

Effect of Silica Fume on Mechanical and Durability Properties of Self-Compacting Concrete

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ABSTRACT: By using available materials in Egypt, a concrete produced which has the properties of Self-Compacting Concrete. The aim of this thesis is to study the effect of silica fume on the properties of self-compacting concrete in fresh, hardened states and durability properties, locally produced Silica Fume (SF) were used. For achieving goals of this study four samples produced: three of them contain different percentages of silica and the last one is control mixture without silica fume M₀. The fresh properties, hardened properties and durability characteristics were measured. Mechanical properties were determined by measuring compressive strength, split tensile strength and flexural strength. Durability properties were determined by measuring sulphate resistance, chloride resistance and permeability of specimens. Sulphate and chloride resistance were measured by immersing the specimens in two concentration of magnesium sulphate (MgSO₄) and sodium chloride (NaCl) respectively and loss on weight and strength were detected after 28,90 days. Permeability was determined by measuring absorption and sorptivity of mixtures. From results There is a noticeable enhancement on the mechanical and durability properties of self-compacting concrete by increasing the percent of silica fume to about 16% by weight of cement.

KEYWORDS: -Self Compacting Concrete (SCC) -Silica Fume (SF) -Hardened Properties -Durability properties Chloride resistance -sulphate resistance -Water Permeability

I. INTRODUCTION

Self-compacting concrete was first developed at 1998 in Japan to achieve durable concrete structures [1]. Self-compacting concrete (SCC) is defined as the concrete that is able to consolidate under its own weight. The highly fluid nature of SCC makes it suitable for placing in difficult conditions and in sections with congested reinforcement.

Use of SCC can also help minimize hearing-related damages on the worksite that are induced by vibration of concrete, Another advantage of SCC is that the time required to place large sections is considerably reduced [2]. [3] told that SCC must have the following characteristics to achieve self-comptability: Filling ability, passing ability and high resistance to segregation as illustrated in Figure 1.



Figure 1: Mechanisms of achieving self-compactability [3]

II. RELATED WORK

Mechanical properties of SCC can be enhanced by the addition of silica fume, mechanical properties studied including compressive strength, split tensile strength and flexural strength. [4] concluded that SCC specimens with SF15 (15% replacement) by weight of cement had the highest compressive strength with 73.87 MPa for 130 days. [5] reported that inclusion of silica fume in the range of 5 -25% increases compressive strength about 6-30% for water cement ratio in the range of 0.26-0.42. [6] observed that the replacement of cement by silica fume (up to 18%) and the addition of superplasticizer increased the strength of cement paste. [7] reported that at 15% silica fume content, tensile strength of concrete found to be in the range of 4.79-5.34% of its compressive strength. [8] reported that at 15% replacement level, tensile strength of silica fume concrete increased in the range of 27 -34% as compared to concrete without silica fume. [9] reported that splitting tensile strength and tensile elasticity tension modulus of concrete at age of 3 days increased gradually with the increasing of silica fume content from (5% to 15%) by weight of cement. [10] concluded that silica fume have a pronounced effect on flexural strength in comparison with splitting tensile strength. For flexural strengths, even very high percentages of silica fume significantly improved the strength. Also it was found that there was a steady increase in the flexural strength with increase in the silica fume replacement percentage. The problem of self -compacting concrete durability still exists, particularly in terms of physicochemical properties. Durability properties studied including chloride resistance, sulphate resistance and water permeability. Chloride attack to concrete is most commonly initiated when chloride ions ingress from the surface of the material, Chloride ions exist in salts, sea water and contaminated water . [11] reported that the chloride permeability in SCC is somewhat reduced compared to corresponding normal vibrated concretes; this reduction is more distinct when cement replacement materials are incorporated into the mixtures. At 100 and 300 days of contact the effect of a solution of sodium sulphate on SCC was small but a ccelerated from 300 until 900 days of experiment due to the increased porosity parallel to the increase of air content [12]. Water permeability of concrete is thought to be essential for the preservation of inner quality of the structure, at later ages and after the cease of hydration reactions, it may cause critical deterioration of the concrete and reinforcements

The addition of silica fume cause considerable pore refinement transformation of bigger pores into smaller one due to their pozzolanic reaction concurrent with cement hydration, this enhance the durability properties of self-compacting concrete. [14] reported that combination of micro silica and nano silica with 15% of micro silica and 3 liters of nano silica improve the compressive strength, split tensile strength, flexural strength by 25.61%, 25%, 19% respectively and enhanced fresh properties with the aid of VMA and improved Saturated Water absorption, Sulphate Resistance, Acid Resistance. [15] performed an experimental study on self-compacting concrete by partial replacement of cement with silica fumes and GGBS. He found that silica fume of 6% gives best results, The percent of GGBS was fixed to 20%. [16] presented the effect of mineral admixtures on durability of self-compacting concrete with various partial replacements of fly ash, silica fume and combination of both fly ash and silica fume and he concluded that 15% replacement of silica fume shows the maximum durability factor and lower sorptivity. [17] examined the variation of durability properties of self-compacting concrete containing different mineral admixture and found that the silica fume is the most effective mineral admixture in enhancing durability characteristics, incorporation of silica fume with percent 10% and 20% increased the compressive strength, at the age of 28 days, to 75.5 and 79.5 MPa, reduced final absorption from 4.5% to 2.76% and 2.57% respectively.

