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Study and improvement the effect of internal sulphate on properties of normal and light weight concrete

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ABSTRACT

Sulphate attack is a major difficulty which has a local effect on the constructional materials, specially the concrete. Internal sulphate attack takes place due to the source of sulphate being incorporated into the concrete at the period of mixing, while adding gypsum in the cement etc. This project aims to investigate the influence of internal Sulphate Attack (ISA) on some characteristics of light weight (LWC) and normal concrete (NC). In this study, two types of concretes have been prepared, light weight and normal concrete. Two levels of sulphates (3% and 6%) are added as a part of sand to determine the influence of sulphates on NC and LWC that produced a local material and compared it with control normal mix. These added ratios of sulphate are highly convergence of the actual reality of internal sulphate. To decrease the harmful effect of internal sulphate coming from 3 and 6% by weight of sand, two ways have been utilized in this study. First one, using type I cement with 20% of silica – fume as replacement with a part of ordinary cement, second one by SRPC instead of type I is preferred to resist internal effect of sulphate. Light weight concrete has been prepared by total replacement for gravels by crushed bricks. As a result of this research, it concluded that the increment of SO_3 amount caused a decrement in the compressive strength by 43.81% at 90 days and by 33.5 % at 60 days but there is a slight effect appear at 28 for samples consist of OPC with presence of 3% SO_3. When sulphates increased to 6%, compressive strength decreased by 49.3% at 90 day, and by 38.3% at age of 60 days with very slight effect at age of 28 days. Tensile strength of NC follows same the behaviour as that of the compressive strength. For light weight concrete, the reduction in compressive and tensile strength will result from combined effect of the ettringite formation and high porosity due to introducing crushed bricks as total replacement for gravels. LWC was highly effected by sulphate attack even at early ages and it concluded that the increment in the SO_3 amount by (0-3) % by weight of sand, the compressive strength of LWC, decreased by 20.11 % at age of 28 days, 29% at 60 days, while they decreased by 44 % was at 90 days. Using of 20% silica fume with type I cement heals the effect of 3% and 6% calcium sulphate in the A4 and A5 samples and produced a compressive and tensile strength approximately equal to that of control samples. Using of SRPC with 3% and 6% calcium sulphate in the A7, A8, L7 and L8 samples prevented the effect of internal sulphate in both NC and LWC and gave compressive and tensile strength higher than that of standard samples (without sulphate).

Keywords: *Compressive strength, Internal Sulphate, Light weight concrete, Ordinary Portland cement, Normal concrete, Silica fume, Tensile strength*

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1. Introduction

Salts attack concrete when they are existing in solutions, they could be reacting with hydrated cement paste; they do not attack concrete in their solid state. The most popular sulphates that attack concrete are calcium, magnesium, potassium and sodium sulphate. Sulphate attack mechanism involves sulphate ions penetration within concrete structures and their reaction with cement components. Most of the expansion and disruption in concrete structures has been attributed to Ettringite formation. Generally, there are two stages for Ettringite formation, first stage called "early ettringite formation" (EEF) in which ettringite occurs homogenously at early hours of concrete casting, this type of ettringite does not produce any warning to concrete structure. Early ettringite formation has been attributed to the reaction that occurs between gypsum and tri-calcium aluminate as in Eq. (1) [1]

$$C_3A + 3(CaSO_4.2H_2O) + 26H_2O \longrightarrow C_3A.3CS.H32 \quad (1)$$

This type of ettringite does not cause any considerable generalized disruptive effect, it is an act as a retarder for setting process of hydrated cement mixtures. Retardation effect occurs due to the formation of coating surrounding the surface of cement grains immediately after mixing cement with water. This form of ettringite formation also termed as "Primary" ettringite.

The "secondary" ettringite formation stage which termed as "Delay Ettringite formation" (DEF) occurs after several months or even after years. DEF is responsible about the cracking of concrete structures after heat curing temperatures become too high. Ettringite is an expanding product, thermodynamically unstable and when the concrete sets at temperature higher than 158°F, it will be decomposed to give hydrated calcium mono-sulphoaluminate and releasing sulphates in solution, which then tapped on the surface of hydrated calcium silicate (gel) by the mechanism of physical absorption. During the storage or service at ambient temperature and moisture atmosphere, the C-S-H gel start to release the sulphates that tapped on its surface and making them present in solution again. Sulphate ions will diffuse into micro cracks and interact with C_3A inside the crack and produce ettringite (expanding product) which will expand and destroy the concrete members. ISA effect has been presented by the diagram demonstrated in Figure 1 [1, 2].

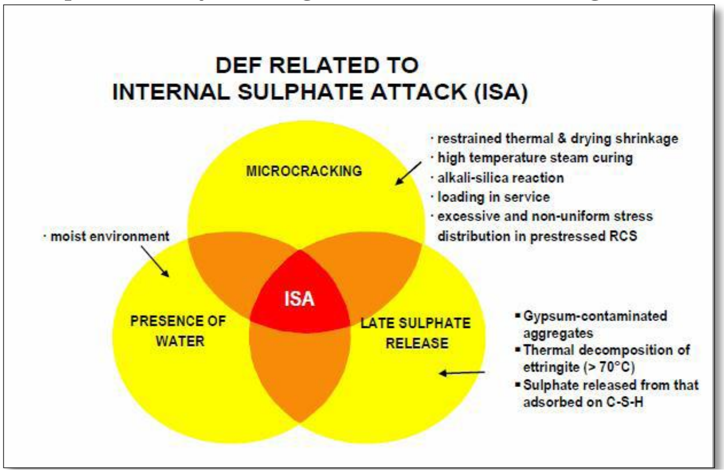


Figure 1. Ternary representation of the DEF associated with ISA [3]

1.1. Utilized materials

Ordinary Portland Cement: Utilized cement conforms Iraqi Specification No.5/1984. Chemical and Physical characteristics are demonstrated in Table 1 and 2.

