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Study and Improvement the Mechanical Properties of Concrete Containing High Percentage of Internal Sulphate

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Original Research Article

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Abstract: Sulphate attack is a significant problem which locally affects concrete and other constructional materials. The aim of this work is to study the effect of internal sulphate which is present in concrete raw materials. Gypsum was used as a source of internal sulphate. Specimens were prepared for mechanical tests in formed of (150mm cubes) for compressive test and (100*100*400 mm prisms) for flexure test with selective mix proportions of 1:2:4 by weight and water/cement ratio of 0.5 by weight. Results have shown that the compressive strength of concrete at age of 60 days decreases by 46%, 52%, 65% when added sulphate is in 3%, 5%, and 7% by weight of sand to concrete mixes, respectively. Also results have shown that when the percentage of cement content increased by 3% , 5% , 7% in concrete mixes ,which contain sulphates in 3% , 5% , 7% by weight of sand ,the compressive strength of concrete at 28 and 60 days has been increased and has the same compressive strength of concrete without sulphates. Moreover, flexural strength decreased by 10%, 25% and 38% when added sulphate is in 3% , 5%, 7% by weight of sand to concrete mixes and at age of 60 days, respectively. This decrement in flexural strength has been tempered by increasing the cement percentage by (3, 5, 7) % of cement weight to become equal to the value of standard specimens.
Keywords: Internal Sulphate, Normal Concrete, Iraqi Sand, Compressive Strength, Flextural Strength.

INTRODUCTION

Internal sulphate attack is a phenomenon that has been identified relatively recently, and is thus less understood that external sulphate attack.

Internal sulphate attack is commonly characterized as any sulphate attack caused by sulphate originating from within the concrete (i.e. hydration products, aggregate)[1]. Due to a soluble source being incorporated into the concrete at the time of mixing, gypsum in the aggregate, for example. Waterborne sulphates react with hydration products of the tri-calcium aluminate (C_3A) phase of Portland cement, and with calcium hydroxide ($Ca(OH)_2$) to form an expansive crystalline product called ettringite. Expansion due to ettringite formation causes tensile stresses to develop in the concrete [2]. When these stresses become greater than the concrete's tensile capacity, the concrete begins to crack. These cracks allow easy ingress for more sulphates into the concrete and the Deterioration accelerates. Sulphates also cause chemical disintegration of some of the cement hydration products [2].

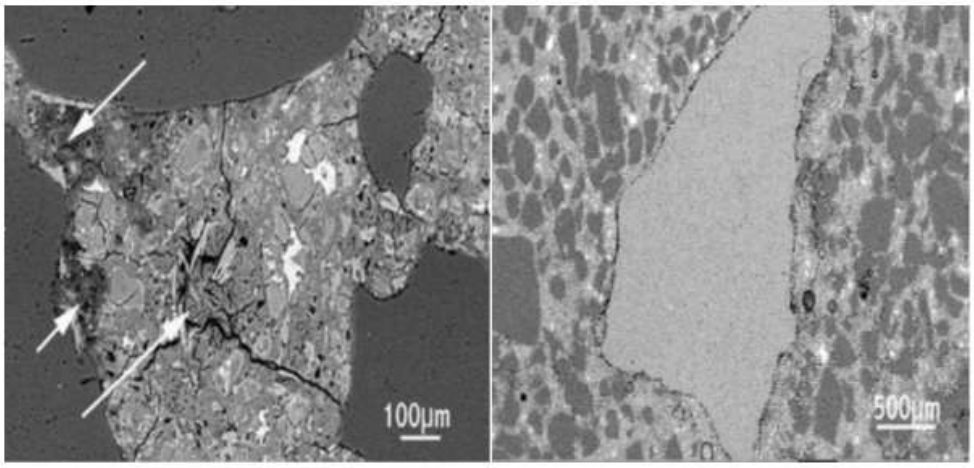

Fig-1: Sulphate attack on cement mortar [2]

MATERIALS AND EXPERIMENTAL WORK

Materials

Ordinary Portland cement manufactured by Kufa factory was used throughout this investigation. This cement was complied with the IQS No.5/1984 with SO_3 content of 2.25%. Natural sand from Al-Akaidur region was used it complied with IQS No.45/1984 zone 3. The coarse aggregate was Al-Nibaee gravel with a maximum aggregate size of 20mm; this aggregate was complying with IQS No.45/1984 with SO_3 content of 0.06 %. Tap water was used for both mixing and curing of concrete. Gypsum was added to the sand to change the SO3 content. The added gypsum was natural gypsum rock (from Kufa cement factory) which crushed, sifted and graded just like sand. The used gypsum has a 42% SO3 content.

