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Effect of Superplasticizer on the Properties of Sulfate Resistance Concrete

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Abstract

Today new applications of admixtures have been brought into the market for the production of high strength and flowing concretes, in this research, the chemical admixture used in sulfate resistance concrete is superplasticizer. Superplasticizers (SP) are commonly known as High Range Water Reducers because it permits low water-cement ratio as well as workability also affected. In this study, sulfate resisting Portland cement (SRC) and one family of superplasticizers have been used which it is sulfonated naphthalene formaldehyde (SNF) condensate and their effect on properties of fresh and hardened concrete has been studied and the properties of concrete inspected are slump test, setting time and compressive strength and slump test.

In this experimental work, we are comparing the properties of superplasticizer-based concrete with that without SP added to concrete, which used amounts of 700, 1000, 1500, 2000, and 2500 ml/100 kg of cement were prepared at constant water to cement (w/c) ratio of 0.54 % and a variable of w/c ratio the study the effect of the SP on the properties of concrete and to determine the optimum dosage of SP in concrete to improve the properties of concrete.

The results revealed that the effect of admixture on the properties of concrete is dependent upon its dosage which, workability, setting time, and compressive strength were increased by adding SP compared with concrete without SP..

Keywords: Superplasticizer; Sulfate Resisting Portland Cement (SRC); Workability; Setting Time; Compressive Strength.

1. Introduction

Concrete is the most widely used construction material which is heterogeneous and is composed of different ingredients like fine aggregate, coarse aggregate, cement, and water. Some additional ingredients such as additives and admixtures are also added for the improvement of its properties [1-3]. Concrete is the most highly consumed construction material around the world due to its high resistance against weathering action and freedom of casting into any shape. The demand for concrete is increasing every year due to the rapid infrastructure development of countries like China and India. Concrete is composed of cement, sand, stone, and water [4].

Concrete properties such as compressive strength, hardness, durability, workability, etc. vary with time. It has versatile behavior and can be molded into any shape. It is very important to evaluate the concrete properties at an early age to achieve construction quality [3, 5, 6].

While concreting in hot weather, both setting time and compressive strength are adversely affected.

To prevent concrete from the adverse effects of hot weather, admixtures are usually incorporated into it. A retarding admixture holds back the hydration process, leaving more water for workability and allowing sufficient time for the concrete to be placed, compacted, and finished. Superplasticizers (SP) are used to increase the workability without changing the water/ cement ratio, or they can be used to increase the ultimate strength of concrete by reducing water content while maintaining adequate workability [7].

The development and use of admixtures have greatly accelerated in the last two decades. Today, the commonly used admixtures in concrete technology can contain set retarding or set accelerating chemicals, which obviously will directly impact kinetics. Most concretes in developed countries also use cement dispersing agents, commonly called water-reducing or plasticizing admixtures. These water-reducing admixtures exhibit a more powerful dispersing capability and are called high-range water-reducing admixtures (HRWRA) or superplasticizers (SPs). These materials both increase workability and reduce the amount of agglomerated cement particles. These agglomerates can lead to low w/c regions, which limits cement hydration in those areas while

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allowing other regions to be higher than nominal w/c. Thus, SP can often lead to improving the strength and permeability even at equal w/c. If a water reduction is also taken, more substantial improvements in both are achieved. SP compositions may also include materials that directly impact hydration kinetics beyond the dispersion effects. Such admixtures frequently contain some combination of set retarding and accelerating components [8].

HRWRA are broadly classified into four groups, sulfonated melamine-formaldehyde condensates (SMF), sulfonated naphthalene-formaldehyde condensates (SNF), modified lignosulfonates (MLS), and polycarboxylate derivatives (PCEs) [9].

SNF dispersing agent was the first synthetic admixture [10]. Its dispersing ability has been shown to vary with cement composition [11-14].

Superplasticizers (SP) are an irreplaceable compound for construction chemistry in as much as they improve the workability and flowability of concrete and mortar. They can be used to produce modern products such as self-leveling compounds [15] and high-performance concrete [16]. When they are used in concrete a reduction of water content can result in improved mechanical properties [17].