Table 1. Chemical properties of O.P.C (according to IQS No. 5/1984)

Compound	Chemical Name	Test Results %	IQS No. 5/1984
Lime	CaO %	60.14	-
Silica	SiO_2 %	19.77	-
Alumina	Al_2O_3 %	4.38	-
Iron Oxide	Fe_2O_3 %	5.20	-
Sulphate	SO_3 %	2.15	≤ 2.8
Magnesia	MgO %	1.71	≤ 5
Free Lime	Free CaO %	1.12	-
Loss On Ignition	L.O.I. %	3.19	≤ 4
Insoluble Residue	I.R. %	1.23	1.5
Lime Saturation	L.S.F.	0.95	0.66 – 1.02
Main Compounds	Percent by weight of cement		
Tricalcium Silicate	C_3S	57.47	-
Dicalcium Silicate	C_2S	12.55	-
Tricalcium Aluminates	C_3A	6.06	-
Tetracalcium Alumino Ferrite	C_4AF	10.83	-

Sulphate Resistance Portland Cement: SRPC manufactured by Al-Kufa factory has been utilized in this study, this cement confirms Iraqi Specification No.5/1984 with SO3% content of 1.9%. Chemical characteristics of SRPC are demonstrated in Table 3.

Table 2. Physical properties of O.P.C (according to IQS No. 5/1984)

Physical Properties	Test Results	IQS No. 5/1984
Setting Time (Vicat's Method)	101 250	≥45 min ≤600 min
Fineness (Blaine Method),m2/kg	300	≥230 m2/kg
Compressive Strength, MPa 3 days 7 days	 19.6 30.4	 ≥15, MPa ≥ 23, MPa

Table 3. Chemical properties of SRPC (according to IQS No. 5/1984)

Compound	Test Result %	IQS No. 5/1984
SiO_2 %	20.17	-
CaO %	60.91	-
MgO %	1.37	≤ 5
Fe_2O_3 %	5.28	-
Al_2O_3 %	4.23	-
SO_3 %	1.9	≤ 2.5
L.O.I. %	3.64	≤ 4
Free Lime	2	≤ 4
Insoluble Materials %	1.07	≤ 1.5
L.S.F	0.82	0.06 – 1.02
C_3S%	55.47	-
C_2S%	24.3	-
C_3A%	2.28	≤ 3.5
C_4AF%	17.03	-

1.2. Coarse aggregate

Utilized gravel obtained from Al-Nibai quarry, with (20 mm) maximum size and 2.65 specific gravity. This aggregated complying Iraqi Standard No. 45/1984. Grading, chemical, and physical characteristics of coarse aggregate utilized in this study have been listed in Tables 4. and 5. Figure 2. demonstrated coarse aggregate grading curve.

Table 4. Grading of Coarse Aggregate (IQS No.45/1984)

Sieve (mm)	Passing %	IQS No. 45/1984
37.5	100 %	100 %
20 mm	98.54 %	95 % – 100 %
10 mm	45.48 %	30 – 60 %
4.75 mm	1.96 %	0 – 10 %

Table 5. Properties of Coarse Aggregate (IQS No.45/1984)

Physical Properties	Test Results	IQS No. 45/1984 for Zone II
Specific Gravity	2.65	-
Sulfate Content	0.10 %	≤ 0.1%
Absorption	0.5 %	-
Clay Content	0.14 %	≤ 3%

1.3. Fine aggregate

Natural sand utilized in this study has been obtained from Al – Ukhaider quarry with the maximum size of 5mm. Table 6. demonstrated grading of fine aggregate and Table 7. demonstrated chemical and physical characteristics of sand which comply with Iraqi Specification No.45/1984, figure 3. illustrated sand grading.

Table 6. Grading of Fine Aggregate (IQS No.45/1984)

Sieve Size	Passing %	IQS No. 45/1984 for Zone II
10 mm	100	100
4.75 mm	98.58	90 – 100
2.36 mm	84.5	75 – 100
1.18 mm	72.08	55 – 90
600 µm	36.83	35 – 59
300 µm	9.92	8 – 30
150 µm	8.67	0 – 10

Table 7. Properties of Fine Aggregate (IQS No.45/1984)

Properties	Test Results	IQS No. 45/1984 for Zone II
Specific Gravity	2.60	-
(SO_3) %	0.28	≤ 0.5%
Absorption %	0.75	-
Clay Content %	3.67	≤ 5%

