

OPTIMUM COMPONENTS AND PROPORTIONS FOR SELF COMPACTING CONCRETE IN SULFATES ENVIRONMENT

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The purpose of this paper was to know more about self-compacting concrete (SCC) in sever sulfate environment compared with its reference vibrated concrete (VC) with similar mixes proportions of SCC for different ages up to 400 days. Such tests can be more reliable in evaluating emerging concrete types such as self consolidating concrete (SCC). Several applications of SCC involve its exposure to both freezing–thawing cycles and chemical attack, particularly to sulfate-rich media.

Sixteen mixes of SCC and VC were therefore made with the same raw materials with changing some factors in the mix such as: cement content, coarse to fine aggregates proportions, coarse aggregate size, coarse aggregate type and cement type. After 28 days of potable water curing, a standard compressive tests was carried out for all samples of both SCC and VC then they were immersed in sodium sulfates solution with 5% concentration according to (ASTMC 1012). The specimens were cyclically exposed to 5% Na₂SO₄ solution and air every alternate 5 days after 28 days curing by potable water. Age factor till 400 days have been also considered in this research. In addition, fresh properties of SCC and VC are recorded for all concrete mixes. The results of this research show that the compressive strength for SCC mix gave a significant reliable results compared with VC where all subjected to a cyclic immersion in 5% sodium sulfates. However, more factors in the component of SCC mixes. Factors such as cement content and type, aggregate type, size and ratio and powder type were studied for SCC component.

Results indicated that SCC exhibited more residual strength compared with VC especially utilizing high cement content of Sulfate Resistance Cement (SRC) type, basalt as coarse aggregate, with maximum nominal size 10 mm with ratio coarse to fine aggregate (C/F) =0.35:0.65 utilizing Silica Fume (SF) type in addition to superplastisizer and viscosity enhancement admixture VEA.

KEYWORDS: *Self-compacting concrete; Sulfate attack; Durability; Aggregate type; Compressive strength; Residual strength.*

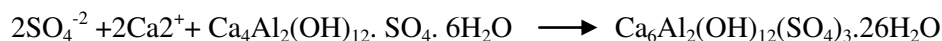
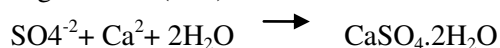
INTRODUCTION

This study concerns the durability of self-compacting concrete (SCC). Since its first use in Japan at the end of the century, SCC has been increasingly used in ready-mixed concrete and in the precast industry to improve several aspects of construction. SCC is

expected to replace vibrated concrete (VC) in many applications in the long term because of its various advantages: reduction of the harmful effects of sound in urban environments, possibility of pouring in strongly reinforced places or with complex geometry, and reduction in the industrial process costs [1]. But some questions remain unanswered, for example: is SCC as durable as VC, especially in terms of physicochemical durability, at the same level of compressive strength?. The few results available [2–4] partly answer this question but they usually concern high-performance concrete (HPC). Few studies provide results on SCC with low or average compressive strength [5]. This research program was therefore set up to study concrete with a compressive strength of about 20–70 MPa. The main goal of the project was to compare the durability properties of SCC and VC with equivalent compressive strength. The properties studied were those recommended by the French Association of Civil Engineering for evaluation and prediction of reinforced concrete durability by means of durability indicators [6].

The behaviour of self-compacting concretes, in relation to the water absorption by capillarity, represented by the sorptivity coefficient (one of the parameters used to foresee durability) is equal or better than the one of a normal concrete compacted by vibration.

The addition of fly ash, used in this work, resulted in a better performance of the self-compacting concrete appraised through the water absorption by capillarity. The same additive mixed with hydraulic lime also improved the concrete performance at the age of 28 days. The silica fume, a more expensive additive, imparts in the self-compacting concrete a similar behaviour to the one of normal concrete compacted by vibration. Apparently this behaviour is caused by an incompatibility between the silica fume and superplasticiser requiring an increase of water/cement ratio for the same concrete workability. 21 Dissolved sulfate salts can enter into chemical reactions with cement-based materials causing expansion, cracking and spalling, and/or softening and disintegration. Hence, the action of sulfates on concrete has been a key durability issue, and a subject of extensive investigation for many decades [7]. The classical form of sulfate attack involves alkali sulfates such as sodium sulfate (Na_2SO_4), which reacts with portlandite (CH) and monosulfate and unreacted C3A to form gypsum (C-S-H) and ettringite (C-A-S-H), which can cause expansion, cracking, and deterioration of concrete. Yet, the exact mechanism of expansion and the role of gypsum and ettringite in the deterioration process remain subjects of controversy [8]. Santhanam [9] pointed out the role of gypsum formation in the expansion and deterioration of cementitious matrices under external sulfate attack. Brown and Taylor [10] reviewed the mechanisms (topochemical growth, through-solution reactions, oriented crystal growth, etc.) by which ettringite can cause disruptive pressures in cement-based materials. Migration of $(\text{SO}_4)^{-2}$ ions into concrete causes the following chemical reactions



Self-consolidating concrete (SCC) readily flows and consolidates under its own weight with little or no vibration. It is particularly suitable for precast applications, hard-to-reach areas and heavily reinforced sections. The mixture design of SCC usually incorporates an efficient superplasticizer, relatively high amounts of

fine materials, low water-to-powder materials and Structures ratio, and controlled proportions of coarse aggregates with adequate particle size and gradation. Viscosity modifying admixtures can be used in SCC to enhance stability of the flowable material and inhibit segregation and bleeding [11]. Hence, the fresh properties and rheological characteristics of SCC are different than that of normal concrete, but both SCC and normal concrete may exhibit comparable mechanical properties if designed for similar strength grades. Yet, due to the difference in mixture design, placement and consolidation techniques, the durability of SCC may be different than that of normal concrete, and thus needs thorough investigation [12, 13]. Persson [14] investigated the resistance of SCC to a solution of 1.8% Na_2SO_4 at a temperature of 5°C up to 900 days. The SCC concrete mixtures incorporated a cement content of 409–427 kg/m^3 , high amounts of limestone filler (94–375 kg/m^3), water-to-cement ratio (w/c) of 0.39 and entrained air content of 5–8%. Some SCC mixtures immersed in the Na_2SO_4 solution suffered significant mass loss without a corresponding decrease in internal fundamental frequency. This was ascribed to the mixing sequence since limestone filler was introduced last during the mixing stage, which may have caused inadequate dispersion of limestone particles in the matrix. Therefore, loose limestone particles at the concrete surface were in direct contact with the sulfate solution leading to surface scaling [14]. Nehdi et al. [15] evaluated the sulfate resistance (ASTM C 1012 Standard Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution) of environmentally efficient SCC prepared with high-volume replacement binary (two component), ternary (three component) and quaternary (four component) composite cements and water to cementitious materials ratio (w/cm) of 0.38. Bars of mortar extracted from SCC mixtures were immersed in a 5% Na_2SO_4 solution to observe the length change with time for 9 months. It was observed that quaternary SCC mixtures made with 50% OPC, 24% Class F fly ash or slag, and 6% silica fume or rice husk ash had the lowest expansion compared to that of other mixtures [15].