High-range water reducers, also known as superplasticizers (SPs), are often added to OPC-based concrete to improve its rheology, workability, and mechanical properties [18-20].

It is a common practice to use SPs to improve the workability of OPC-based concrete with lower water content and achieve higher strength and durability.

There are several types of SPs commercially available, including lignosulphonates, naphthalene-based, melamine-based, and modified polycarboxylates [20]. In the last few decades, the effect and mechanism of SPs in OPC have been widely studied by many researchers [9, 21-25].

Sulfate attack often occurs in arid areas with highly concentrated sulfate in soils. When exposed to groundwater, external sulfates in the soil can be dissolved and cause damage to foundations, retaining walls, and other underground concrete structures [26, 27]. In addition to sulfate, other chemicals such as chloride ions, when penetrated through concrete, may accelerate the corrosion of steel reinforcement within concrete, and possess a serious threat to infrastructures [28].

Previous studies found a positive relationship between the tri-calcium aluminate (C_3A) content in Portland cement and the expansion of cement mortar and concrete [29]. The resistance of concrete to sulfate attack can be improved by using sulfate-resisting cement with a low C_3A content [30], or adding supplementary cementitious materials (SCMs) such as fly ash and slag [31].

Uchikawa [32] confirmed that SNF polymer is more particularly adsorbed on hydrated C_3A when the immediate addition procedure is adopted. The superplasticizer effect is improved with SNF delayed addition because of the lower adsorption of the polymer on the hydrated C_3A. Also, the fluidity of fresh cement paste prepared by later addition is improved due to the water fixed in the spaces inside the flocks of cement particles being decreased from its uniform dispersion. Thereby, water film which has a relatively uniform thickness is formed on the surface of cement particles. The setting of cement is further delayed by the later addition of SNF, the superplasticizer remaining in the mixing water after the initial setting consumes some of the calcium ions (Ca^{2+}) and decreases its concentration in the freshly prepared cement paste. Then, the final setting time is elongated.

Although SPs were developed and optimized to work in OPC-based mixtures, several studies have investigated the efficiency of SPs in conventional concrete OPC-based mixtures. However, studies on the effect of commercial SPs on the properties of concrete SRC-based mixtures are very limited.

2. Experimental Procedures

2.1. Materials

The materials used for experimentation in this study consisted of; cement, fine and coarse aggregates, water, and superplasticizer.

2.1.1. Cement

Sulfate Resisting Portland Cement (SRC) Type V 42.5N was provided by EL MYNIE Cement Company, Egypt is used in this study. This has the strength grade of 42.5 and it is produced in accordance with the ES 4756-1 2013 and BS EN 197-1/2011. The properties of the cement (SRC) are shown in Table1.

2.1.2. Fine aggregates

The fine aggregates are used from locally available natural sand quarry from Qeft, Qena, Egypt, are used as fine aggregate in the concrete design mix. The properties of fine aggregate are shown in Table2.

2.1.3. Coarse aggregates

The coarse aggregates are used from locally available natural sand quarry from Qeft, Qena, Egypt, the crushed aggregate limestone with two different particle sizes, such as 5–12 mm and 12–25 mm used in the experiments. The properties of coarse aggregate are presented in Table3.

2.1.4. Water

Water should be free from sewage, oil, acid, strong alkalis or vegetable matter, clay, and loam. The water used in the concrete is potable and is satisfactory to use. Properties of the water used are shown in Table4.

2.1.5. Superplasticizer

Sikament® R2008 superplastic sings, high range, water-reducing admixture was used in all concrete mixes, meeting the requirements ASTM C- 494 Type G and B.S. 5075. Sikament® R2008 was used as a superplasticizer because it is a high-range water-reducing admixture as well as non-hazardous and non-toxic under relevant safety and health issue. Sikament® R2008 is a highly effective superplasticizer with a set retarding effect for producing free-flowing concrete in hot climates. Sikament® R2008 is compatible with all types of Portland cement, including SRC (Sulfate Resisting Cement). The specifications of the SP investigated in this paper are presented in Table5.