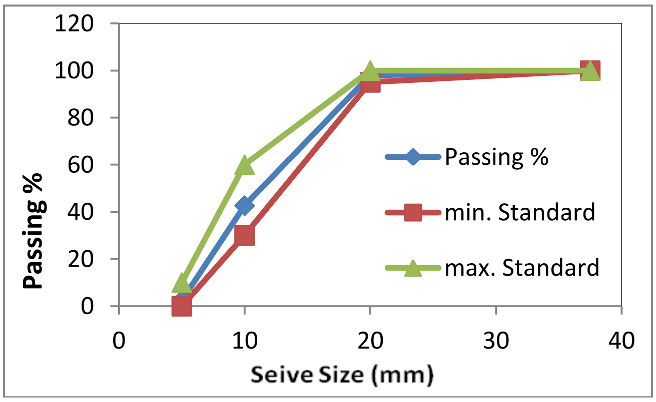


Figure 2. grading curve of coarse aggregate

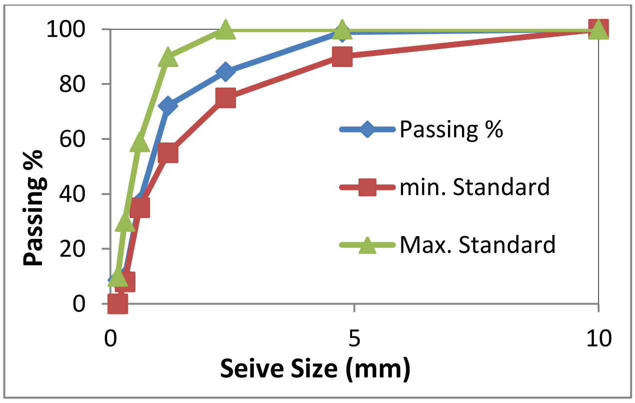


Figure 3. Grading of fine aggregate

1.4. Silica fume

Table 8. and 9. demonstrated the characteristics of silica fume that was utilized in this study.

Table 8. chemical analysis of Silica Fume

Oxide Composition	Oxide Content %	ASTM C1240-05 Limitations
SiO_2	89.16	> 85
$A1_2O_3$	0.36	-
Fe_2O_3	1.16	-

Oxide Composition	Oxide Content %	ASTM C1240-05 Limitations
Na_2O	0.05	-
K_2O	0.07	-
CaO	1.25	-
MgO	2.45	-
SO_3	0.9	-
L.O.I.	3.8	< 6.0
Moisture content	0.8	< 3.0

Table 9. Physical properties of Silica Fume

Physical Properties	Test Result	ASTM C1240-05 Limitations
Percent retained on 45µm (No. 325) sieve, maximum. %	7	≤ 10
Accelerated Pozzolanic Strength Activity Index with Portland cement at 7 days, minimum. %	125.6	≥ 105
Specific Surface, minimum, (m^2/g)	21	≥ 15
Color	Gray powder	

Gypsum: Gypsum has 43% SO_3, it is utilized in this study as a source for calcium sulphate. The added gypsum was a natural gypsum rock obtained from Al-Kufa cement factory.
Recycled Coarse Aggregate: Crushed bricks were utilized as a recycled aggregate. It is cleaned, crushed and graded just like gravels
Mixing Water: In this study, tap water has been utilized for mixing and curing.

2. Material and method

In the present study, in order to study the effect of sulphate on the characteristics of concrete, concrete samples were prepared with selective mix proportions of 1:1.5:2.5 by weight and water/cement ratio of 0.45 by weight. The prepared models aged at 28, 60 and 90 days by using tap water at room temperatures. Specimens were prepared for mechanical tests in forms of (150*150*150 mm cubes) to obtain samples for compressive strength, (300*150 mm cylinder) to obtain samples for splitting strength. Proportions of normal concrete and light weight concrete mixes are summarized in Table 10.

Table 10. Mix proportions of normal and light weight concrete

Normal Concrete							Light Weight Concrete						
Mix	OPC Kg/m^3	SRPC Kg/m^3	Sand (Kg/m^3)	Gravels (Kg/m^3)	SO_3 %	Silica Fume %	Mix	OPC Kg/m^3	SRPC Kg/m^3	Sand Kg/m^3	Crushed Bricks Kg/m^3	SO_3 %	Silica Fume %
A1	480	0	720	1200	0	0	L1	480	0	720	461	0	0
A2	480	0	698.4	1200	3	0	L2	480	0	698.4	461	3	0
A3	480	0	676.8	1200	6	0	L3	480	0	676.8	461	6	0
A4	384	0	698.4	1200	3	20	L4	384	0	698.4	461	3	20
A5	384	0	676.8	1200	6	20	L5	384	0	676.8	461	6	20
A6	0	480	720	1200	0	0	L6	0	480	720	461	0	0
A7	0	480	698.4	1200	3	0	L7	0	480	698.4	461	3	0
A8	0	480	676.8	1200	6	0	L8	0	480	676.8	461	6	0

2.1. Compressive strength test
For the hardened concrete, compressive strength test was carried out according to BS 1881 part 116:1983. All cubes were tested by using a hydraulic compressive machine of 2000kN (ELE digital testing machine). All specimens were cured in water until testing age. Each compressive strength value was an average of three specimens [4]
2.2. Splitting Tensile Strength:
The splitting tensile strength was resolute according to the procedure outlined in BS 1881 part 117:1983. Cylinders were cast, molded and cured in a similar way as the cubes. Each value was average of three specimens for each age [5].
2.3. Workability
Slump was performed on fresh concrete according to BS 1881 part 102, 1983[6].