EXPERIMENTAL PROGRAM

A total of sixteen different concrete mixes for both (SCC) and (VC) which represent the main parameters of this research, were tested to study the resistance of sulfate attack (5% sodium sulfate solution) for both (SCC) and (VC) by measuring compressive strength at different ages definitely, 28, 50, 100, 200, 300 and 400 days. In addition, these mixes were tested after 28 days to show their standard compressive strength. Details of their respective mix design are given in detail in Table 2. Each mix had the following parameters mixed in different proportions:

- a) Cement type: Ordinary Portland Cement and Sulfate Resistance Cement (OPC, SRC) and cement content: (380 to 480 kg/m^3)
- b) Water/cementitious materials (cement + fine powder) ratio: (0.27 to 0.57)
- c) Type of coarse aggregate (gravel, basalt and dolomite)
- d) Nominal size of coarse aggregate (10 mm and 19mm)
- e) Coarse/Fine aggregate ratio (C/F): (65%:35%), (50%:50%), (35%:65%)
- f) Binder type: Lime Stone Powder (LSP) and Silica Fume (SF) with ratios: (0%:25%), (12.5%:12.5%), (25%:0%) respectively.
- g) Concrete age considered till 400 days (28, 50, 100, 200, 300 and 400 days).

MATERIALS

Type of cement used was normal Portland cement and sulfate resistance cement SRC (specific gravities: 3.15, 3.17 respectively). The fine aggregate was river sand (specific gravity: 2.61, water absorption: 1.61%, FM: 2.51). Three types of coarse aggregates had been used (gravel, basalt and dolomitic crushed limestone) with nominal maximum sizes of 19 mm, a crushing strength of 4%, 9, and 8% and specific gravity of 2.69, 2.64 and 2.70 respectively. The specific gravity of silica fume and lime stone powder were 2.15 and 2.68 respectively and its chemical proportions was shown in Table (1). F type of high range water reducers (HRWR) superplasticizers based on polycarbocylate was used according to ASTM C494. The type of segregation reducing agent or viscosity enhancement admixture VEA was acrylamide by weight of cement.

Table (1) Chemical compositions of SF and LSP

Powder type	Percentage of SF and LSP chemical structure														
	SiO ₂	C	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	Na ₂ O	R ₂ O ₃	K ₂ O	SO ₃	Cl	LOI	TiO ₂	CaCO ₃	MgCO ₃
Silica fume SF	96.0	0.6	0.25	0.6	0.3	0.6	0.2	-	0.65	0.18	0.02	0.6	-	-	-
Lime stone LSP	7	-	2.53	1	48.77	1.15	0.5	-	-	0.19	-	38.86	-	-	-

EXPERIMENTAL PROCEDURE

All mixing process were carried out in a room having an ambient temperature of 20±5 C° and a relatively humidity of not less than 50%. The concrete batches were mixed in a 50 liter pan-type revolving paddle mixer. Before the rotation of the mixer started, both coarse aggregate and fine aggregate has been put into the pan. After 3 minutes from the starting time, the cement and fine materials (SF, LSP) were added while the mixer was still rotating. After 5 minutes from the starting time high range water reducer (superplasticizer) and VEA with the required water were added to the mixer gradually over a period of two minutes. After all the constituents had been put in the mixer, mixing was continued for 5 minutes until the batch was fully homogenous. The slump was carried out according to BS (88): PART 102: 1983. Also, destructive compressive strength test was carried out on 15X15X15 cm cubes, at different ages, utterly, 28, 50, 100, 200, 300 and 400 days according to the British Standard BS (88): part (2): 1983. The determination of water absorption of aggregate was according to AS1141.5 and AS 1141.6.1. The determination of aggregates density was according to AS1141.5 and AS1141.6.1.

DISCUSSION ON RESULTS

Actually, the importance and vital results are shown in figures 1 to 12. Each value of the results for standard compressive strength after 28 days are shown in Fig. (1), is the average of three test specimens. Moreover, the proportions for mixes used in this

research results are shown in Table (2). On the other hands, fresh concrete tests were carried out for all mixes used as regarded to table (3) according to ASTM C1611.

Table (2) Proportions for mixes used in this research

Mix name	Cement type	Cement (kg.)	Gravel type	C/F	Powder		HR WR	VEA	Water to Cementitious
					LSP	SF			
VC	OPC	440	Gravel (19)	65:35	0.0%	0.0%	0.0%	0.0%	0.5
VC-G10	OPC	440	Gravel (10)	65:35	0.0%	0.0%	0.0%	0.0%	0.57
VC-B	OPC	440	Basalt (19)	65:35	0.0%	0.0%	0.0%	0.0%	0.5
VC-D	OPC	440	Dolomite (19)	65:35	0.0%	0.0%	0.0%	0.0%	0.5
VC-SRC	SRC	440	Gravel (19)	65:35	0.0%	0.0%	0.0%	0.0%	0.55
SCC	OPC	440	Gravel (19)	65:35	0%	25%	3%	0.10%	0.29
SCC-C380	OPC	380	Gravel (19)	65:35	0%	25%	3%	0.10%	0.3
SCC-C480	OPC	480	Gravel (19)	65:35	0%	25%	3%	0.10%	0.27
SCC-P12-12%	OPC	440	Gravel (19)	65:35	12%	12%	3%	0.10%	0.29
SCC-P25-0%	OPC	440	Gravel (19)	65:35	25%	0%	3%	0.10%	0.3
SCC-50:50	OPC	440	Gravel (19)	50:50	0%	25%	3%	0.10%	0.29
SCC-35:65	OPC	440	Gravel (19)	35:65	0%	25%	3%	0.10%	0.29
SCC-G10	OPC	440	Gravel (10)	65:35	0%	25%	3%	0.10%	0.33
SCC-B	OPC	440	Basalt (19)	65:35	0%	25%	3%	0.10%	0.3
SCC-D	OPC	440	Dolomite (19)	65:35	0%	25%	3%	0.10%	0.3
SCC-SRC	SRC	440	Gravel (19)	65:35	0%	25%	3%	0.10%	0.32