Table1. The properties of the cement (SRC).

Cement Type	Chemical Properties									
	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	CaO %	MgO %	SO_3 %	Cl%	Free CaO%	L.O.I. %	I.R. %
SRC	19.69	4.35	4.53	56.15	1.32	2.62	0.04	1.00	3.45	1.53

Cement Type	Physical Properties						
	Setting Time		Blaine cm²/g	Hot Exp. mm	Compressive Strength		
	Initial min	Final h: min			2 Days N/mm²	7 Days N/mm²	28 Days N/mm²
SRC	191	03:50	3341	1.00	19.50	33.75	49.18

Table2. The properties of fine aggregate

Chemical properties of fine aggregate					
Aggregate Type	Size (mm)	Parameter	Results	Limits	Specification
Limestone	0–5	Cl %	0.044	Max. 0.06%	EN 1744-1/2009
		SO_3 %	0.034	Max. 0.4%	

Physical properties of fine aggregate				
Aggregate Type	Size (mm)	Specific gravity %	Volumetric gravity t/m³	Silt content %
Limestone	0–5	2.54	1.65	0.90

Table3. The properties of coarse aggregate

Chemical properties of coarse aggregate					
Type	Aggregate Size (mm)	Parameter	Results	Limits	Specificati
Limestone	5–12	Cl %	0.022	Max. 0.04%	EN 1744-1/2
	12–25	SO_3%	0.013	Max. 0.40%	

Physical properties of coarse aggregate				
Type	Aggregate Size (mm)	Specific gravity %	Volumetric gravity t/m³	Silt conte %
Limestone	5–12	2.61	1.37	**0.40**
	12–25	1.37	1.32	**0.16**

Table4. Properties of the water used

Parameter	Results	Limits as per IS8112-1989
pH	8.2	Min. 7
Chlorides (ppm)	14	Max. 500
Sulphates (ppm)	50	Max. 300
TDS (ppm)	176	Max. 2000

Table5. Chemical and physical properties of superplasticizer.

Test Parameter	Test Results
pH Value@ 20° C	8
Specific gravity@ 20° C	1.2
Solid Content (%)	39
Appearance	Dark Brown Liquid

2.2. Mixture Proportions

The experimental program performed was divided into two parts (Part I and Part II).

In Part I, six mixtures was prepared without and with different SP (SNF), w/c kept constant equal to 0.54 %. In this part, the letter 'B' shows the mixture having a superplasticizer, while the number written in the subscript shows the percentage of SP dosage. Mixture B0 does not contain any superplasticizer while mixtures B0.7, B1.0, B1.5, B2.0, and B2.5 contain 0.7, 1.0, 1.5, 2.0, and 2.5 % superplasticizer dosages respectively, these mixture proportions are as shown in the Table6

In Part II, six mixtures were prepared without and with different SP (SNF), w/c is a variable. Mixture S0 does not contain any superplasticizer while mixtures S0.7, S1.0, S1.5, S2.0, and S2.5 contain 0.7, 1.0, 1.5, 2.0, and 2.5 % superplasticizer dosages respectively; this mixture proportion is as shown in the Table7.

2.2.1. Mixing, Casting, and Curing of Specimens

The ingredients were weight batched and mixed using a specific procedure similar to that stated in the Egyptian Code specification.

This experimental study was based on normal strength concrete with characteristic strength of 250 kg/cm2 at 28 days. ACI mix design method (Volumetric) was followed for mix design and the volumetric ratio of ingredients (1: 1.61: 3.47) was selected.

This study will focus on normal strength concrete with characteristic strength of 250 kg/cm2 at 28 days, which used Sulfate Resisting Cement (SRC) as a binder, coarse aggregate is a mixture of two different particle sizes such as 5–12 mm and 12–25 mm at a ratio of 50 to 50% (So that the total is 1140 kg/m3), natural sand and superplasticizer.

Sikament® R2008 as superplasticizer. One control mix will be prepared without the use of any admixture.