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III. EXPERIMENTAL PROGRAM

3.1. Materials

Cement

In this study, Portland cement (CEM I 42.5 N) were used. The chemical and physical characteristics are satisfied the Egyptian Standard [18] and [19]. The physical and mechanical properties are as given in Table 1.

Table1: Physical and mechanical properties of Portland cement

Property		Test result	ES 4756-1/2013
Specific surface area (cm ² /gm)		3600	Not less than 2750
Setting Time (min)	Initial	75	Not less than 60 min
	Final	210	--
Compressive strength (MPa)	2 days	24	Not less than 10 (MPa)
	28 days	54	Not less than 42.5 (MPa)

Silica fume

Silica fume was added in percentage of 8%, 12% and 16% by weight of cement. Table 2 shows the physical properties of silica fume used.

Table 2: Physical properties of the silica fume used

Property	Value
Specific surface area (cm ² /g)	170,000
Particle size (µm)	8.00
Specific gravity	2.2

Aggregate

Coarse aggregate used in the experimental work is a crushed dolomite type (4/12.5) with a maximum nominal size of 12.5 mm. Natural sand type (0/4) was used as fine aggregates. The properties of crushed dolomite and sand used were carried out according to the Egyptian Standard [20] as shown in Tables 3 and 4.

Table 3: The physical properties of the used crushed dolomite

Property	Test results	ES 1109/2008
Specific weight	2.6	-
Bulk density (t/m ³)	1.67	-
Coefficient of abrasion (Loss Angloss) %	17	Less than 30
Coefficient of Impact %	12.2	Less than 30
Crushing value %	22.5	Less than 30
Absorption %	1.6	Less than 2.5
Clay and fine dust content %	0.8	Less than 3.0

Table 4: The physical properties of the used fine aggregate

Test	Test result	ES 1109/2008
Specific weight	2.55	-
Bulk density (t/m ³)	1.70	-
Fineness modulus	2.8	-
Material finer than No 200 sieve %	2.6	Less than 3%

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Superplasticizer

The high-range water-reducing (HRWR) admixtures help in increasing the workability of concrete without adding water and helping the fine particles to fill the void spaces and to decrease the amount of water in the mix. In this study a superplasticizer namely ViscoCrete 3425 is a third generation superplasticizer locally produced was used. It is an aqueous solution of modified polycarboxylate and 1.08 specific gravity. It complies with [21]-Type G and F.

Water

Drinking water used in all concrete mixes as the mixing water. The same water used for curing the specimens. Water added in the percentage of 0.38 by weight of cementitious materials (W/cm), where: cm=(cement + silica fume).

3.2. Mix proportions

Four Self Compacting Concrete (SCC) mixtures were designed M0,M8,M12 and M16 where: The number of mix indicates the percent of silica fume used in the mixture. For all mixes, 450 kg/m³ portland cement were used. The control mix (SCC) was made without adding silica fume. The other three mixtures were made with adding three different percentage of silica fume 8%, 12% and 16% by weight of cement. The mix components of concrete mixtures are listed in Table 5.

Table 5: The components of the mixes by kg/m³

Mix	C	SF	FA	CA	W	W/cm	SP
M0	450	0	730	730	171	0.38	6.75
M8	450	36	700	700	184.7	0.38	6.75
M12	450	54	700	700	191.5	0.38	6.75
M16	450	72	700	700	198.2	0.38	6.75

C: cement, SF: Silica fume, SP: superplasticizer, W: water, FA: fine aggregate, CA: coarse aggregate.

3.3 Mixing, Casting and Curing

For each mixture, the ingredients were placed into the laboratory mixer in the following order: coarse aggregate, and fine aggregate for thirty seconds, then cement was added, silica fume in dry condition and mixed. After sixty seconds from the start of the mixing process, Seventy-five percent of water added to the mixture. Then the remainder of the water and superplasticizer were added into the mixture gradually to provide homogeneity to the mixture.

The total mixing time was four minutes to ensure the uniformity. A cubes with dimensions of 100x100x100 mm for compressive tests, cylinder 150 mm diameter and 300 mm height for tensile tests, and prisms 40x40x160 mm for flexural strength were used. To study the fresh concrete properties (filling ability, passing ability and segregation resistance), the slump-flow test, T50 flowing time L-box and GTM screen stabilities were measured. Specimens were then cast without vibration. The specimens were kept at room temperature for 24 hours. The specimens placed in water until 28 days then the specimens were taken out of the water at room temperature for 24 hours.