3. Results and discussion
3.1. results of fresh concrete
Table 11 revealed slump test values for normal and light weight concrete. For normal concrete, slump for all mixes has been measured and it was in range of (60 – 65 mm), this meant that workability was in medium level because of low water/cement ratio (W/C = 0.45) for mixing, except sample A4 and A5 that consist of (OPC + 3% SO_3 + 20% silica fume) and (OPC + 6% SO_3 + 20% silica fume) respectively exhibited low slump values. Low values of slump in samples A4 and A5 may be attributed to the effect of pozzolanic material (Silica fume). Water demand increased with addition of silica fume. Addition of silica fume to normal concrete mixes lead to decrease slump value but produce more cohesive mixes and have very high dense packing zones [3, 7].Silica fume makes the fresh concrete sticky in consistency, hard to handle and it reduced concrete bleeding. Generally, micro-silica acts as lubricated materials in cement paste unified without any segregation but decreased slump because of its high surface area which demands high water content, for this reason, samples A4 and A5 will have low workability as illustrated in figure 4 a [2].While LWC, as compared with NC, it has lower slump values, this behavior has been attributed to high porosity of crushed bricks which increased water demand and produce arid mixes. High concrete porosity consumed all mixing water and made the crushed bricks saturated with water, consequently poor adhesion zone between cement paste and aggregate has been generated, for this reason the produced mix has low workability. Samples L4 and L5, have high workability values, addition of 20% silica fume as a percent of cement weight improves workability of LWC. Large pores of LWC have been occupied with silica fume which acts as densely packed system (DPS) and then low porosity mix with suitable constancy without segregation has been produced. Figure 4b illustrated slump behavior of LWC [7].

Table 11. Slump values of NC and LWC

Normal Concrete		Light Weight Concrete	
Samples	Slump, mm	Samples	Slump, mm
A1	60	L1	55
A2	63	L2	54
A3	64	L3	55
A4	48	L4	91
A5	50	L5	90
A6	65	L6	57
A7	64	L7	55
A8	64	L8	56

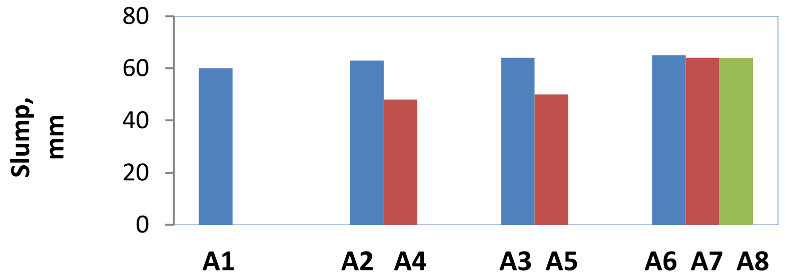


Figure 4 a. Slump test of normal concrete mixes

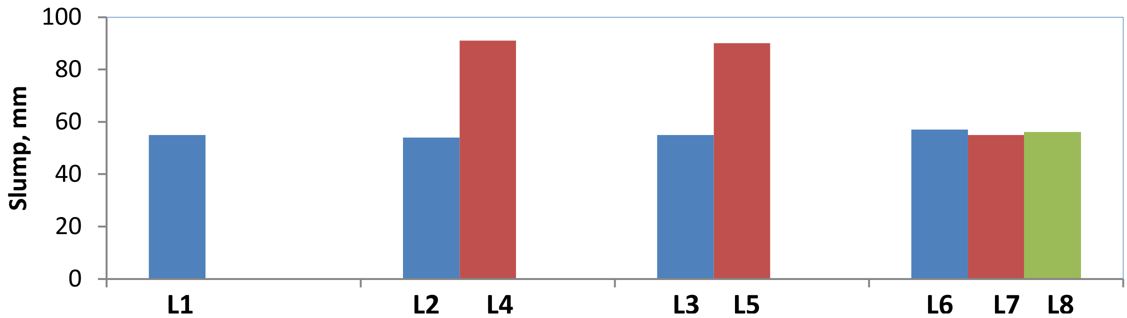


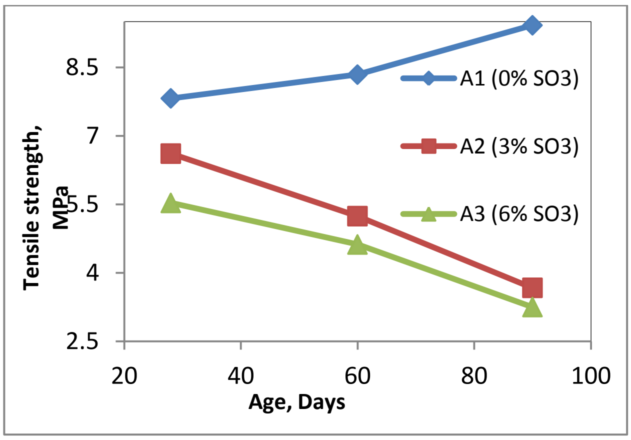
Figure 4 b. Slump test of light weight concrete mixes

3.2. Results of hardened concrete

Table 12 demonstrated values of mechanical strengths for normal and light weight concrete at different curing ages. Figure 5 demonstrated how compressive strength has been decreased with increasing SO_3 percent and progression of age. When sulphate percent increased from (0 – 3) %, reduction in compressive strength was 7% at 28 day, 33.5% at 60 day and 43.81% at age of 90 day. When sulphate percent increased from (0 – 6) %, the reduction in compressive strength was 3.6% at 28 day, 38.3% at 60 day and 49.3% at age of 90 day.