To investigate the effects of superplasticizer, five additional mixes were prepared using admixture dosages of 700, 1000, 15000, 2000, and 2500 ml/ 100kg of cement, the water to cement ratio (w/c) was kept constant at 0.54 and six different (w/c) ratios, namely, 0.60, 0.56, 0.54, 0.52, 0.50, and 0.48, the quantities of mix proportion for one cubic meter of concrete is shown in Tables6 and 7, respectively.

Cement, fine aggregate, and coarse aggregates were first mixed in a dry condition for one minute and then mixed for 3 minutes after the addition of water and required superplasticizer dosages [33]. The temperature at the time of mixing was noted.

The concrete was mixed in a counter-current mixer with a maximum capacity of 0.04m3. Before batching, the mixer pan was wiped down with water to ensure that all of the mixing water was used to hydrate the cement. All dry materials were placed in the pan and mixed until uniform.

Water was added to the dry materials and then slowly added the superplasticizer to the concrete. Concrete was mixed for an additional 3 minutes after all materials had been added as they were mixing.

The thoroughly mixed concrete is filled into the mould and compacted in three equal layers. Excess concrete is removed with a trowel after proper compaction and the top surface is smoothened. The site program consisted of casting 150 × 150 mm concrete cubes, and then the specimens were demolded after 24hrs and were stored in a moist room in water at 23 ±2o C until the testing day. For each mix, six specimens were prepared and tested at 3, 7, 28, and 90 day ages for compressive strength in accordance with EN 12390-3 [34] standard. Three samples of every superplasticizer were tested for 3, 7, 28, and 90 days compressive strength (Fig.1). An automatic loading rate within the range of 0.04 MPa/s to 0.06 MPa/s was applied to the specimen until failure occurred (Fig.2). The capacity of the testing machine was 2000 kN maximum loading.

Fig.1: Cement concrete cubes in dry state

Fig.2: Test of cube specimen for compression strength contents

2.3. Properties of concrete and testing methods

2.3.1. Properties of concrete

The effect of superplasticizers on the properties of concrete will be investigated in the mixes with and without superplasticizers. Fresh properties that were determined included workability (slump) and the setting time. Hardened properties included the compressive strength that was determined at 3, 7, 28, and 90 days.

Table6. The mixture proportions with different SP (SNF), w/c kept constant

Mix ID	Cement kg/m³	Sand kg/m³	Course aggregate kg/m³	Water Ltr/m³	w/c	SP	
						%	Ltr/m³
B0	350	720	1140	190	0.54	0	0
B0.7	350	720	1140	190	0.54	0.7	2.5
B1	350	720	1140	190	0.54	1.00	3.5
B1.5	350	720	1140	190	0.54	1.50	5.3
B2	350	720	1140	190	0.54	2.00	7
B2.5	350	720	1140	190	0.54	2.50	8.4

Table7. The mixture proportions with different SP (SNF), variable w/c ratio

Mix ID	Cement kg/m^3	Sand kg/m^3	Course aggregate kg/m^3	Water Ltr/m^3	w/c	SP	
						%	Ltr/m^3
S0	350	720	1140	210	0.60	0	0
S0.7	350	720	1140	196	0.56	0.7	2.5
S1	350	720	1140	189	0.54	1.00	3.5
S1.5	350	720	1140	182	0.52	1.50	5.3
S2	350	720	1140	175	0.50	2.00	7
S2.5	350	720	1140	168	0.48	2.50	8.4

2.3.2. Testing methods

The slump with used SR cement is conducted using a slump cone for all samples of concrete without and with superplasticizers (SNF). The workability of each mixture was measured immediately after completion of the mixing process by determining the slump of hydraulic-cement concrete of freshly mixed Portland cement concrete and is a modification of ASTM C 143/C 143M.

The current practice of determining the initial setting time of concrete is based on ASTM C 403 [35]. The setting time was measured from the time that the water was added to the dry materials.

Cube specimens for compressive strength tests are conducted in accordance with the BS EN 12390- 3 [34].