3.4 Testing procedure

The Compressive Strength was measured after 7, 28 and 90 days. Splitting tensile strength and flexural strength was measured after 28 days. Chemical resistance including chloride resistance and sulphate attack resistance were measured after 28, 90 days from exposure in NaCl (0.4M and 0.8M) and MgSo₄ (3% and 6%) respectively by determining the loss on weight and strength. Water permeability was measured by evaluating water absorption and sorptivity after 90 days of curing in water.

IV. TEST RESULTS AND DISCUSSIONS

4.1 Fresh properties

There is many tests that done in the experimental program to express the fresh properties of self-compacting concrete as follows: The slump flow, T500 slump flow time to measure flow ability of concrete. V-funnel test to measure passing ability. Screen stability (GTM) to measure segregation resistance of concrete as shown in Table 6 and Figures 2, 3.

Table 6: Workability of all mixture

Mix No.	Mo	M8	M12	M16
Slump-flow mm	750	710	680	650
T500 (second)	2.5	3.5	4	4.8
L-box H2/H1	0.95	0.90	0.88	0.85
GTM (%)	11	10.2	9.5	8.8

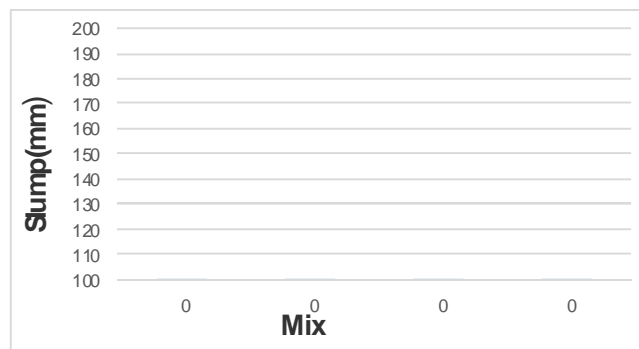


Figure 2: Relationship between SF content and slump flow

From Figure 2 it's observed that increase of silica fume replacement lead to decrease in slump flow, This has been due to the higher specific surface of silica fume, which needs more water to complete hydration and for workability. Due to increase in the number of contact points between solid particles, the cohesiveness of mortar mixture greatly improves when silica fume is present and this is clear from Figure 2 when silica fume added with 16% by weight of cement, the slump flow decreased with percent 13.33%, the previous results were coincident with conclusions of the research that was carried out by [22] who reported that the presence of too much silica fume in mortar (10% by weight of cement) tends to make the mixture stiff.

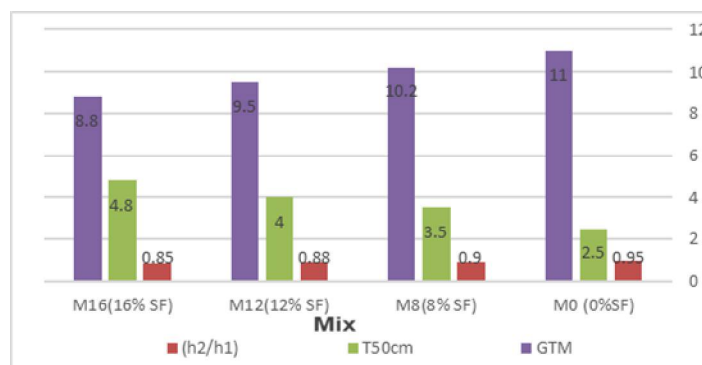


Figure 3: Workability properties results including (T500, L-box H2/H1 and GTM)

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Blocking ratio decreased with higher volume of silica fume because there is net decrease in water requirements in concretes containing high concentration of silica fume and water-reducer or superplasticizers as [23] told. So, when silica fume percent increased from 8% to 16% by weight of cement, the blocking ratio decreased compared with control mix from 5.26% to 10.52% as shown in Figure 3 . Concrete containing silica fume shows substantial reduced bleeding. Additionally silica fume reduces bleeding by physically blocking the pores in the fresh concrete because of its fines particles [23]. So, when silica fume percent increased from 8% to 16% by weight of cement, the segregation resistance of SCC enhanced from 7.27% to 20% as illustrated in Figure 3.

4.2 Hardened properties Test Results and Discussion

Compressive Strength

Compressive strength is the most important mechanical property of concrete. The compressive strength of a concrete primarily depends on W/B ratio, binder/aggregate (B/A) ratio, mixture composition, and degree of consolidation. Table 7 and Figure 4 show the mechanical properties results for different mixes.