Table (3) Fresh concrete properties of all mixes

Mix name	Slump p (mm)	Slump flow (650-800 mm)*	V-Funnel (6-12 Sec.)*	U-Box (0-30 mm)*	Filling-Box (90- 100%)*	L-Box (h_2/h_1) (0.8-1)*
VC	145	730	7	15	90	0.87
VC-G10	120	-	-	-	-	-
VC-B	135	-	-	-	-	-
VC-D	130	-	-	-	-	-
VC-SRC	150	-	-	-	-	-
SCC	265	730	7	15	90	0.87
SCC-C380	260	670	10	20	94	0.80
SCC-C480	280	700	8	12	90	0.82
SCC-P12.5-12.5%	260	700	7	12	95	0.87
SCC-P25-0%	270	720	8	18	90	0.87
SCC-50:50	280	780	7	8	95	0.94
SCC-35:65	290	800	6	5	95	0.96
SCC-G10	290	790	6	7	95	0.95
SCC-B	275	750	7	10	90	0.88
SCC-D	270	730	7	14	90	0.85
SCC-SRC	275	700	8	19	96	0.8

*Limits according to EFNARC [16]

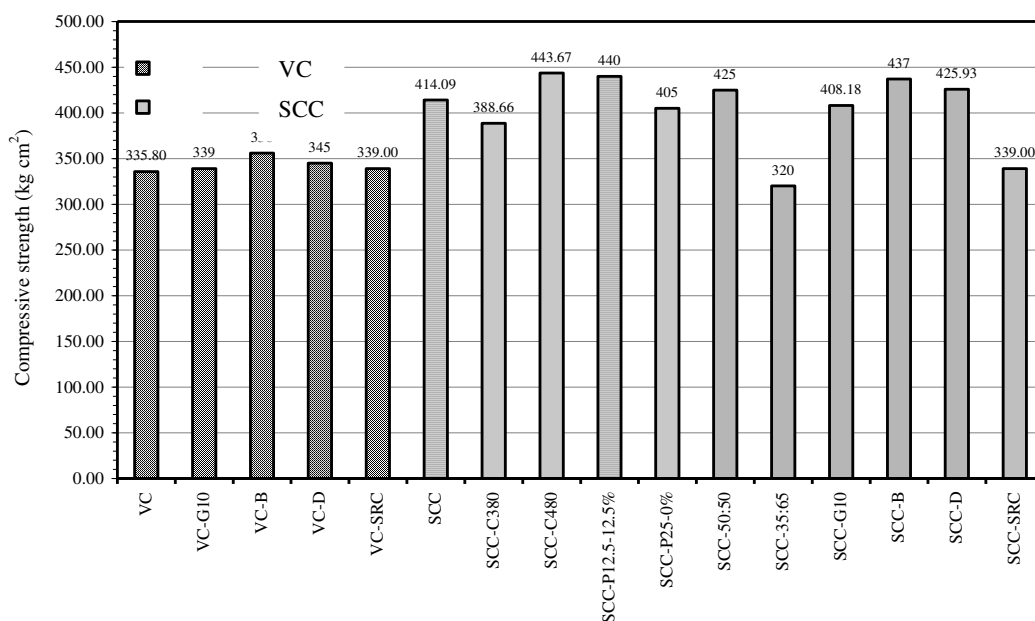


Fig. (1) Standard compressive strength on 28 days for all mixes.

Comparison between VC and SCC for Sulfate Attack

Figure (2) shows the results of compressive strengths of all mixes of both VC and SCC which indicated more durability of SCC in all ages. Ranges were 123, 144, 206, 225, 280 and 288 kg/cm² on ages 50, 100, 200, 300 and 400 days respectively. On 28 days, the range was 123 kg/cm² between the lowest and maximum values of the sixteenth mixes whereas this range was about 288 kg/cm² after 400 days cyclic immersion in 5% sodium sulfates. This means that some mixes exhibited most of its residual stresses (SCC) and others losses most of it (VC) which appeared on 400 days age. On the other hands, the relations between ages and compressive strengths of all SCC mixes and control VC mix were indicated in Fig. (3) as a relative or residual strengths for all mixes which shows that the standard strength at 28 days was indicated by 100%. The figure supported the results in Fig. (2) and indicated that all mixes of self compacting concrete increases at early ages due to solution absorption filling of voids with reaction product (ettringite). Dissolved sulfate salts can enter into chemical reactions with cement-based materials causing expansion, cracking and spalling so, degradation of compressive strengths were after just the maximum expansion as shown in Fig. (3) which indicated that mixes of SCC-SRC and SCC-35:65 were the best mixes gives more durable and best residual strengths after 400 days (about 84%-87% respectively) compared with VC which gave 6% residual strength after 400 days immersion in sodium sulfates. A finer capillary pore system is obtained in SCC due to incorporation of filler materials which results in a better ability to withstand sulfate attack.

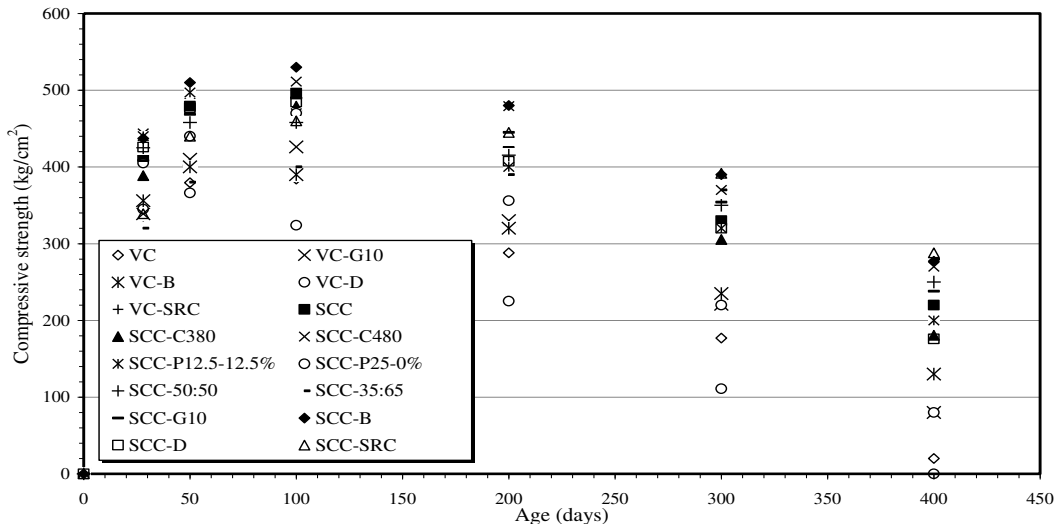


Fig. (2) Compressive strength for all mixes at different ages.