Fourier transform infrared (FTIR) spectroscopy was carried out to identify the chemical and structural changes using (Model Bruker ALPHA II), it can be used to verify or identify unknown materials in a matter of min. The ART, DRIFT, and External Reflection modules give the flexibility to analyze a wide range of sample types. It can be integrated into routine sampling or used for more targeted identification and verification. FTIR data was recorded using 15 scans summation and equipped with a universal ATR, with a range from 400 up to 4000cm-1 and a resolution of 2 cm-1, to evaluate the shifting of functional groups, at Micro-Analytical central, Sohag University, Egypt.

3. Results and Discussions

3.1. Workability

We study the effect of superplasticizer (SNF) on workability (slump value) of concrete with used SR cement without and with superplasticizers (SNF), w/c the water to cement ratio of concrete was maintained at 0.54% and variable, with various dosages of superplasticizers (SNF). The results as tabulated in Tables 8 and 9, respectively. In Fig.3, it is clear; that the slump values of the concrete mixes increased gradually as the SP contents increased.

The control mix B0 had a slump value of 20 mm and its values were 100, 120, 190, 220, and 240 mm at B0.7, B1, B1.5, B2, and B2.5. These values are in good agreement with, as SP was added to concrete mixes, the rapid adsorption of SP molecules on cement particles cause strong dispersion, thus generating high fluidity of cement paste [36]. Also, the adsorption of admixtures, which contains SO3− group, on the surface of cement grains leads to electrostatic repulsion forces between cement grains. This leads to the prevention of the formation of flocculated structures and the consequent increase of the fluidity of the fresh pastes. The maximum water reduction increases as the dosage of the admixture increases, which reflects the role of these admixtures on the characteristics of the hardened cement pastes [37]. This factor may also be investigated in the future, to determine the optimum dosage of superplasticizer if the w/c ratio is maintained at a constant value of 0.54%.

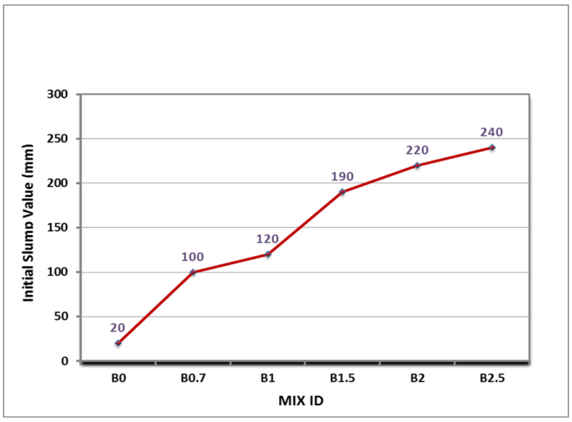

Fig.3: Effect of SP dosage on the initial slump of concrete with used SR cement at constant w/c ratio

From Fig.4, it has been observed that the slump value of is concrete enhanced with the addition of a superplasticizer with a variable w/c ratio, the slump increases by increasing dosages, and its values for control mix S0, S0.7, and S1 were 100, 180, and 200 mm, respectively. Then, the rate of increase diminishes with its addition beyond 1% of SP dosage, and then there was a kind of stability in the value of initial slump at 180 mm in both specimens S1.5, S2, and S2.5.

The optimum amount of superplasticizer must be 1% because, with an increase in the dose of more than 1%, the slump value remains constant, and this is considered an unnecessary cost. concrete with used SR cement at variable w/c ratio.