Table 7: Mechanical Properties for Different SCC Mixes

Mix No.	Compressive strength F_{cu}			f_{ct} at 28 days (MPa)	f_b at 28 days (MPa)
	7 days	28 days	90 days		
M0	29	45	58	3.07	4.56
M8	33	48	62	3.17	4.76
M12	38	51	66	3.27	5.10
M16	42	56	70	3.71	5.54

(f_{cu} : compressive strength, f_{ct} : tensile strength, and f_b : flexural strength) in MPa

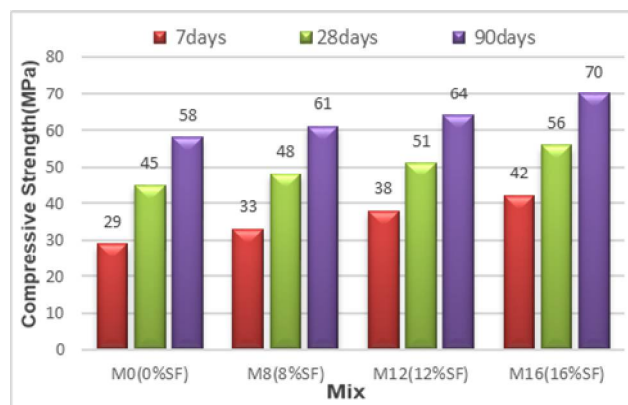


Figure 4: Relationship between SF content and compressive strength at different ages

Table 7 and Figure 4 shows that there is a great positive effect of increasing silica fume content on the compressive strength of SCC at 7 , 28 and 90 days tests of samples. Increasing silica fume content to 16% by weight of cement improves the compressive strength at the age of 7 ,28 and 90 days by about 37.93 % , 24.24% and 20.69 respectively,

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the degree of hydration decreased with time, so its observed from results shown in Figure 4 that the rate of increase in compressive strength decreased from 7 to 90 days . Our results coincident with [5]. Concrete containing silica fume as a mineral additive exhibited an increased compressive strength largely because of the improved strength of cement paste matrix.

Tensile Strength

The tensile strength of concrete is much lower than the compressive strength, because of the ease with which cracks can propagate under tensile loads. The tensile strength of concrete is evaluated using a split cylinder test. The indirect tensile strength test results are shown in Table 7 and Figure 5.

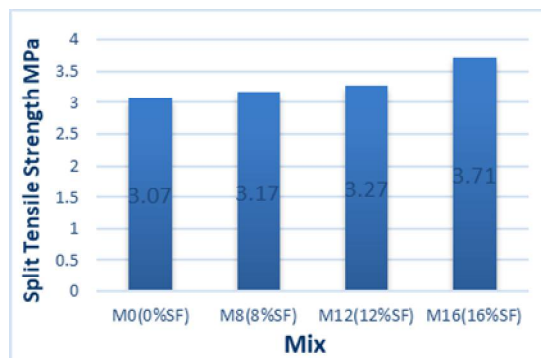


Figure 5: Relationship between SF content and split tensile strength

Figure 5 shows that at 16% silica fume content, tensile strength was 6.6 % of compressive strength, this is slightly coincident with [7] results. From Figure 5 for M16 (16% SF), tensile strength increased to 20.84%, this results were slightly agreed with results of [8].

Flexural Strength

The flexural strength test results are shown in Table 7 and Figure 6.

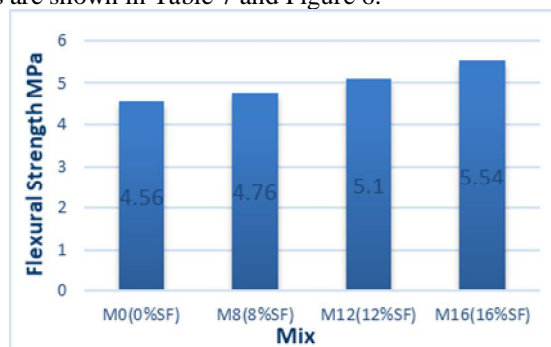


Figure 6: Relationship between SF content and flexural strength.

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The flexural strength test results show that the increasing in silica fume content has a valuable positive effect on the flexural strength of SCC at 28 days. Its shown that Increasing silica fume content to 16% by weight of cement improves the flexural strength at the age of 28 days by about 21.49 %. Silica fume have a pronounced effect on flexural strength in comparison with splitting tensile strength. For flexural strengths, even very high percentages of silica fume significantly improved the strength. In addition, there was a steady increase in the flexural strength with increase in the silica fume replacement percentage [10].

4.3 Durability Test results and Discussion

Chloride resistance

In order to study the durability characteristics, that is the chloride attack, the SCC cubes were immersed in sodium chloride solution (NaCl) with concentration of 0.4M and 0.8M. The cubes were demoulded and dipped in the solution. Then the cubes were taken from the solutions after 28 and 90 days and their corresponding compressive strengths and loss on weight were noted. Table 8 and Figures 7, 8 clarify the effect of sodium chloride in compressive strength.