Table 12. Compressive and tensile strength of normal and light weight concrete

Normal Concrete							Light weight concrete						
Mix / Days	Compressive Strength, MPa			Splitting Tensile Strength, MPa			Mix / Days	Compressive Strength, MPa			Splitting Tensile Strength, MPa		
	28	60	90	28	60	90		28	60	90	28	60	90
A1	30.5	38.2	42	7.82	8.34	9.42	L1	23.42	24.76	27.81	3.60	4.40	5.70
A2	28.3	25.4	23.6	6.61	5.24	3.67	L2	20.62	19.14	17.33	3.5	2.76	1.94
A3	29.4	23.6	21.3	5.53	4.62	3.25	L3	18.76	17.63	15.51	3.2	2.41	1.42
A4	34.1	36.2	43	7.63	8.52	9.41	L4	27.15	31.39	34.21	4.23	6.46	7.82
A5	35	38.3	44.2	7.74	8.62	9.56	L5	24.78	28.12	30.50	4.63	6.32	7.91
A6	31	33.1	46	7.88	8.78	8.84	L6	22.21	23.31	25.50	4.00	5.51	5.97
A7	30.2	32.6	46.5	7.52	8.35	8.89	L7	22	24.28	25.29	4.11	5.60	6.02
A8	30.6	33	46.4	7.29	8.77	9.32	L8	22.71	23.63	26.11	4.12	5.62	6.13



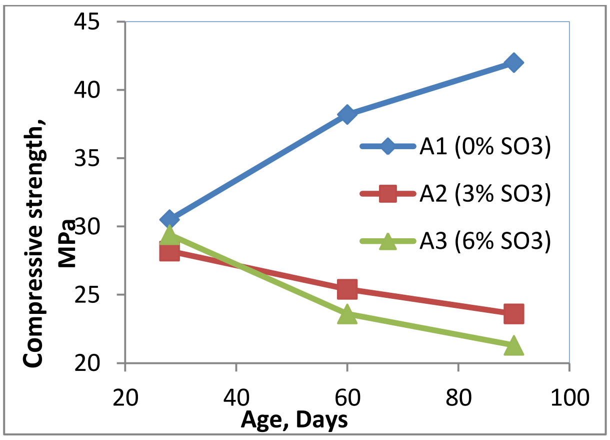


Figure 5. Effect of 3% and 6% SO_3 on compressive Figure 6. Effect of 3% and 6% SO_3 on Splitting

Strength of normal concrete as a function of age. Tensile strength of normal concrete as function of age.

Tensile strength behavior of normal concrete mixes is illustrated in figure 6. The obtained results revealed that the tensile strength continuing reduction at all ages. When sulphate percent increased from (0 – 3) %, reduction in tensile strength was 15.5% at 28 day, 37.2% at age of 60 day and 60.2 % at age of 90 day. This reduction in both tensile and compressive strength of normal concrete has been attributed to combined effect of sulphate attack reactions. First sulphate reaction came from interaction between SO_3 from gypsum with tri-calcium aluminate (C_3A) in through solution, secondary ettringite resulting from this reaction which it an expanding product combined by volume increasing of 227% and then produce cracking and spilling [1, 7]:

$C3A + 3(CaSO_4 . 2 H_2O) + 26 H_2O \longrightarrow C3A. 3CS.H32$

Hydrate lime (Ca $(OH)_2$) is one of hydration products generated in concrete throughout hydration process of tri-calcium silicate and di-calcium silicate. Second sulphate attack established by the reaction of calcium hydroxide (Ca $(OH)_2$) with SO_3 leading to gypsum formation with volume increasing was 124% which eventually caused concrete cracking and splitting because of its expanding nature. Secondary ettringite which formed after several months (DEF) reached its peak at 90 day and up wards and it is not understandable at early ages, because it is a very slow reaction and sometimes appears after one year and more [8]

Light weight concrete produced by introducing porous low weight aggregate of low apparent specific gravity. Crushed bricks have been utilized as a total replacement for gravels. Figure 7a demonstrated compressive strength of NC and LWC. The decrease in the density of the concrete may be attributed to the presence of voids in crushed bricks and in the interstices between crushed bricks particles [7, 9]. For this reason, the existence of these voids decreased the compressive strength of light weight concrete in sample L1 as compared with normal concrete A1. Figure 7b illustrated the comparison between tensile strength of NC and LWC.