Experimental Work

In the present work, a study of the effect of sulphate contaminated fine aggregate (sand) on some mechanical properties of normal concrete was conducted. One concrete mix was considered and three different levels of SO3 content in sand were investigated, these levels were 3 %, 5% and 7% by weight of sand, then improvement the concrete properties by increasing the percentage of cement content by 3%, 5%, 7% in concrete mixes, which contain sulphate in 3%, 5% and 7% by weight of sand. So, there were three groups of specimens that prepared in this work which as follow:

First group

Standard specimens which do not contain any sulphate and used as a reference in this study, its 9 specimens for each test, termed by (St.).

Second group

Experimental specimens which contain sulphate in 3%, 5% and 7% by weight of sand, it 27 specimens for each test and termed by (Ex1).

Third group

Experimental specimens which contain sulphate in 3%, 5% and 7% by weight of sand, and increased the percentage of cement content by 3%, 5%, 7% to remove the effect of sulphate, termed as Ex2, its 27specimens for each test. The moulds used in this study were as follows:

- (150*150*150) mm cubes to obtain concrete specimens for compressive strength.
- (100*100*400) mm prisms to obtain concrete specimens for flexural Strength.

TESTING OF CONCRETE SPECIMENS

Compressive Strength Test

For the hardened concrete, the compressive strength test was carried out according to BS 1881 part 116:83. All cubes were tested by using a hydraulic compression machine of 2000kN (ELE digital testing machine). All specimens were cured in water until testing age. Each compressive strength value was the average of three specimens.

Flexural Strength Test

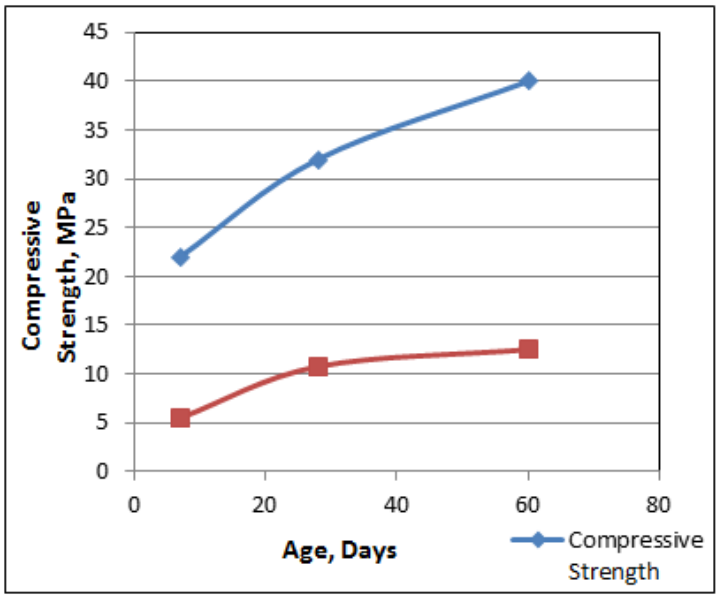

Fig-2: Compressive and Flexural strength as a function of age

This test was carried out according to (BS 1881 part 118:83) procedure using two point load test and calculated from the simple beam bending formula:

$R = PL/bd^2$ …… (1)
Where:
P= max. Applied load (N), L= span length (mm)
b= specimen width (mm), d= specimen depth (mm)

All specimens were cast, molded and cured in as way as the cubes. Each flexural strength value was the average of three specimens.

RESULTS AND DISCUSSION

Compressive Strength Test

- The compaction factor for all mixes has been measured and it was equal to (0.8), this means that the workability was very poor because of low water/cement ratio (W/C) for mixing.
- Fig.(2) shows the development of compressive and flexural strength with age for standard specimens, it has been found that the strengths increased linearly with progressive of the age. This increment in compressive and flexural strength has been attributed to increment in curing period which lead to complete the hydration reactions so, the gel (hydrated calcium silicate) quantities has been increased and for this reason the strength has been increased.
- Fig.(3) shows the effect of different sulphate percentages (3%, 5%, 7%) on concrete strength at different ages of (7, 28, 60) days. From these results it can be seen that the decrease in the compressive strength was by (40-55) % at age of 7days, (43- 60) % at age of 28 days, and by (46-65)% at age of 60 days when the amount of sulphates increased from (3-7)% by wt. of sand.