Table 8: Compressive strength of cubes immersed in NaCl solution for Different SCC Mixes

Solution/Mix	Compressive strength(MPa) <i>F_{cu}</i>							
	Mo		M8		M12		M16	
	28	90	28	90	28	90	28	90
Water curing	45	58	48	61	51	64	56	70
0.4M NaCl	40	48	44	54	47	58	53	65
0.8M NaCl	38	44	42	50	45	55	51	63

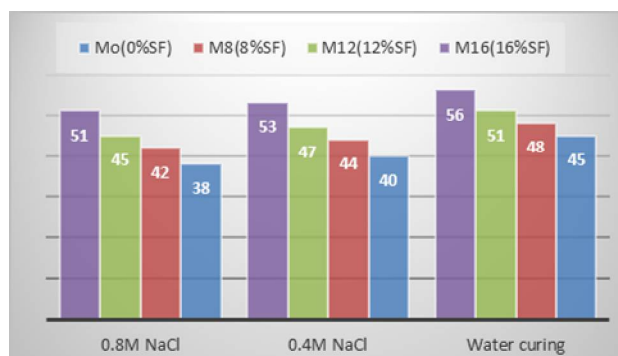


Figure 7: The effect of NaCl solution on compressive strength after 28 days

Figure 7 describe the effect on compressive strength after 28 days immersion of the specimens in NaCl solution and it's obvious that increasing the concentration of the NaCl solution causes decreasing in compressive strength.

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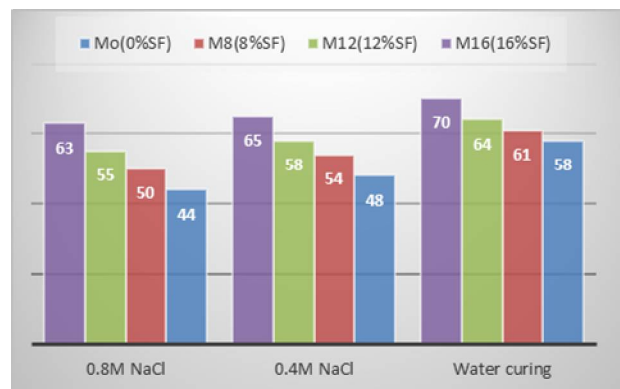


Figure 8: The effect of NaCl solution on compressive strength after 90 days

Figure 8 describe the effect on compressive strength after 90 days immersion of the specimens in NaCl solution and it's obvious that increasing the concentration of the NaCl solution causes decreasing in compressive strength. Adding silica fume with 16% by weight of cement decreases the loss of strength than control mix at 28 and 90 days as follow: loss on strength decrease from 15.55% to 8.92% after 28 days and decreases from 24.14% to 10 % after 90 days as a result to 16% SF mineral additive by weight of cement, the rate of decrease on strength increased with increasing the duration of immersing in the chlorides solution, this is due to the deterioration of concrete. From Figure 7,8 the decrease in strength due to 0.8M of NaCl is higher than the decrease in strength due to 0.4M of NaCl as while the strength of solution increased, the strength of concrete decreased.

Table 9: The effect of NaCl solution on loss of weight for SCC Mixtures after 28 and 90 days

Mix No.	Test date / Loss of weight			
	Loss of weight after 28 days		Loss of weight after 90days	
	0.4M NaCl	0.8M NaCl	0.4M NaCl	0.8 NaCl
M0	1.2911	1.4286	1.7964	1.9688
M8	1.1598	1.2658	1.3977	1.3617
M12	1.0169	1.0832	1.1745	1.268
M16	0.818	1	1.0148	1.1297

its shown from Table 9 that loss on weight decreases as silica fume replacement percentage increases, as silica fume enhances the pores of concrete and make it more dense and resistant to chloride attack. this results coincident with results of many researchers as follow: replacing 20% of silica fume by weight of cement shows very good resistance to chloride attack than conventional concrete, This is due to the improvement of micro structure, The filler effects of silica fume resulting in fine and discontinuous pore structure [24]. SF showed a decrease in total charges as SF content increased from 0% to 11% [25].

Sulphate resistance

In order to study the durability characteristics, that is the sulphate attack, the SCC cubes were immersed in Magnesium sulphate solution. The cubes were demoulded and dipped in the solution. Then the cubes were taken from the solutions after 28 and 90 days and their corresponding compressive strengths and loss on weight were noted. Magnesium sulphate solution of two different strengths were used. Magnesium sulphate of percent 3% and 6% were used. Table 10 and Figures 9, 10 clarify the effect of Magnesium sulphate in compressive strength.