Effect of Cement Content

Figure (4) obviously explains that at early age the gain strengths due to chemical reactions and filling of voids was clearly appears in mix SCC-C380 where the gain was 23% compared with SCC mix which contain 440 kg/m³ and gave 19% gain in its compressive strength. On the other hands, the gain strength was about 15% only for the mix SCC-C480. This is related to that for poor mixes with cement, there is a more

chance for reactions products to fill the voids especially at early age. Inversely results were supported with severe sulfate attack on late ages (300,400) days. This is due to the rich amount of cement materials which reduces voids and gives denser concrete resulting in withstanding of sulfate attack especially at long terms where the residual strength was about 60% compared with 46% for mix SCC-C360 and 6% for VC.

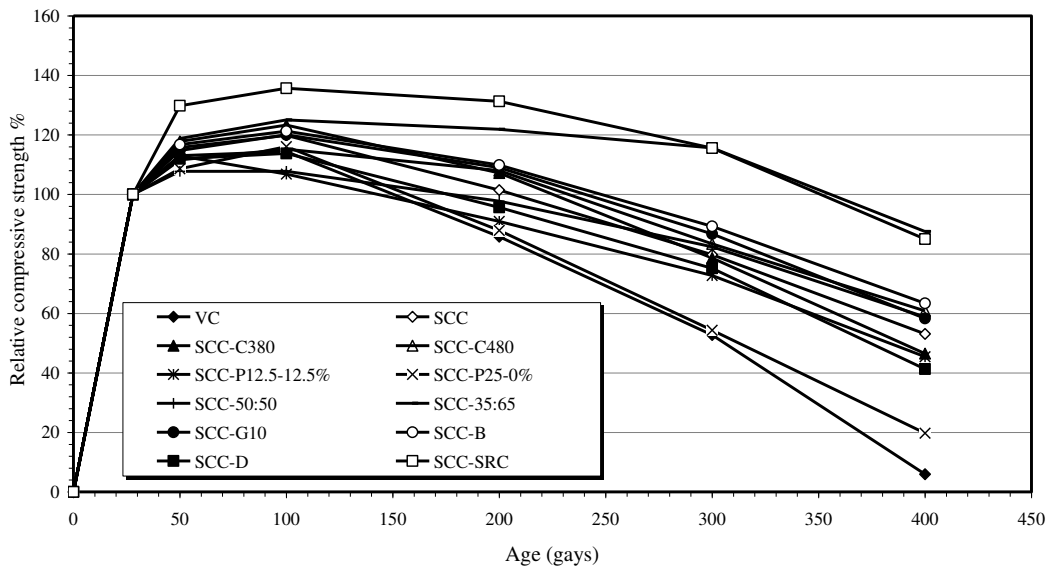


Fig. (3) Relative compressive strength for all SCC mixes and VC mix for all different ages.

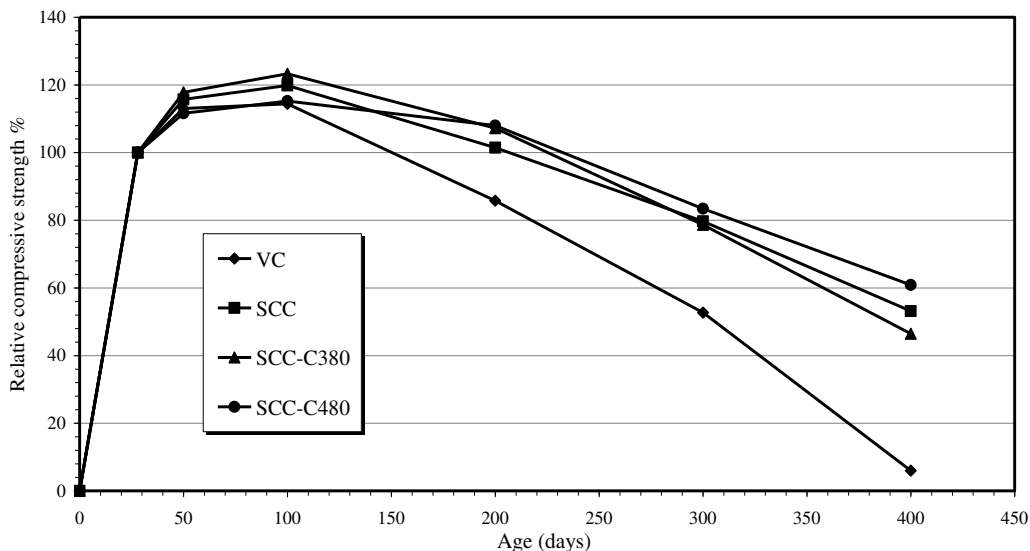


Fig. (4) Effect of cement content on 400 days resistances of SCC mixes and VC mix against sulfate attack.

Effect of Cement Type

Figure (5) illustrated the effect of cement type on the compressive strength of the mixes shown where the SRC type was more significant in resisting sulfate attack for all ages of the tests. The residual strengths at the end of the test reached about 85% for mix SCC-SRC whereas it was 53% for the same mix but with OPC. Results showed that the residual strength for the mix VC-SRC was 35% compared with VC which was 6%. Comparatively, in deeper regions of specimens (more than 10 mm from the surface), acicular ettringite clusters were only observed in specimens from mixtures prepared with OPC. The absence of ettringite in specimens from SRC was likely due to its lower C3A content. specimens made with OPC suffered notable surface scaling on all of their faces, along with disintegration at the edges accompanied by significant swelling and transverse macro-cracks. Specimens made with SRC were quite intact with moderate surface scaling and minor pop outs and no evidence of significant expansion.

