IOP Conference Series: Materials Science and Engineering

PAPER • OPEN ACCESS

Some Properties of Concrete by Replacing Sand with Sulphate Content Higher than Specification Limits with Slag Sand

To cite this article: Zainab H. Mahdi 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **518** 022080

IOP Conf. Series: Materials Science and Engineering **518** (2019) 022080 doi:10.1088/1757-899X/518/2/022080

Some Properties of Concrete by Replacing Sand with Sulphate Content Higher than Specification Limits with Slag Sand

Zainab H. Mahdi
Building & Construction Technology Engineering Dept., Technical Engineering College-Baghdad, Middle Technical University, Baghdad, Iraq
E-mail: Zainabengineeringcollege@yahoo.com

Abstract. There are many recent problems in several quarries of natural sand containing sulphate ratios outside the limits of the specification has led to difficulty in obtaining sand conforms to specifications in terms of the proportion of sulphate. To solve this problem, in this search was used the iron industry waste called slag iron that forming a burden on the environment. Where it was broken down and converted into a sand and then use the replacement rates (0, 25, 35, 50 and 100)% from a failing natural sand. Test conducted compressive strength and electrical resistivity to find out the impact of replaced the slag sand by failing natural sand on its. The results showed that the best replacement ratio was 50% by weight of failing sand and the rate of increase in the compressive strength (31.3 and 7)% at age 28 day compared mixture containing failing natural sand and the mixture containing the successful natural sand respectively. But when the total replacement of the failing sand by slag sand was the percentage increase (79.1 and 46) % compared to the same mixtures and age. The results of electrical resistivity tests showed significantly reduced for the mixtures which were the replacement the failing sand by slag sand with rates (0, 25, 35 , 50 and 100) % compared to the mixtures containing successful natural sand where the rate of decline at age 28 day (30.8, 52.7, 60.8, 64.8 and 86.2) % respectively.

1. Introduction

The problem of sulphate attack on concrete it is the big construction problems that drew the attention of researchers and engineers over the past century and still raise the same concern at the present time especially after it appeared that the impact of the problem on a lot of important installations around the world [1]. in general, there is a two main sources of sulphate salts that attack concrete is sulphate in the groundwater or surface or in the surrounding soil with concrete this is what is known as the external sulphat and sulphate contained within materials used in the production of concrete such as sand, gravel, cement, water and additives This is what is known as internal sulphate [2]. The attack on the Interior sulfate concrete it has not received similar attention of attention oriented attack the external sulphates in most countries of the world it seems so obvious from the lack of research that dealt with the problem of internal sulphates compared with many of the research that touched on attack the external sulphates. It is likely that the reason for this is due to the scarcity of problems of this kind in those countries but locally this problem seems clear through the manifestations of corrosion worsening in many installations and buildings both in concrete cast in situ or precast concrete units the reason for this is the high proportion of sulphate in the sand and groundwater. Al-Samarrai pointed out that the fragmentation of the concrete impact of salt is one of the most important problems facing the engineer and that there are sulphate in the soil and underground water it is widespread surface and depth, especially in the central region and as they noted both Kazimi and Abdul Latif quoting from Al Rawi that the sulphate content in most of the sand in the Middle East countries is higher than permitted in the specifications therefore, large quantities of sand in Iraq cannot be used because of high sulphate content [3, 4, 5, 6]. Al Rawi indicated that attacking internal sulphates is the main reason for the failure of facilities in the Middle East Most of the sand is contaminated with sulphate, which is made up of calcium [6]. Al-Rubaie explained in his study of strength to high performance concrete exposed to the attack of internal and external sulphates in which the natural gypsum was added as a partial replacement of the weight of the sand and in proportions ranging from 0.5- 2.5% to the detrimental effect internal sulphate appears in early ages (starting 7 days) and increases with age unlike the effect of external sulphates which does not show a negative effect in early life [7]. In a similar study conducted by Al-galawi and Hassooni on the effect of cement and admixture types on the resistance of high Performance concrete to internal sulphate attack, they found results similar to that of al-Janabi and al-Rubaie, that the use of pozzolanic materials reduces the negative effects of internal sulphate, especially in advanced ages [8, 9]. Al-Rubaie study was conducted to assess the possibility of using sand with sulphate content higher than the upper limit of the (0.5%) to produce pre-cast concrete units: hollow concrete block and paving concrete brick, where the total amount of sulphate has been controlled by decreasing the sand content in the adopted mixes [10]. To control the problem of attacking the internal sulphate salts for concrete and reduce its effects and develop appropriate solutions most countries in the last three decades have included in their specifications and codes limits of acceptance and rejection for concrete or its primary components such as sand and gravel based on sulphate content therein, depending on the conditions of each country and quality the concrete produced or the nature of its use and its exposure conditions. Table 1 shows some of the international standards adopted in this matter.