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Table 10: Compressive strength of cubes immersed in MgSo4 solution for Different SCC Mixes

Solution/Mix	Compressive strength(MPa) Fcu							
	Mo		M8		M12		M16	
	28	90	28	90	28	90	28	90
Water curing	45	58	48	61	51	64	56	70
3% MgSo4	41	50	45	56	48	60	54	67
6% MgSo4	39	47	44	54	47	57	53	65

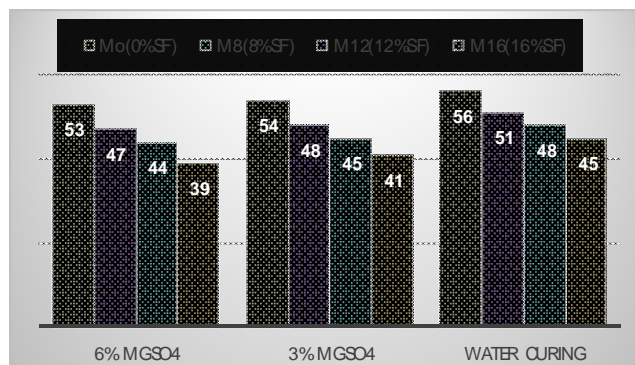


Figure 9: The effect of MgSo4 solution on compressive strength after 28 days

Figure 9 describe the effect on compressive strength after 28 days immersion of the specimens in MgSo4 solution and it's obvious that increasing the concentration of the NaCl solution causes decreasing in compressive strength.

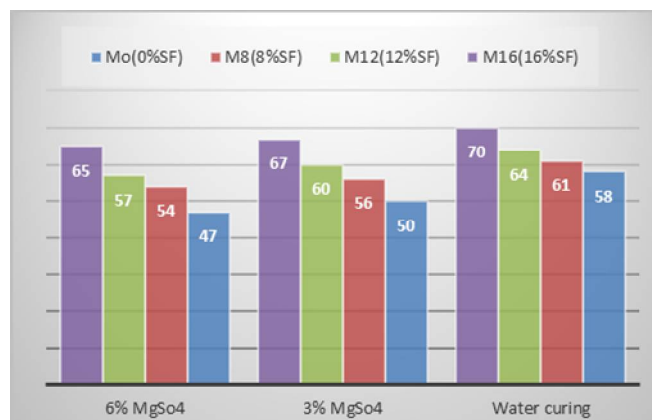


Figure 10: The effect of MgSo4 solution on compressive strength after 90 days

Figure 10 describe the effect on compressive strength after 90 days immersion of the specimens in MgSo4 solution and it's obvious that increasing the concentration of the NaCl solution causes decreasing in compressive strength. Adding silica fume as a mineral additive of 16% by weight of cement decreases the

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loss of strength than control mix at 28 and 90 days as follow: loss on strength decrease from 13.33% to 5.36% after 28 days and decreases from 18.96% to 7.14% after 90 days, as a result to 16% SF mineral additive by weight of cement, the rate of decrease on strength increased with increasing the duration of immersing in the sulphate solution, this is due to the deterioration of concrete. From Figure 9,10 the decrease in strength due to 6% of MgSo4 is higher than the decrease in strength due to 3% of MgSo4 as while the strength of solution increased, the strength of concrete decreased. sulphates react with calcium hydroxide and forming gypsum then reacts with the tricalciumaluminat to form ettringite and monosulphoaluminat. This reaction results in a substantial increase in volume and led to more loss on weight as shown from Table 11 but its still noted that loss on weight decreases as silica fume replacement percentage increases. it is suitable to use SCC instead of conventional concrete as it has a better resistance to sulfuric acids [12]. Partial replacing 20% of silica fume by weight of cement shows very good resistance to sulphate attack than conventional concrete, This is due to the improvement of micro structure and this is slightly coincide with our results due to using 16% SF [24]. The filler effects of silica fume resulting in fine and discontinuous pore structure. From our results its clear that effect of chloride is more harmful on concrete than sulphate effect and that's appear on rate of decrease for compressive strength and weight.

Table 11: The effect of MgSo4 solution on loss of weight for SCC Mixtures after 28 and 90 days

Mix No.	Test date / Loss of weight			
	Loss of weight after 28 days		Loss of weight after 90days	
	3% MgSo4	6% MgSo4	3% MgSo4	6% MgSo4
M0	0.8065	1.25	1.0946	1.9646
M8	0.6061	1.1694	1.0212	1.4658
M12	0.553	1.0788	0.9411	1.2097
M16	0.4825	0.7243	0.8839	1.0089

Water permeability

Water absorption

Water absorption measured for cylinder of height 100mm and diameter 50mm after 90 days of water curing as illustrated in Table 12 and Figure 11 as listed below.

Table 12: Water absorption test results

Mix	M0	M8	M12	M16
W.A%	2.075	1.26	0.836	0.467

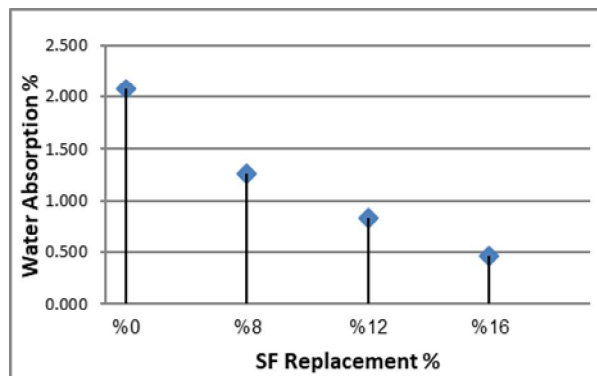


Figure 11: The relationship between SCC mixtures and water absorption after 90days

Figure 11 describes the ability of water to path through concrete from voids with different silica fume

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replacement contents.