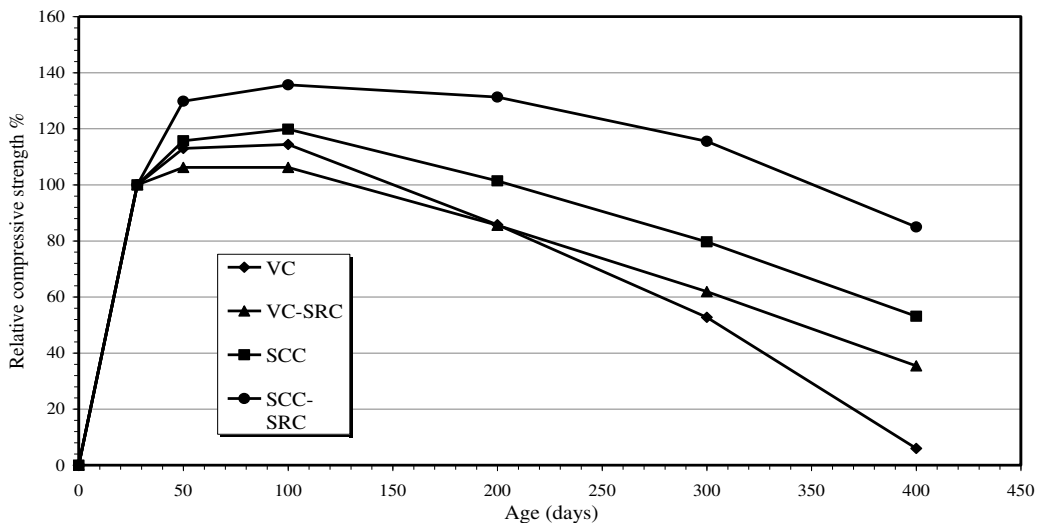


Fig. (5) Effect of cement type on 400 days resistances of SCC mixes and VC mixes against sulfate attack.

Effect of Binder Type and Content

Figure (6) illustrated the relative strengths during the period test (400 days) for mixes contain silica fume and limestone powder with different ratios. The silica fume and blended binders gave the best results of compressive strength. Whereas the mix SCC containing silica fume gave a residual strength of 53% and for blinded binders was 45% compared with 20% for the mix SCC-P25-0%. The deterioration rate and grade during sulfate attack are influenced by the C3A content of the cement. The incorporation of high amounts of limestone filler in SCC makes it more vulnerable to thaumasite form of sulfate attack (TSA). In the case of TSA, ettringite is commonly formed as a precursor mineral and nucleus for subsequent thaumasite formation. Direct formation of thaumasite without ettringite seems to be a rare case requiring supersaturated solutions with high ionic.

Blended binders, especially those with multicomponent of variable particle sizes and reactivity presumably produce a dense and discontinuous pore structure due to complementary physical filling and pozzolanic effects.

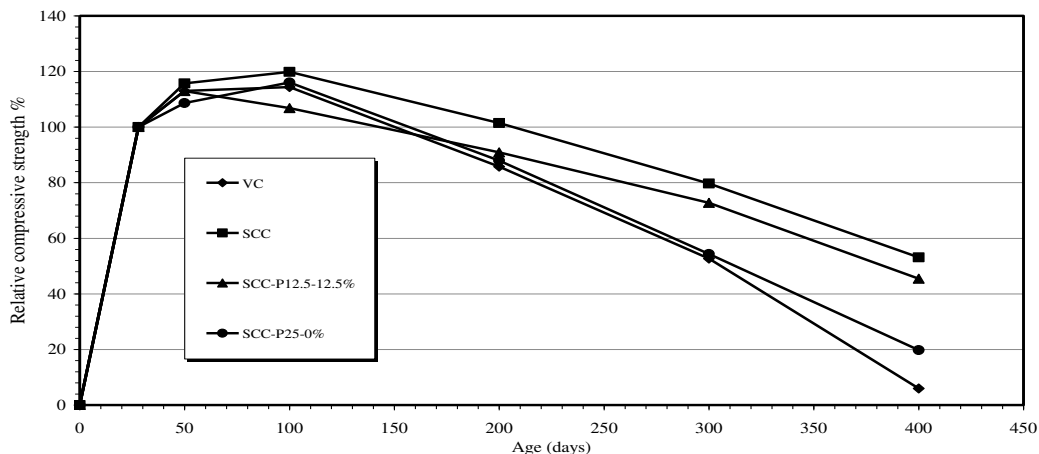


Fig. (6) Effect of powder type and content on 400 days resistances of SCC mixes and VC mix against sulfate attack.

Effect of Coarse to Fine Aggregate (C/F) Ratio

Coarse to fine aggregate C/F had a mixed effect on the results on mixes as shown in Fig. (7). Whilst it did not have a statistically significant effect on expansion and mass change results, it affected the compressive strength results. This indicates that the change of C/F from 65%: 35% to 50%: 50% or 35%: 65% was an insignificant parameter in compressive strength. Generally, specimens with C/F of 35%:65% had higher residual compressive strength than that of corresponding specimens with C/F of 65%:35%. Residual strength reached 87% for mix SCC-35%:65% where mix SCC-50%:50% achieved 58% whereas the SCC containing C/F 65% to 35% was achieved 53% compared with 6% for VC. Results are generally sensitive to the volume of coarse aggregates and the interfacial zone with the cementitious matrix. The results of the experimental study assure that the ratios of both coarse to fine aggregate have a vital effect on the withstanding of sulfate attack especially for ratio 35%:65% inversely to the traditional values 65%:35% which used in concrete. This may be due to the reduction of voids and more dense concrete enhancing with superplasticizer and silica fume.

Size Effect of Coarse Aggregate

Figure (8) showed the results of compressive strength for different sizes of coarse aggregate (19 mm, 10 mm) for both SCC and VC where the results indicated more durable results for mix SCC-G10 which exhibited a residual strength of 58% compared with the same size for mix VC-G10 which gave 23% residual strength. On the other hands, the residual strength for SCC mix was 53%. This size of gravel (10 mm) gave best results due to the compatibility between this size and cement mortar which contributed with silica fume or lime stone powder and superplasticizer which in role gave more dense and little air voids resulting in resistance to sulfate attack.