Table 1. Some local and international standards are adopted in determining the upper limit of the allowable sulphate in aggregates and concrete.

Specifications	Number and date	The maximum allowable of sulphate	Notes
British	B.S 5328-1976	%4	The total allowable ratio in concrete mix as a percentage of weight cement
		%0.4	The percentage of salts allowed as a percentage of the weight of fine and coarse aggregates
Germany	DIN 4226-1971	%1	The percentage of salts allowed as a percentage of the weight of fine and coarse aggregates
Iraq	I.S 45-1984	%0.5	The percentage of salts allowed as a percentage of the weight of fine aggregates
		%0.6	The total percentage allowed in concrete blocks as a percentage of cement weight

Indian	Part1-1976	%0.5	The percentage of salts allowed as a percentage of the weight of fine and coarse aggregates
Russia	4797-1969 4798-1969	%1	The percentage of salts allowed as a percentage of the weight of fine and coarse aggregates
Bulgaria	BSS 177-1977	%0.5	The percentage of salts allowed as a percentage of the weight of sand for pre stress concrete
		%1	The percentage of salts allowed as a percentage of the weight of sand for other concrete types
Yugoslavia	JUS U.M2.010	%1	The percentage of salts allowed as a percentage of fine aggregates

Objectives. The primary objectives of this search are:
To rid the environment of waste iron industry, this constitutes a significant burden on the environment, which is called slag. The country exposed to a substantial loss as a result of the presence of numerous quarries containing the sand with a ratio of sulphate higher than limited by the Iraqi specification, namely, (0.5%) To avoid this loss was conducted this research to try and presence solutions for use this slag as a sand in concrete and used in extensive areas of modern construction by replacing part of the failing natural sand by slag sand.

2. Materials and Mix Proportion

2.1 Cement

Ordinary Portland cement made in Alhabibia cement factory / Iraq type I was used throughout this research. The chemical compositions of cement used throughout this research are shown in Table 2. Test results were indicated that the adopted cement was conformed to the Iraqi specification No.5/1984.

Table 2. Chemical compositions and main compounds o cement

Oxides composition	Content %	Limits of Iraqi specification No.5/1984
Calcium oxide CaO	66	-
Silica dioxide SiO_2	20.6	-
Aluminum oxide AI_2O_3	5.1	-
Iron Oxide Fe_2O_3	3.8	-
Sulfur dioxide SO_3	2.2	< 2.8%
Magnesium oxide MgO	2.8	< 5.0%
Loss by burning L.O.I	3.8	< 4.0%
Insoluble residues	0.9	< 1.5%
Alkali ($Na_2O + 0.658K_2O$)	0.277	
Forced saturation factor	0.95	**1.02-0.66**
Main compounds (Bogue's equations)		
C_3S	66.084	
C_2S	9.295	
C_3A	7.093	
C_4AF	11.552	

IOP Conf. Series: Materials Science and Engineering **518** (2019) 022080 doi:10.1088/1757-899X/518/2/022080

2.2 Fine aggregate

It was used two types of natural sand:

The first type natural sand located within the gradation area (2) conformable to the British Specification numbered (882) for the year 1992 as shown in Table 3 a ratio of sulphate (0.0134) less than 0.5%

The second type natural sand located within the gradation area (2) conformable to the British Specification numbered (882) for the year 1992 as shown in Table 4 a ratio of sulphate 1.34 higher than 0.5%.

Table 3. Gradation of sand with sulphate content 0.0134

Sieve diameter (mm)	Ratio passes %	The limits of British Standard No. (882) for the year 1992 include the area No. (2)
4.75	97.78	100-90
2.36	93.7	100-75
1.18	85.06	90-55
0.6	59.97	59-35
0.3	16.206	30-8
0.15	2.04	10-0

Table 4. Gradation of sand with sulphate content of 1.34

Sieve diameter (mm)	Ratio passes%	The limits of British Standard No. (882) for the year 1992 include the area No. (2)
4.75	91.09	100-90
2.36	79.o7	100-75
1.18	65.4	90-55
0.6	44.98	59-35
0.3	14.7	30-8
0.15	2.66	10-0