Sorptivity

Sorptivity measured for cylinder of height 50mm and diameter 100mm after 90 days of water curing as illustrated in Table 13 and Figure 12 as listed below.

Table 13: Sorptivity test results

Mix	M0	M8	M12	M16
W.A%	1.688	1.125	0.75	0.75

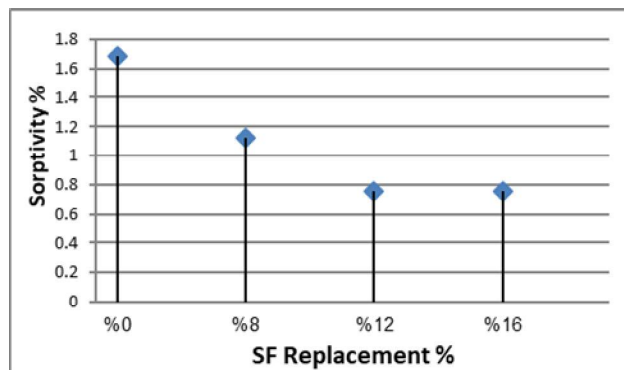


Figure 12: The relationship between SCC mixtures and sorptivity after 90days

Figure 12 describes the ability of SCC concrete for suction of water by capillary with different silica fume replacement contents. Silica fume has a great effect in decreasing the sorptivity and water absorption for SCC because of its fine particles. Its shown from Tables 4.28 and 4.30 that improvement in water absorption and sorptivity were 77.49% and 55.57% dut to increase silica fume percent to 16 % by weight of cement.Many researches were coincident with our results such as:

[26]who reported that silica fume significantly reduce the surface water absorption of self-compacting concrete at a water-binder ratio of 0.38, [4] who found that SCC mixtures with SF had the lowest sorptivity values followed by VTC, SCC with only PC and SCC with FA. Furthermore, the water sorptivity values of SCC specimens with SF decreased with increase in the replacement level of SF from 5 to 20%.

V. CONCLUSIONS

1. Addition of silica fume to concrete improves the durability of concrete through reduction in the permeability, refined pore structure, leading to a reduction in the diffusion of harmful ions, reduces calcium hydroxide content which results in a higher resistance to sulfate attack.
2. Incorporating of silica fume with different percentage 8, 12 and 16% by volume of cement decreases slump flow by 33% , 9.33% and 13.33% respectively and T50cm by 40%,60% and 92% respectively.
3. incorporating of silica fume with different percentages 8,12 and 16% by volume of cement increases passing ability by 5.26%,7.37% and 10.52% respectively and segregation resistance by 7.27% , 13.63% and 20 % respectively.
4. incorporating of silica fume with different percentages 8,12 and 16% by volume of cement increases compressive strength after 7 , 28 and 90 days by 13.80%,31.03% and 37.39% , 6.67 % ,13.33% and 24.44% , 5.17% ,10.34% and69 % respectively.
5. Adding silica fume with different percentages 8,12 and 16% by volume of cement increases tensile strength by 3.26%,6.51% and 20.84% respectively and flexural strength by 4.38% , 11.84% and 21.49 % respectively after 28 days.

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6. Increasing silica fume percent to 16 % by volume of cement led to decrease the loss in compressive strength for 0.4M of NaCl solution from 11.11% to 5.66 % after 28 days and from 17.24% to 7.14% after 90 days.
7. Increasing silica fume percent to 16 % by volume of cement led to decrease the loss in compressive strength for 0.8M of NaCl solution from 15.55% to 8.92 % after 28 days and from 24.14% to 10% after 90 days.
8. Increasing silica fume percent to 16 % by volume of cement led to decrease the loss in compressive strength for 3% of MgSo₄ solution from 8.88% to 3.57 % after 28 days and from 13.79% to 4.28% after 90 days.
9. Increasing silica fume percent to 16 % by volume of cement led to decrease the loss in compressive strength for 6% of MgSo₄ solution from 13.33% to 5.36 % after 28 days and from 18.96% to 7.14% after 90 days.
10. Adding silica fume with different percentages 8,12 and 16% by volume of cement decrease sorptivity by 33.35%,55.57% and 55.57% and water absorption by 39.27% , 59.71% and 77.49 % respectively after 90 days