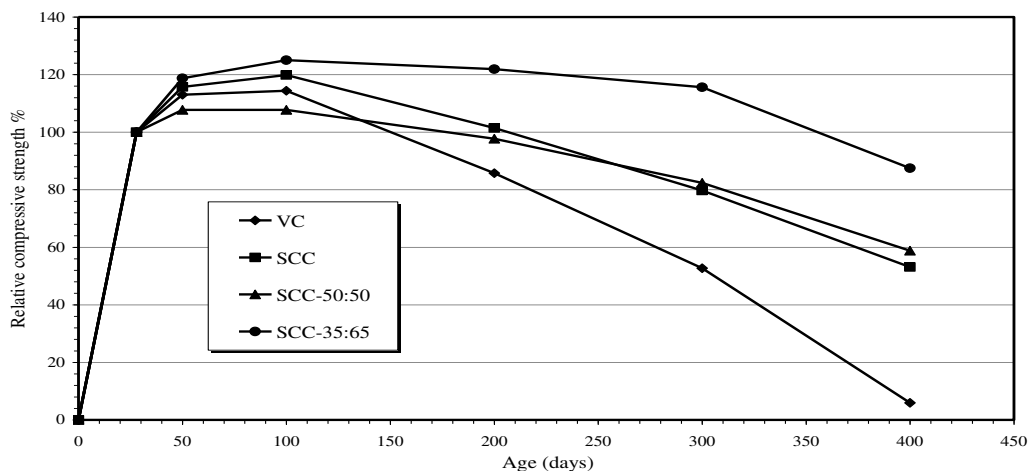


Fig. (7) Effect of C/F on 400 days resistance of SCC mixes and VC mix against sulfate attack.

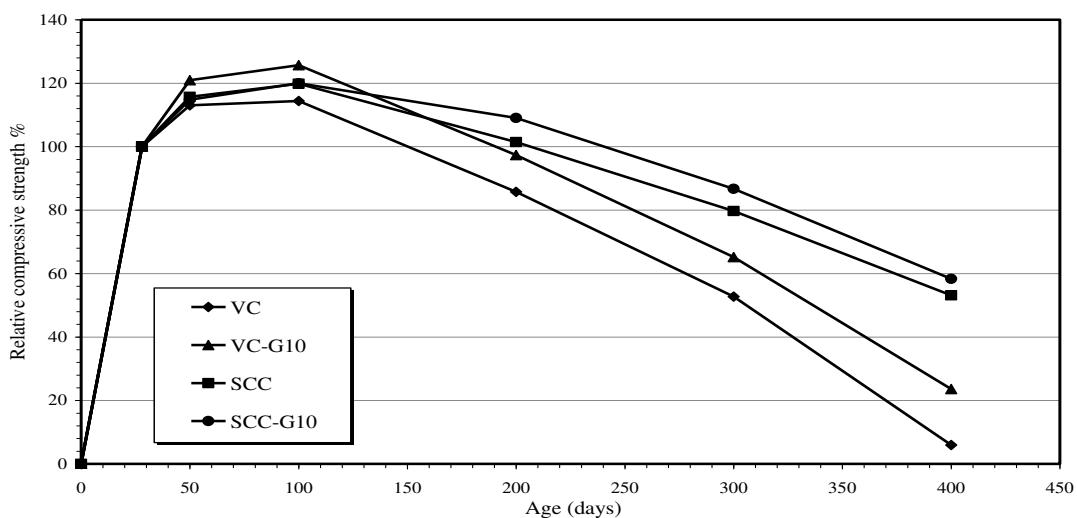


Fig. (8) Effect of coarse aggregate size on 400 days resistances of SCC mixes and VC mix against sulfate attack.

Effect of Coarse Aggregate Type

Figure (9) reported that the basalt coarse aggregate type gave best results for resisting sulfate attack. On the other hands, dolomite aggregate was vulnerable to resist sulfate attack as shown in the figure which indicated that the residual strength of mix SCC-B was 63% on 400 days age cyclic immersion and drying cycle in sodium sulfate solutions. On the other hands, the residual strength of SCC mix was 53% compared with 36% residual strength of mix VC-B. The dolomite as coarse aggregate base was more vulnerable where it gave about 41% residual strength for mix SC-D whereas the mix VC-D failed completely. These results may be due to the chemical components of the aggregate type and the dolomatic powder effects may lead to activation of the ettrengrite components in mixes VC-D and SCC-D whereas the gravel and basalt was better because of its natural texture of its surfaces.

Effect of Age Factor

The results given in Fig. (10) shows the compressive strengths of both SCC mix and its corresponding VC mix as a control mixes (without exposure) and its relative mixes subjected to the cyclic emersion and dry each five days consequently. Regarding with the normal case, compressive strengths of all ages for SCC increases about 20%. Regarding to the cyclic immersion in sulfates, compressive strength increases up to 16% and 20% for ages 50 days and 100 days respectively this due to the filling of air voids by ittrengite. On the other hands, compressive strengths for VC increases by about 14% at ages 50 to 100 days. After about 100 days, degradation observed for both mixes SCC and VC which subjected to sulfates. Results of Fig. (10) shows that on 200 days age, a reduction on compressive strengths was observed compared with 100 days age. Results indicated that the reduction was 15% for SCC mix but compressive strength was still more than standard compressive strength an 28 days whereas, for VC, reduction was 25% compared with compressive strength on 100 days and there was also reduction if compared to the standard compressive strength on 28 days by about 14%.

Age factor on 300 days shows more degradation in compressive strengths for both SCC and VC. The reduction was about 47% for VC if compared with standard compressive strength on 28 days whereas the reduction of SCC was 20% only. On the other hands, results of the compressive strength on 400 days immersion in sulfates was finally indicated the case of the samples with respect to standard compressive strength on 28 days. VC was almost collapsed where SCC still had more than 50% residual strength.