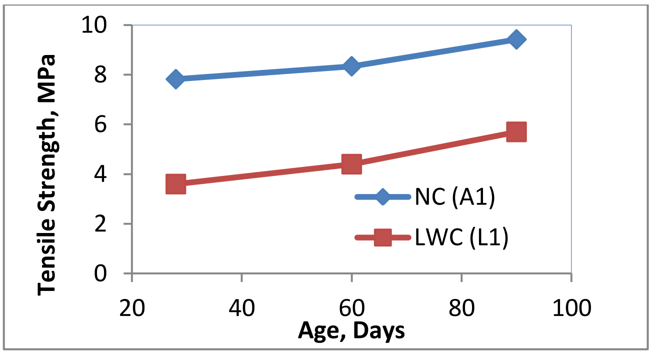


Figure 7b. relation between tensile strength of NC and LWC

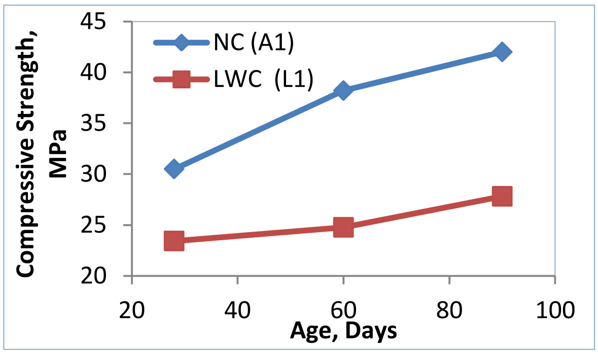


Figure7a. Relation between compressive strength of NC and LW

Figure 8 revealed sulphate attack on the compressive strength of LWC, When SO_3 percent increased from (0-3%), the reduction in compressive strength was 13.6% at 28 day, 23% at 60 day and 38% at 90 day. Increasing sulphate percent from (0-6%) cause strength reduction of 20.11% at 28 day, 29% at 60 day and 44% at age of 90 day. Figure 9 illustrated sulphate effect on the tensile strength of LWC, which followed the same behavior as compressive strength. This reduction in mechanical characteristics may be due to ettringite formation which then diffused through the voids present in crushed bricks and between crushed bricks and mortar eventually caused micro-cracking and splitting of concrete constructions. Such micro-cracks occur as a result of differential changes in volumes between cement paste and crushed bricks [7, 9].

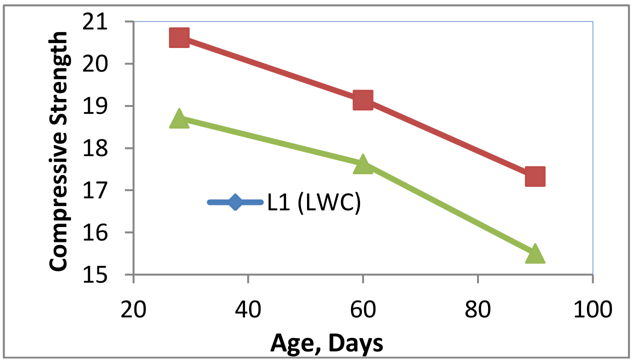


Figure 8. Effect of 3% and 6% SO3 on compressive

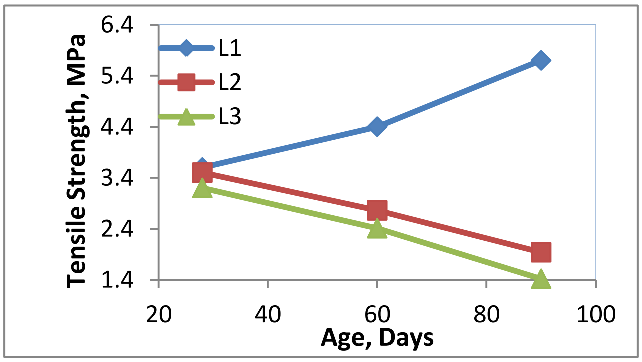


Figure 9. effect of 3% and 6% SO3 on Splitting

Strength of LWC as a function of age. Tensile strength of LWC as function of age.
Calcium hydroxide Ca $(OH)_2$ or as called "hydrate lime" formed in concrete as one of hydration products, it's percent will increase highly after the addition of gypsum, it is an expanding product and it is one of main causes for ettringite formation, so reducing the proportion of this compound is an essential factor to overcome ettringite formation and increase mechanical strength of concrete. To diminish the amount of Ca $(OH)_2$ in concrete and to overcome its bad effects by converting it into cementitious product is an improvement on the technology of concrete [10].
In this study, silica fume has been utilized as a pozzolanic materials which reacts with the calcium hydroxide to form highly stable cementitious compound of complex composition including water, calcium and silica (hydrated calcium silicate or gel); reaction could be placed as following: Water + Calcium Hydroxide+ Pozzolan $\longrightarrow$ $C_3S_2H_3$ (Gel)
This reaction is called a pozzolanic reaction. The distinctive aspect of pozzolanic reaction is slow at the first, with the result that heat of hydration and strength progress will be consequently slow. The reaction involves the consumption of Ca $(OH)_2$ and not the production of Ca $(OH)_2$ [10, 11]. The decrement of Ca $(OH)_2$ increase the concrete durability mixes by making the concrete dense and impervious.