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REFERENCES

- [1] Okamura, H., Ouchi, M., "Self-Compacting Concrete", Journal of Advanced Concrete Technology, vol 1, pp. 5-15 , 2003.
- [2] Dinesh, A., Harini, S, Jasmine, J. P., Jincy, J., and Javed, S., "Experimental Study on Self Compacting Concrete", International Journal of Engineering Sciences and Research, vol 6, 2017.
- [3] Sistonen, E., Fahim, A. N., "Self Compacting Concrete", 2015.
- [4] Turk, K., Karatas, M., and Gonen, T., "Effect of Fly Ash and Silica Fume on Compressive Strength, Sorptivity and Carbonation of SCC", KSCE Journal of Civil Engineering, vo 17, pp. 202-209 , 2013.
- [5] Bhanja, S., Senjupta, B., "Optimum Silica Fume Content and Its Mode of Action on Concrete", ACI Materials Journal, vol 100, 2003.
- [6] Cong, X., Cong, S., Darwin, D., and McCabe, S. L., "Role of silica fume in compressive strength of cement paste, mortar and concrete", ACI Mater. J, vol 89, pp. 375-387, 1992.
- [7] Paillere, A. B. " Effect of fibre addition on the autogeneous shrinkage of silica fumes concrete", ACI Material Journal, vol 86, pp. 139-144 ,1989.
- [8] Sakr, K., "Effects of silica fume and rice husk ash on the properties of heavy weight concrete", Journal Material Civil Engineering , vol 18, pp. 367-376 , 2006.
- [9] Xinjie, W., Pinghua, Z., and Qun, X., "Experimental Research on the effect of Silica Fume on Tensile Basic creep of Early-age concrete", The open Civil Engineering Journal, vol 9 , pp. 997-1001, 2005.
- [10] Siddique, R., "Utilization of silica fume in concrete: Review of hardened properties", Construction and Building Materials, 2011.
- [11] Kanellopoulos, A., Petrou, M. F., and Ioannou, I., "Durability Performance of Self-compacting Concrete", Construction and Building Materials, vol 37 , pp. 320-325 , 2012.
- [12] Persson, B., "Sulphate resistance of self-compacting concrete", Construction and Building Materials, vol 33, pp. 1933-1938, 2003.
- [13] Trezos, G., Sifkas, P. I., Paviou, D. I., "Water Permeability of Self Compacting Concrete", 3rd fib International Congress, Greece, 2010.
- [14] Subramanian, E.S., Arunkumar, P., Arul, N., "Strength and Durability Properties of Self-Compacting Concrete with Micro Silica and Nano Silica", International Research Journal of Engineering and Technology (IRJET), vol 4 , no 1, 2017.
- [15] Tholkapiyan, M., kumar, U. A., "An Experimental Study on Self-Compacting Concrete by Partial Replacement of Cement with Silica Fumes and GGBS", International Journal of Emerging Technology and Advanced Engineering, vol 7, 2017.
- [16] Johnsirani, K. S., Jagannathan , A., "Studies on Effect of Mineral Admixtures on Durability of Self Compacting Concrete", European Journal of Advances in Engineering and Technology, vol 2, pp. 87-94 , 2015.
- [17] Sabet, F.A., Libre, N. A., and Shekarchi, M., "Mechanical and Durability properties of self consolidating high performance concrete incorporating natural zeolite silica fume and fly ash", Construction and Building Mat J, vol 44 , pp. 175-184, 2013.
- [18] ES 4756-1, "Cement-Part 1: Composition, Specifications and Conformity Criteria for Common Cements", Egypt: Egyptian Organization for Standardization, 2013.
- [19] BS EN 197-1, "Cement - Part 1: Composition, specifications and conformity criteria for common cements", 2000.
- [20] ES 1109, "Aggregates for concrete". Egypt: Egyptian Organization for Standardization, 2008.
- [21] ASTM C494, "Standard Specification for Chemical Admixtures for Concrete", ASTM Standards, 2001.
- [22] G. A. Rao, "Investigations on the performance of silica fume-incorporated cement pastes and mortars", Cement and Concrete Research, vol 33, pp. 1765-1770 , 2003.
- [23] Khan, M. I., Siddique, R., "Supplementary Cementing Materials- Chapter 2 Silica Fume", 2011.
- [24] Karthick, M., Nirmalkumar, K., "Durability Properties of High Strength Self Compacting Concrete using Silica Fume and Quarry Dust", International Journal of Scientific Engineering and Applied Science (IJSEAS), vol 2, 2016.
- [25] Assem, H. A., Lachemi, M., and Hossain, K. M., "Effect of metakaolin and silica fume on the durability of self-consolidating concrete", Cement and Concrete Composites, vol 34, pp. 801-807, 2012.
- [26] Leung, H. Y., Kim, J., Nadeem, A., Jaganathan, J., and Anwar, M. P., "Sorptivity of self-compacting concrete containing fly ash and silica fume", Construction and Building Materials, vol 113 , pp. 369-375, 2016.