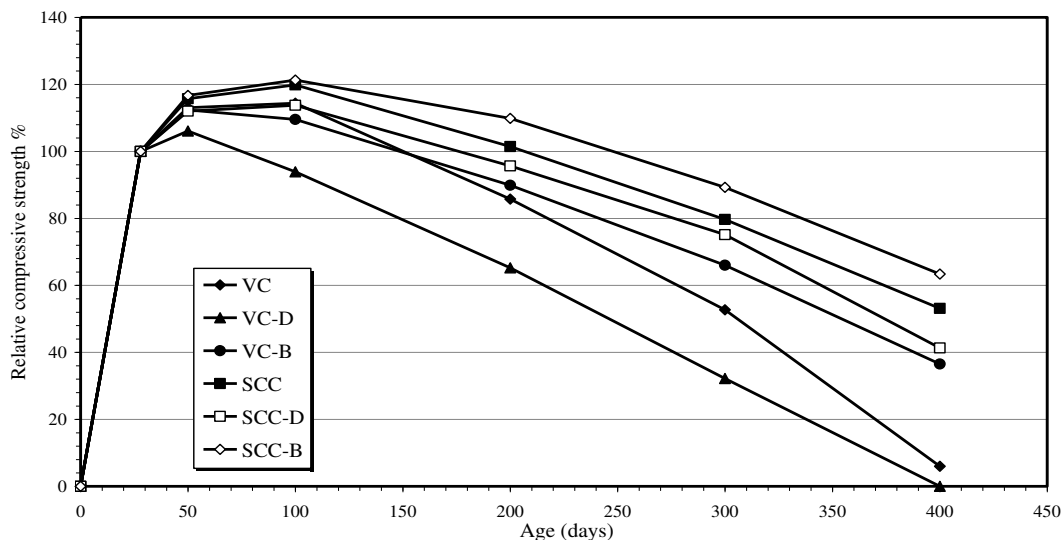


Fig. (9) Effect of coarse aggregate type on 400 days resistances of SCC mixes and VC mixes sulfate attack.

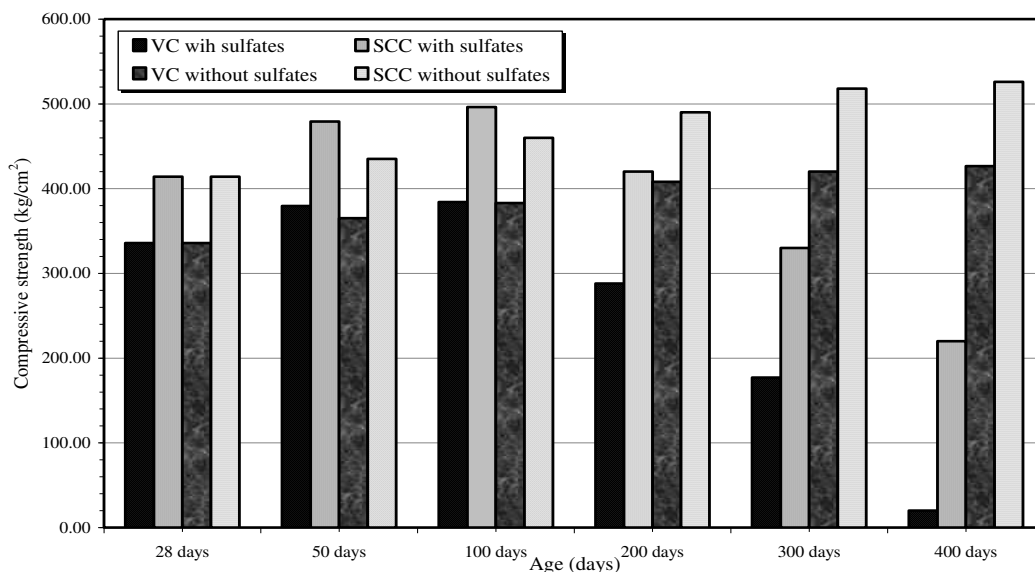


Fig. (10) Comparison between resistances of SCC, VC mixes against sulfate attack exposure.

After 400 days immersion in sulfates solution, it is obviously from Fig. (11) that the relative compressive strengths for comparable SCC and VC indicated that SCC was more withstanding sulfate attack than VC with the same component as a reference. The results indicated that the most effective factor was SRC cement which exhibited more than 85% residual strength with mix SCC-SRC compared with 35% with mix VC-SRC. The second factor was basalt aggregate as a coarse aggregate in mix SCC-B which in role exhibited more than 60% residual strength compared to 36% with mix VC-B. On the other hands, the third factor was 10 mm size of coarse aggregate (gravel) with mix SCC-G10 which exhibited more than 58% residual strength compared with 23% with mix VC-G10. The fourth factor was using the mix SCC with 20 mm gravel with ordinary Portland cement with blended binder 12.5%SF to 12.5%LSP which illustrated that may hold about 53.1% residual strength compared with mix VC. The last factor was using dolomite as coarse aggregate with mix SCC-D gave 41% residual strength compared with 0.0% with mix VC-D.

In general all mixes after 400 days age exposure to a cyclic emersion in sulfate solution as indicated in Fig. (12) shows the results of compressive strengths for all SCC mixes in order to rank the factors of SCC components which gave more resisting to sulfate attack and its relative mixes without exposure to sulfate attack in order to make a comparisons. Using mix SCC as a reference, there are six mixes gave a compressive strength more than SCC these mixes were SCC-SRC, SCC-35%:65%, SCC-B, SCC-C480, SCC50:50 and SCC-G10 which ranked according to more compressive strength that increases about 31%, 27%, 26%, 23%, 14% and 8% respectively.

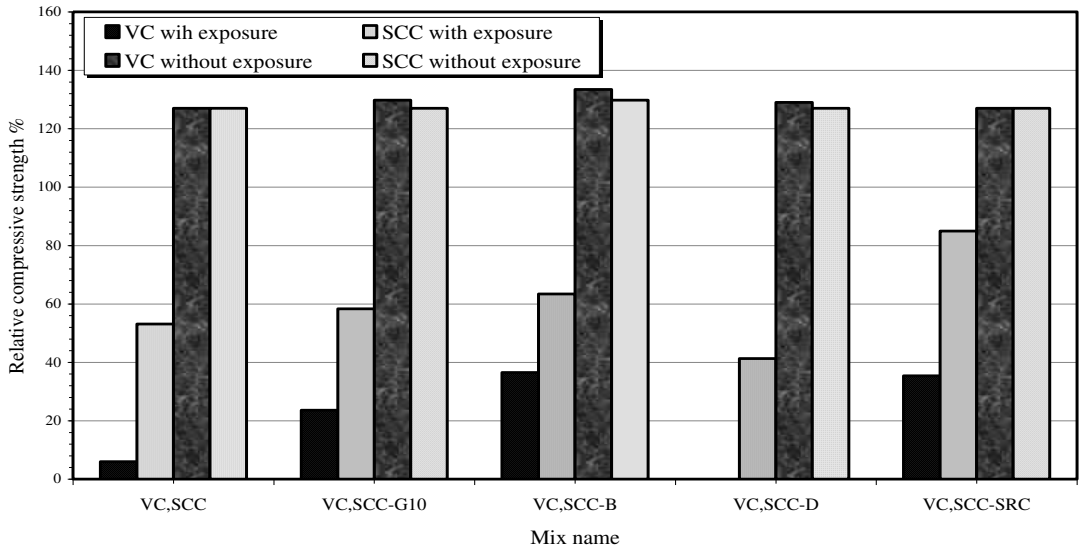


Fig. (11) Relative compressive strength for 400 days age for SCC, VC mixes subjected to cyclic exposed to 5% Na₂SO₄ solution and air every alternat 5 days.