2.3 Gravel

Aggregate rounded passing sieve (9.5 mm) and remaining on the sieve (2.36 mm) is located within the area include No. 2 as shown in table 6 and the proportion of sulphate is 0.027 %

Table 5. Gradation of gravel

Sieve diameter (mm)	Ratio passes %	The limits of Standard No. (882) for the year 1992 include the area No. (2)
12.5	100	-----
9.5	38.92	55-20
4.75	1.33	10 -0
2.36	0.11	5– 0

2.4 Slag

Large blocks were brought from Alsumood factory in Taji it was broken down and graded according to the user grading sand and it is from the gradation area number one, according to the British Standard numbered 882 for the year 1992 as shown in table 7 and the proportion of sulphate which are (0%) that is free of sulphate.

Table 6. Gradation of slag sand

Sieve diameter (mm)	Ratio passes%	The limits of British Standard No. (882) for the year 1992 include the area No. (1)
4.75	99.04	100-95
2.36	62.06	95-60
1.18	35.11	70-30
0.6	21.18	34-15
0.3	13.43	20-5
0.15	8.08	0-10

2.5 Water

In this research was used drinking water in mixing all mixtures. (sulphate ratio where 0.632).

2.6 Mix Proportion

This research included constant mixing ratios with respect to the cement: fine aggregates: Coarse aggregate (1:2:4) and water / cement ratio 0.50% as follow:

1. First mix: mixture constituted from successful natural sand with sulphate content 0.0134%.
2. The second mixture: mixture constituted from failing natural sand with sulphate content 1.43%.
3. The third mix: the replacement of 25% of the failing sand by slag sand
4. The fourth mix: the replacement of 35% of the failing sand by slag sand
5. Fifth mixture: the replacement of 50% of the failing sand by slag sand
6. Sixth mix: has been replaced total of failing sand by slag sand.

2.7 Casting and Curing of Test Specimens

Mixing dry material sand, gravel and cement then adding the water and continue mixing for 4 minutes. After that casting mixture in molds cubic dimensions (100 * 100 * 100 mm) in two layers, and compact each layer on the vibrator device for 20 seconds. After completion of the casting process has to cover molds directly by plastic lid for a period of (24) to prevent the evaporation of water from the soft forms, and then was taken out from molds and placed in a tub of water treatment until the testing date.

3. Result and Discussion

3.1 *Compressive strength*

Compressive strength was tested according to the ASTM (109) C 109 M 2005 specification. Table (1-3) explain mixtures that were made in the laboratory for the ages (7, 14, 28, and 60) day. From this table noted that the less compressive strength for mixing contain failing sand and mixtures which were the replacement of the (25 and 35)% of failing sand by slag sand showed an increase but less than successful mixtures and the mixtures which were the replacement of 50% of the failing sand by slag sand lead to increase in compressive strength where the percentage of increase were (31.3 and 7)% at age 28 day compared the mixtures containing failing sand and the mixtures containing successful sand respectively. While the mixtures which replaced the whole failing sand by slag sand showed an increase in compressive strength where the percentage of increase were (79 and 46)% at age 28 day compared the mixtures containing failing sand and the mixtures containing successful sand respectively.