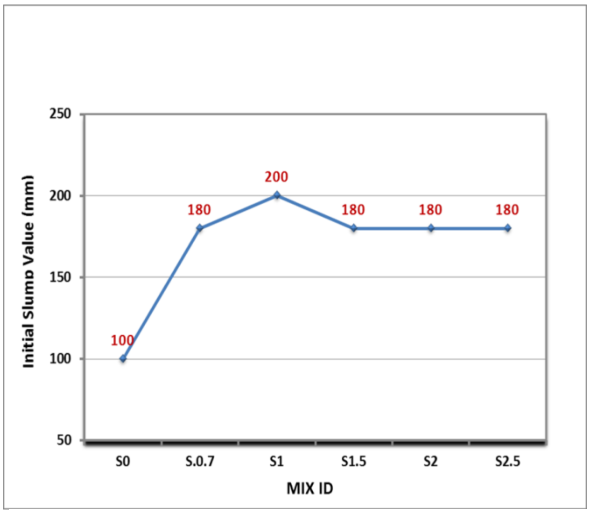

Fig.4: Effect of SP dosage on the initial slump of concrete with used SR cement at variable w/c ratio.

Table8: Variation of SP dosages versus initial slump and setting time at constant w/c ratio

Properties	B0	B0.7	B1	B1.5	B2	B2.5
Temperature (°C)	24	25	21	22	23	22
w/c (%)	0.54	0.54	0.54	0.54	0.54	0.54
Initial slump value (mm)	20	100	120	190	220	240
Initial Setting time (min.)	120	160	190	275	405	510
Final setting time(min.)	180	240	285	413	608	765

Table9: Variation of SP dosages versus initial slump and setting time at constant w/c ratio

Properties	S0	S0.7	S1	S1.5	S2	S2.5
Temperature (°C)	23	24	22	23	24.5	25
w/c (%)	0.60	0.56	0.54	0.52	0.50	0.48
Initial slump value (mm)	100	180	200	180	180	180
Initial Setting time (min.)	110	140	190	225	340	420
Final setting time(min.)	165	210	285	338	510	630

3.2. Setting time

The setting times (initial and final) of the mixes containing different SP dosages using SR cement when the water/cement ratio (w/c) is 0.54% (in the group B) and variable water-cement ratios (in the group S) are shown in Tables 8 and 9, respectively.

The results showed that the setting time of the mixes with SP was significantly extended compared to the mixes without any SP. According to Yamakawa [38], the SP will prolong the setting time of concrete, if the water/ cement ratio is maintained. Because more water is available to lubricate the mix. In groups (B and S), the initial and final setting times of the concrete mixture increase by increasing the SP dosages. Especially, in group B, this result is in good harmony with the findings of Yamakawa et al. [38], where superplasticizers have positive effects on concrete properties in their fresh and hardened forms. In the fresh form, using the superplasticizers decreases the bleeding inclination of the concrete due to the decrease in the w/c ratio, but if the w/c ratio retains, then the superplasticizer increases the concrete setting time because there is more water to plasticize the mixture.

Graphically, both the initial and final setting times in groups (B, S) are shown in Figs.5 and 6, respectively.

3.3. Compressive strength

The results of the compressive strength of the hardened concrete mix made of sulfate resisting Portland cement (SRC), without and with different SP ratios (SNF) at constant and variable w/c ratios are graphically represented as a function of hydration time in Fig.6 and 7, respectively. For all of the concrete mixes made, the compressive strength increases continuously with the age of hydration. This increase in strength is mainly attributed to the formation and later accumulation of the hydration products which act as binding centers between the remaining unhydrated parts of the cement grains. The hydration products of concrete mixes are mainly calcium silicate hydrates and Ca(OH)2 as well as hydrates of the aluminate phase.

Concrete compressive strength was determined using standard cubes at 3, 7, 28, and 90 days. Three specimens were tested each time and their average value was taken.

The compressive strength results of the investigated concrete mixes are given in Table10, with sulfate resisting Portland cement (SRC), with different SP and water-to-cement ratios constant at 0.54% in this investigation at 3, 7, 28, and 90 days.

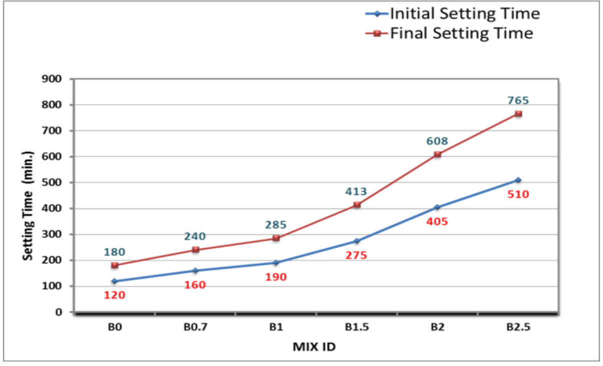

Fig.5: Effect of SP dosage on setting time (initial and final) of concrete using SR cement at constant w/c ratio is 0.54.