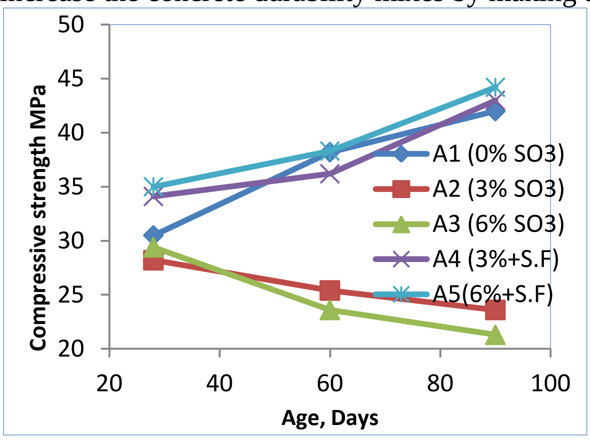


Figure 10. Effect of 20% silica fume on compressive strength of NC

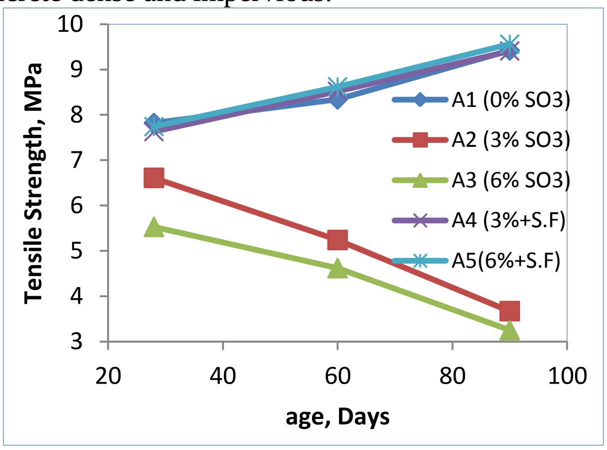


Figure 11. Effect of 20% silica fume on tensile strength of NC

Silica fume has been utilized in samples A4 and A5 to overcome the negative effect of sulphate, A4 heals the disruptive that occurs in sample A2 due to presence of 3% SO_3, A5 heals disorderly that occurs in sample A3 due to presence of 6% SO_3. Figure 10 and 11 demonstrated the effect of 20% wt. of silica as a partial replacement by cement weight on strengths of NC, it can be seen from this figures that using of silica fume leads to increase the strength in A4 and A5 and reached to that of the standard one. The increment in compressive and tensile strength has been attributed to the pozzalanic effect when the silica fume will possess cementitious value in the presence of water.

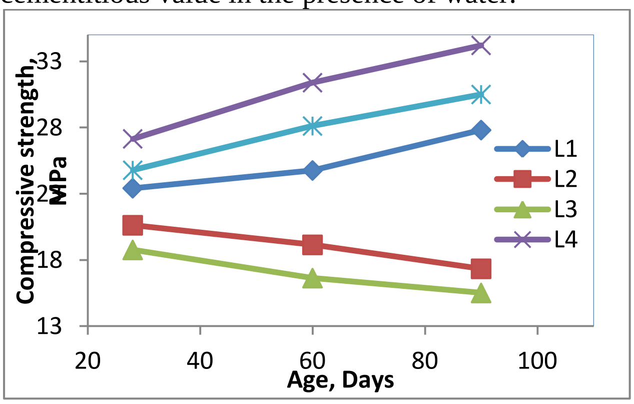


Figure 12. Effect of 20% silica fume on compressive strength of NC

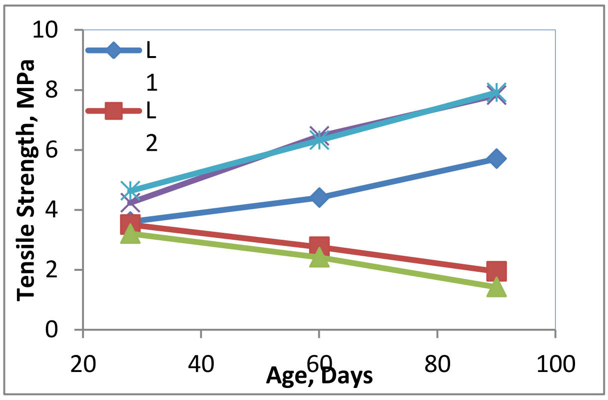


Figure13. Effect of 20% silica fume on tensile strength of NC

For light weight concrete, incorporation of silica fume in L4 and L5 increased mechanical strengths at all ages, silica fume has been consumed all hydrated lime by reacting with it and produces hydrated calcium

silicate which then fills the cavities between crushed bricks and these between bricks and mortar, consuming calcium hydroxide which is the essential cause for ettringite formation also produce a strong mixes although of presence of high sulphate percent [10, 12].
In addition to silica fume, SRPC has been utilized to improve the effect of SO_3. The using of SRPC with 3% and 6% calcium sulphate in the A7, A8 in NC and L7, L8 in LWC samples prevent the effect of internal sulphate and produces compressive and tensile strength higher than that of standard samples for both NC and LWC.
Enhancement in mechanical strength of NC and LWC achieved by silica powder might be attributed to the reaction of silica fume with hydrate lime to form hydrate calcium silicate (one of hydration product), which consequently fills the capillary pores between hydrated cement paste and concrete component [13].