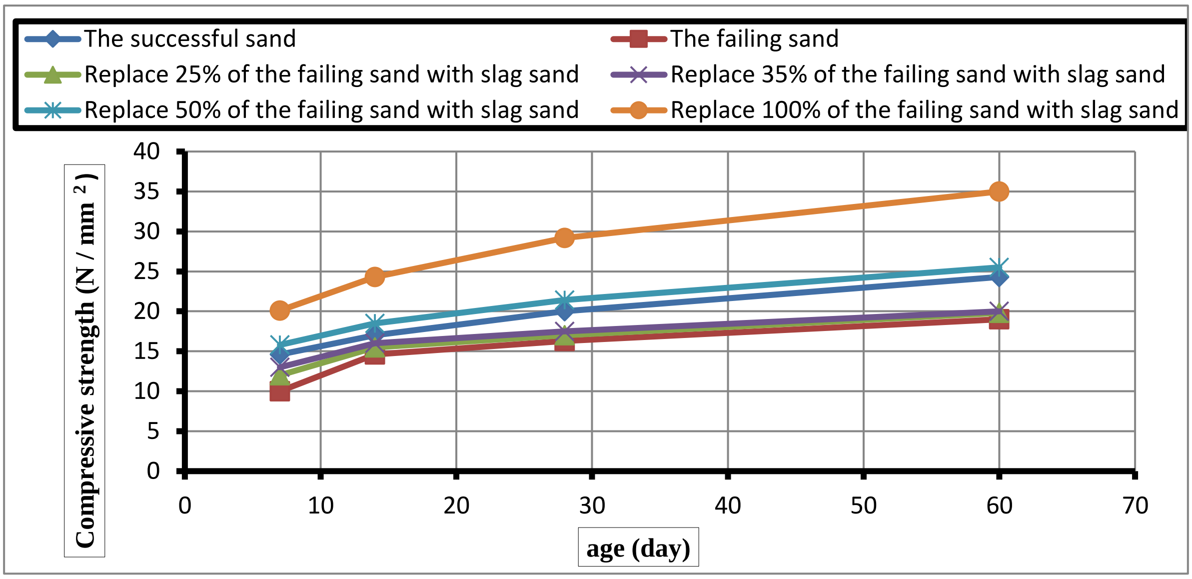

Figure 1. The relationship between the compressive strength and age for various types of mixtures

Table 7. Compressive strength for various types of mixtures

Mixtures	Compressive strength (N / mm ^{2})			
	7 days	14 days	28 days	60 days
The successful sand	14.6	17	20	24.3
The failing sand	10	14.6	16.3	19
Replace 25% of the failing sand with slag sand	12	15.5	17	19.8
Replace 35% of the failing sand with slag sand	13	16	17.5	20
Replace 50% of the failing sad slag sand	15.8	18.5	21.4	25.5
Replace 100% of the failing sand slag sand	20.1	24.3	29.2	35

3.2 Electrical Resistivity

The results of the electrical resistivity test were conducted for all mixes at ages (7, 14, 28 and 60) day as shown in the table and Figure 3-2. The results show that the use of failing sand in mixing leads to lower electrical resistivity where the percentage of decrease was 28.38% at age 28 day compared with mixture containing a successful sand also showed that whenever increase the ratio of the replacement failing sand with slag sand increased the ratio of decrease the electrical resistivity where the rate of decrease (52.7, 60.8, 64.8 and 86.2%) at age 28 day of the mixes that were replacement (25, 35, 50 and 100%) of the failing sand with slag sand respectively.

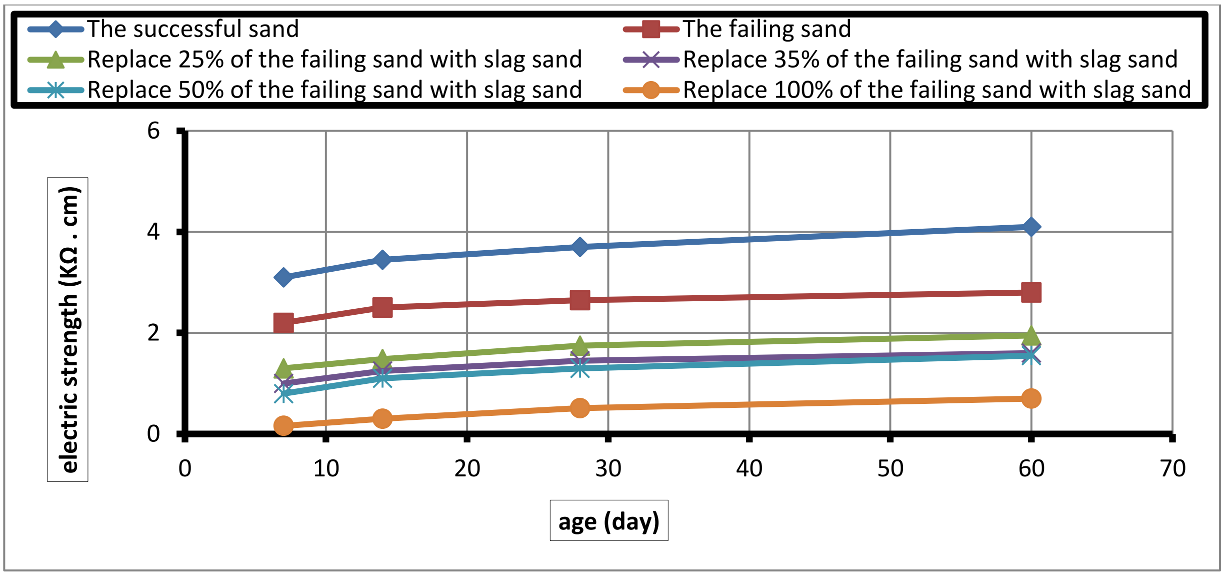

Figure 2. The relationship between the electrical resistivity and age for various types of mixes

