجة نماذج و بنسب مختلفة من محتوى ال SO_3 بمياة ممغنطة (2,4,8,12) لتر اللازمة لكل 1 كغم من الرمل و بشدة (9000و5000)كاوس.

تم تصميم الخلطة الخرسانيه و حسب الطريقة الامريكية و بهطول (75-100) و كانت المقاومة التصميميه 35نت/ملم^2.

تم دراسة مقاومة الانضغاط للخلطات الخرسانية و الحاوية على الرمل قبل و بعد المعالجة , مثل الخلطة الخرسانية الحاوية على الرمل المعالج (SO_3%=0,25) و التي أظهرت زيادة في مقاومة الانضغاط تصل الى (+7,14 , +10,69 و +32,87) في (28, 90, 180 يوم) على التوالي مقارنة بالخلطة الخرسانية الحاوية على الرمل قبل المعالجة (SO_3%=3,0).