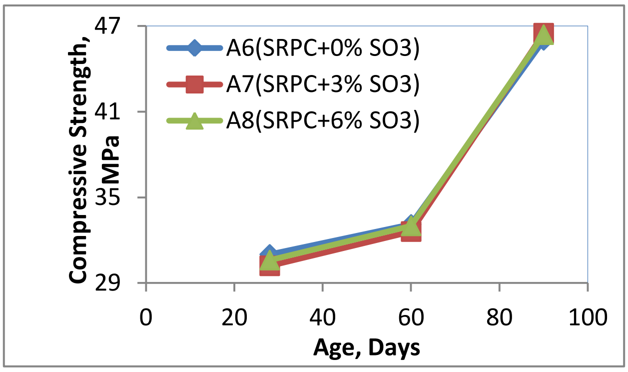


Figure14. Effect of 3% and 6% calcium sulphates on compressive

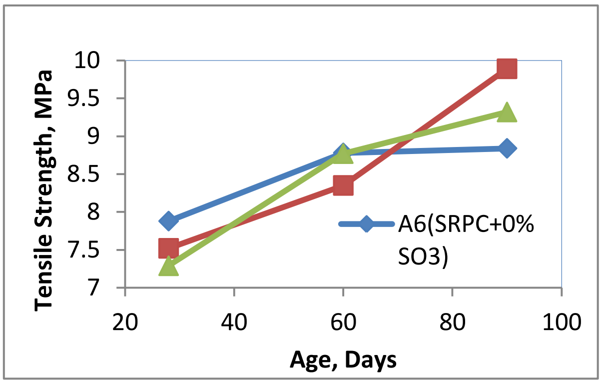


Figure15. effect of 3% and 6% calcium sulphates on tensile

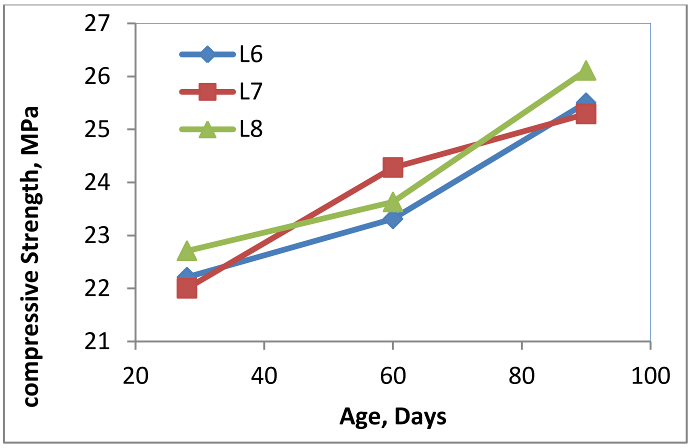


Figure 16. Effect of 3% and 6% calcium sulphates on compressive

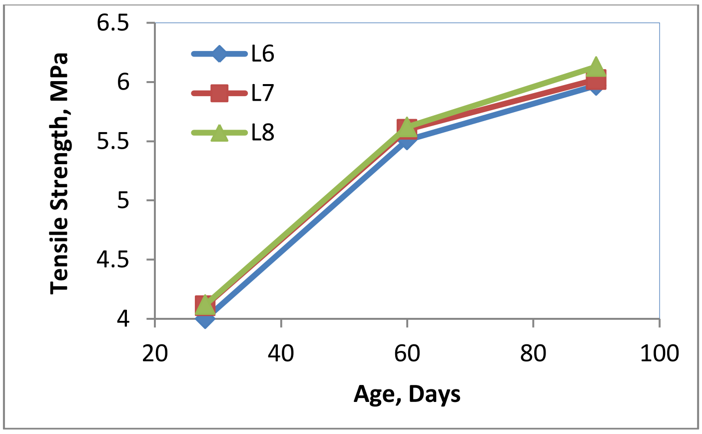


Figure 17. Effect of 3% and 6% calcium sulphates on tensile

4. Conclusions

Increasing sulphate percent up to 6% decreased tensile strength and compressive strength at later ages (28 days and more) for both NC and LWC.

Early Ettringite Formation (EEF) is very important product utilized as a retard for setting time of cement paste at early ages, while Delayed Ettringite Formation (DEF) can generate cracking and spilling in concrete after months.

Workability of NC was in the medium level because of low water/cement ratio which equal to 0.45, while LWC has low slump value due to bad packing between mortar and high porosity crushed bricks.

Presence of 3% SO_3 in NC leads to decrease the compressive strength by 7% at age of 28 days, 33.5% at 60 days and by 43.8% at age of 90 days. Further sulphate increasing cause further strengths reduction, so when sulphate percent becomes 6%, compressive strength of NC decreased by 3.6% at 28 days, by 38.3% at 60 days and by 49.3% at age of 90 days.

Existence of 3% SO_3 in LWC cause decreasing the compressive strength by 13 % at age of 28 days, 23% at 60 days and by 38% at age of 90 days. Further sulphate increasing cause further strengths reduction, so when sulphate percent becomes 6%, compressive strength of LWC decreased by 20.11% at 28 days, by 29% at 0 days and by 44% at age of 90 days.

Tensile strength in both NC and LWC follows the same behaviour as that of compressive strength with sulphate percent’s increasing.

Adding silica fume as percent of cement weight to 20% improved compressive strength by about 45.11% and tensile strength by 61% in NC samples which contains 3% SO_3. Compressive strength of NC samples contain 6% sulphate has been improved by 51.8% at age of 90 days and tensile strength improved by 66% after addition of silica fume. While addition of silica fume to LWC improved both compressive strength and tensile strength by 49% and 75% respectively in samples containing 3% sulphate at age of 90 days.

SRPC has been utilized to improve the effect of SO_3. Using of SRPC with 3% and 6% calcium sulphate prevents the effect of internal sulphate and produces compressive and tensile strength higher than that of standard samples for both NC and LWC.

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