Table 8. The electrical resistivity of various types of mixes

Mixtures	electric strength (KΩ.cm)			
	7 days	14 days	28 days	60 days
The successful sand	3.1	3.45	3.7	4.1
The failing sand	2.2	2.5	2.65	2.8
Replace 25% of the failing sand with slag sand	1.3	1.48	1.75	1.95
Replace 35% of the failing sand with slag sand	1	1.25	1.45	1.6
Replace 50% of the failing sad slag sand	0.8	1.1	1.3	1.55
Replace 100% of the failing sand slag sand	0.16	0.3	0.51	0.7

4. Conclusions

From this research we can conclude the following:-

1. The possibility of using failing natural sand in concrete mixtures by replacing 50% of it's with slag sand.
2. To obtain high compressive strength and to rid the environment of industrial waste can be used slag sand instead of successful sand or failing sand
3. The electrical resistance of the specimen decreases whenever increases the ratio of replacement with slag sand in mixtures.

References

[1] Abbas Y Y 2002 Mechanism of the penetration of sulfur salts in concrete, *Master Thesis*, University of Technology, P1
[2] Neville A M 2005 *Properties of Concrete*, Long Man Group Limited, London, Fourth Edition.
[3] Samurai M Proposal to determine the proportion of salts in sand, National Center for Construction Laboratories, Journal of Civilization, No. 1, first year. P1-3
[4] Al-Kadhimi T K and Hamid F A 1983 Effect of Gypsum Present in Sand on the Properties of Concrete *BRC-Journal* **2** 17-41.
[5] Abdul-Latif A M 2001 Mathematical Model for The Optimum Gypsum Content in Concrete, *PhD. thesis* University of Baghdad, Baghdad, pp. (1-14).
[6] Al Rawi R S 1985 Internal Sulphate Attack in Concrete Related to Gypsum Content of Cement with Pozzolan Addition *ACI-Rilem, joint symposium*, Monterrey, N.L.Mexico, p 543

IOP Conf. Series: Materials Science and Engineering **518** (2019) 022080 doi:10.1088/1757-899X/518/2/022080

[7] Al-Robayi A H 2005 *Resistance of High Performance Concrete to External and Internal Sulfate Attack*, M.Sc. Thesis University of Technology, Baghdad, P (100-102).

[8] Al-galawi N M and Hassooni S A 2016 The Effect of Cement and Admixture Types on the Resistance of High Performance Concrete to Internal Sulphate Attack *Journal of Engineering* **22** 74-92.

[9] Al-Janabi T H 2007 *Behavior of High Performance Concrete Exposed to Internal Sulphate Attack*, M.Sc. Thesis University of Technology, Baghdad, pp.(113-115).

[10] Al-Robayi M F 2009 Properties of concrete units ready-casting produced using fine aggregates with the content of salts% higher than 0.5 *Iraqi Journal for Civil Engineering* **6** No.1.

[11] Colangelo F and Cioffi R 2013 Use of Cement Kiln Dust, Blast Furnace Slag and Marble Sludge in the Manufacture of Sustainable Artificial Aggregates by Means of Cold Bonding Pelletization *materials* **6** 3139-3159.

[12] Maruthachalam V and Palanisamy M 2014 *High performance concrete with steel slag aggregate*, Građevinar, PP. 605-612.

[13] Miyamoto T, Torii K, Akahane K and Hayashiguchi S, 2015 *Production and Use of Blast Furnace Slag Aggregate for Concrete,* Nipponsteel & Sumttomo Metal Technical Report, No. 109 PP. 102-108.

[14] Nadeem M and Pofale A D 2012, Utilization of Industrial Waste Slag as Aggregate in Concrete Applications by Adopting Taguchi's Approach for Optimization *Open Journal of Civil Engineering* **2** 96-105.

[15] Nataraja M C, Dileep Kumar P G, Manu A S and Sanjay M C 2013 Use of Granulated Blast Furnace Slag as Fine Aggregate in Cement *International Journal of Structural and Civil Engineering Research* **2** 61-68.

[16] Tran M A, Nguyen C V, Nawa T and Stitmannaithum B 2014 Properties of High Strength Concrete Using Steel Slag Coarse Aggregate *ASEAN Engineering Journal Part C* **4** 22-32.