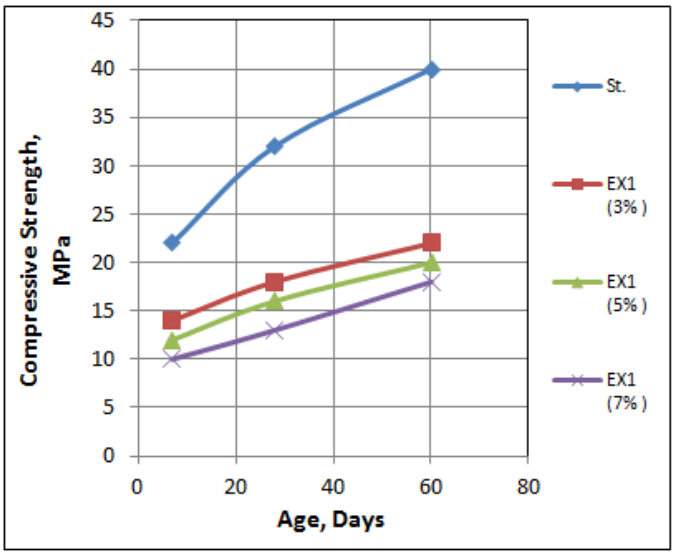

Fig-3: Effect of sulphate on compressive strength as a function of age

Fig (4) shows the effect of different sulphate percentages (3%, 5%, 7%) on concrete flexural strength at different ages of (7, 28, 60) days. From these results it can be seen that the decrease in the flexural strength was by (40-60) % , (15-43)% and by (10-38)% at age of 7, 28 and 60 days respectively, when the amount of sulphates increased from (3-7)% by wt. of sand.

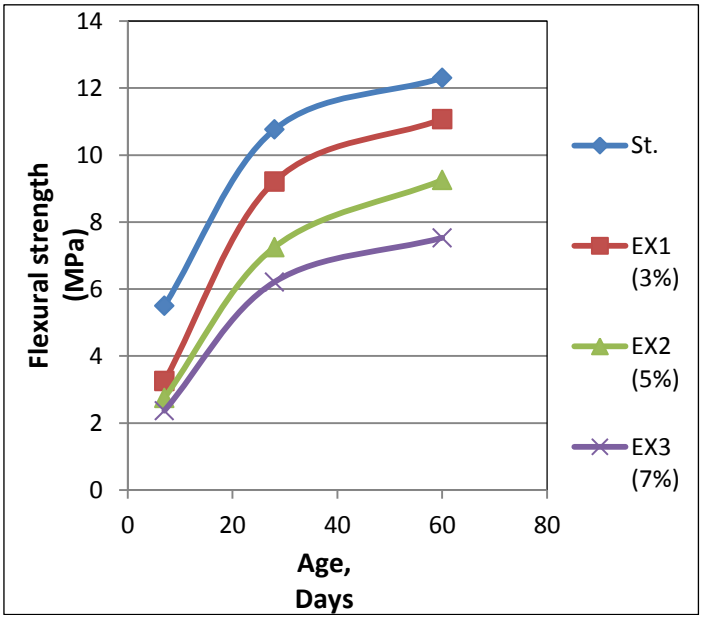

Fig-4: Effect of sulphate on flexural strength as a function of age

This decrement in both compressive and flexural strength has been attributed to the formation of an ettringite at early stage of the reaction between sulphate and C_3A which associated with expansion, ettringite will act as a coating around the grains of cement soon after mixing cement with water acts as a set of retarded in PC mixture:

C3A+ 3(CaSO4. 2 H2O) + 26 H2O C3A. 3CS.H32

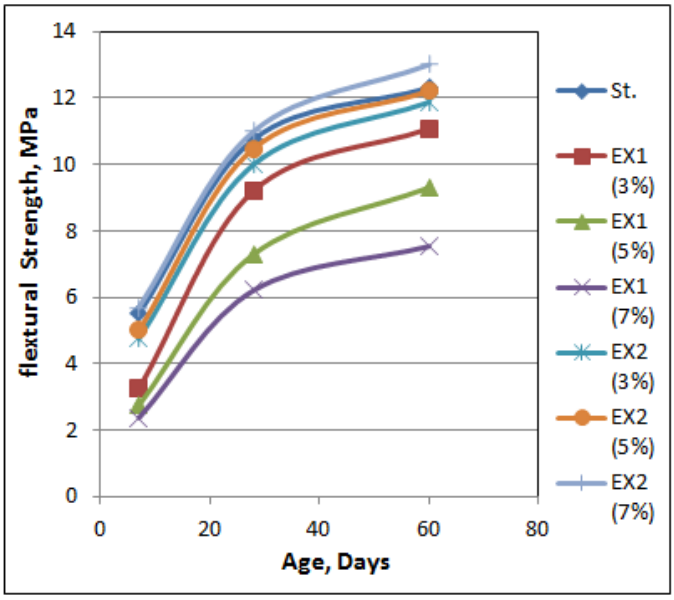

Fig-5: shows the improvement the compressive strength by addition different percentages of cement of (3,5,7)% of cement weight. From

Fig.(4) it can be seen that the addition of 3% cement to the mix which content 3% gypsum the compressive strength will increased to value that exceeded the compressive strength of standard mix. Moreover, this increase in the cement content by (5%, 7%) leads to increase the compressive strength of samples contains gypsum in (5,7)% to approaches the standard values.

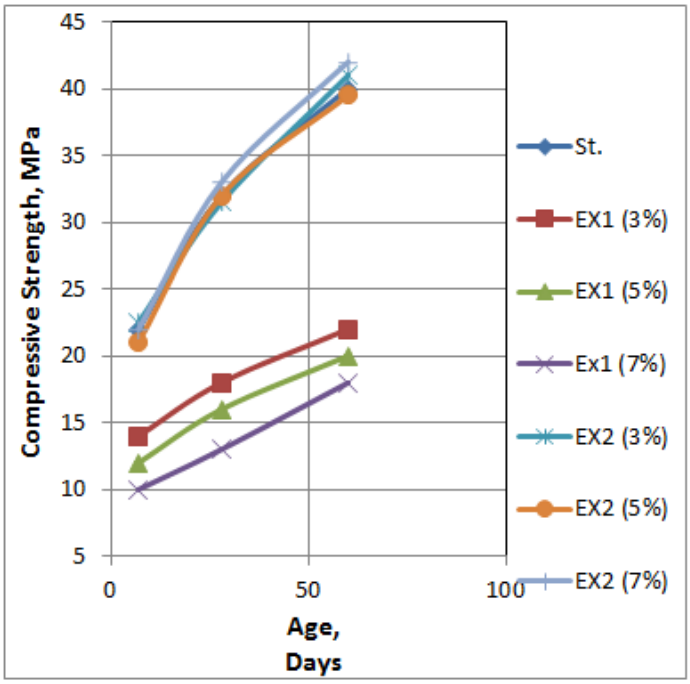

Fig-5: Effect of different percentages of sulphate on compressive strength as a function of age

6-The test results of the 7, 28 and 60 days flexural strength of concrete samples with various percentages of gypsum content in sand with increasing the cement percentages by (3, 5, 7)% are shown Fig.(6). Fig.(6): Effect of different percentages of sulphate on flexural strength as a function of age.

Fig(6) and (5) has been shown that the addition of the cement to concrete mixes that containing sulphate will increased the compressive and flexural strength at all ages and reach the values of standard specimens. The increment in the compressive and flexural strength has been attributed to the increment in the cement percentage for mixing which cause the further

formation of hydration products (gel) which lead to increase both compressive and flextural strengths.

CONCLUSIONS

- When the amount of SO3 increased by (3, 5, 7) % by weight of sand, the compressive strength decreased by (51, 56, 63) % at 7-days.
- When the amount of SO3 increased by (3-5) % by weight of sand, the compressive strength decreases by (41-48) % and by (51-56) % at 28 and 60-days respectively.
- While the decrement was (48-55) % and (56-63) % at 28 and 60-days respectively when the SO3 increased by (5-7) % by weight of sand.
- Increasing the cement percentage by 5% of sand weight, lead to increasing the compressive and flextural strength at all ages and reaches the value of standard specimens when the cement content was 7% of sand weight.

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