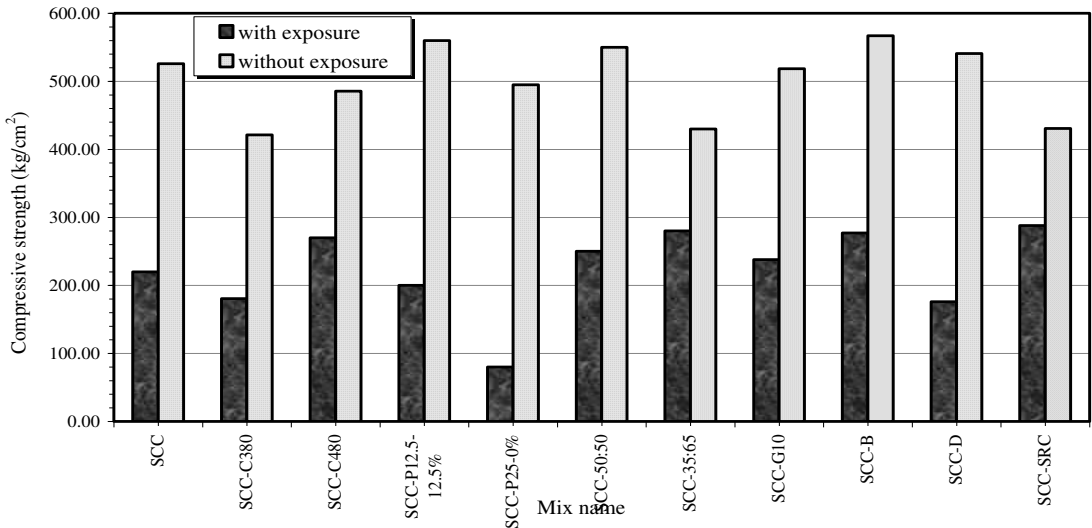


Fig. (12) Comparison between 400 days compressive strength of SCC mixes cyclic exposed to 5% Na₂SO₄ solution and air every alternate 5 days

CONCLUSIONS AND RECOMMENDATIONS

The results of the experimental work on different SCC and VC mixes and associated compressive strength and results have been considered in this research. On the sound of results obtained in this paper, the following conclusions can be drawn as follows:

- 1- Utilizing self compacting concrete SCC with all mixes used in this research are reliable in achieving sulfate resistance and durable concrete.

- 2- Incorporating silica fume SF and blinded binders SF with lime stone powder LSP to produce durable concrete from SCC considered vital and produce better results than utilizing LSP only as a binder.
- 3- Utilizing basalt type and size 10 mm with ratios C/F 35:65 achieved high resistance against sulfate attack whereas utilizing dolomite gave a vulnerable results compared with basalt or gravel but still more resistance with compared to VC.
- 4- Cement content and type have a vital effect on the resistance of SCC mixes whereas rich mixes with SRC type gave good results for resisting sulfate attack.
- 5- Residual strengths for SCC mixes after 400 days cyclic immersion in sulfates solution ranged from (41%-85%) compared with VC mixes which ranged from (0%-36%).
- 6- Recommended results to produce more qualified SCC resisting sulfate attack may be using rich cement type SRC and basalt size 10 mm with ratio 35%:65% to sand using silica fume with 25% and superplasticizer by 3% with 0.1%VEA and 0.3 w/cementitious.

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المكونات و النسب المثلى للخرسانة ذاتية الدمك فى وسط أملاح الكبريتات

أشرف محمد حنيجل

تتجه أنظار العالم اليوم إلى تطوير استخدام الخرسانة ذاتية الدمك لتحسين نواحي عديدة فى مجال التشييد منها حل المشاكل المترتبة على كثافة حديد التسليح التى قد ينتج عنها تعشيشات وعليه فان استخدام الخرسانة ذاتية الدمك يترتب عليها جودة عالية للمنشآت بالإضافة إلى تقليص العمالة و تقليل الضوضاء الناتج عن الدمك.

وللحقيقة لم تكن هذه الفكرة وليدة اليوم فقد سبق ذلك في دول متعددة تعاني من تعرض منشاتها إلى دورات متتالية من التليج يتبعه جفاف فى ظل تواجد أملاح الكبريتات وعليه قامت بعض الأبحاث بدراسة متانة الخرسانة ذاتية الدمك خصوصا عند تعرضها لأملاح الكبريتات.

واستكمالا لمتابعة البحث في هذا المجال على المستوى المصري فقد قام هذا البحث بدراسة عملية تحليلية منتهجا لمنهج البحث التجريبي للإجابة عن السؤال الهام وهو " هل الخرسانة ذاتية الدمك تعطى متانة أفضل من الخرسانة المعتادة؟".

وقد اعتمد هذا البحث أساسا على تعرض عينات الخرسانة بعد معالجتها لمدة 28 يوما في مياه معالجة عادية يليها التعرض لدورات متتالية لمحلول أملاح الكبريتات لمدة خمسة أيام يليها تعرض مباشر للهواء خمسة أيام أخرى و لمدة 400 يوما من خلال دراسة ستة عشر خلطة مختلفة قامت أساسا على العديد من المتغيرات منها نوع الركام الكبير ومحتواه و مقاسه وكذلك نوع الأسمنت و محتواه بالإضافة غبار السيلكا فيوم ومحتواه مع بودة الحجر الجيري.

وقد توصل هذا البحث إلى نتائج هامة منها انه الخرسانة ذاتية الدمك قد أعطت نتائج ذات كفاءة عالية في اختبارات الضغط في حال تواجدها في أوساط تحتوى على محلول أملاح الكبريتات و أفضل بكثير من الخرسانة المعتادة و خصوصا مع استخدام خلطة غنية بالاسمنت المقاوم للكبريتات مع استخدام ركام البازلت مقاس 10 مم بنسبة 35% الى 65% رمل في ظل وجود غبار السيلكا بنسبة 25% من وزن الأسمنت مع السوبربلاستيسيز بنسبة 3% و مادة تحسين اللزوجة بنسبة 1%.