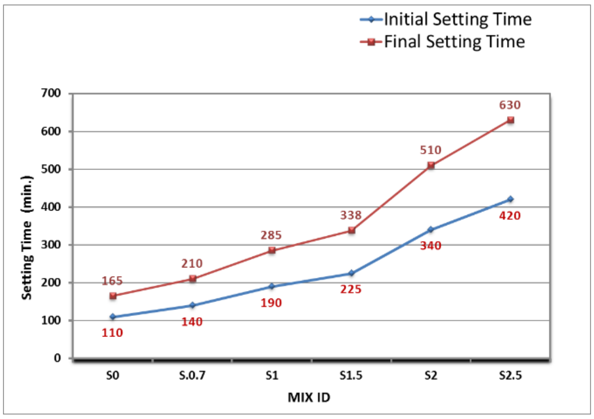

Fig.6: Effect of SP dosage on setting time (initial and final) of concrete using SR cement at variable w/c ratio.

In Fig.6, although the water-to-cement ratio is 0.45% in this investigation, the compressive strength values for the different superplasticizer dosages are higher than control mix B0 concrete.

The concrete compressive strength for control mix B0 at 3, 7, 28, and 90 days were determined as 130, 214, 341, and 371 kg/cm2, respectively, and its values increased as the SP dosages were added.

This is due to the increase in the rate and degree of hydration of cement at early ages resulting in higher early strength. On the other hand, the increase in the final degree of hydration achievable due to good dispersion of hydrating products is responsible for the increase in strength at later ages [40].

Then the concrete compressive strength values decreased at B1 "SP=1 % dosage" to become at 3, 7, 28, and 90 days were determined as 156, 241, 346, and 412 kg/cm2, respectively. And then increased again with increasing SP dosages reached to be the maximum at B2, the concrete compressive strength values were 212, 313, 396, and 426 kg/cm2 at 3, 7, 28, and 90 days, respectively. Finally, its values reduced at B2.5 "SP=2.5 % dosage".

The optimum dosage of SP is found based on the highest ultimate strength that they present at age 28 and 90 days. From the graph, we can observe that the optimum dosage for the admixtures is 2000 ml/100 kg of cement. Dosage lower or higher than this optimum value will reduce the compressive strength. Fig.7 presents the compressive strength of concrete mixes with sulfate resisting Portland cement (SRC) with different SP and with different water-to-cement (w/c) ratios.

At 3 days, the concrete compressive strength values increase by increasing the SP dosages were 159, 199, 213, 219, 261 and 268 kg/cm2 at S0, S0.7, S1, S1.5, S2, and S2.5, respectively.

By comparing the concrete mixes; the concrete compressive strength without any SP control mix (S0) was 24.76, 34.11, 37.87, 63.76, and 68.4 %, respectively higher than that of S0.

By comparing the concrete mixes, the concrete compressive strength at 7, 28, and 90 days without any SP, it was found that the compressive strength of S0.7 “SP dosage= 0.7 %” concrete was 30.63, 23.30, and 22.12 %, respectively higher than that of S0 “mixture without SP” concrete. While, by increasing the SP dosage, the rate of increase increases to become 32.88, 37.63, and 38.94%, respectively at S1 “SP dosage= 1 %” higher than that of S0.7 concrete. With the continuity of the increase of the SP dosage, the rate of increase decreases and becomes 22.97, 25.81, and 22.74 %, respectively at S1.5 “SP dosage= 1.5 %”, lower than that of S1 concrete, then the rate increases again until it reaches its maximum value at S2.5 to be 50, 35.13, and 36.76 %, respectively.

All of the previous results are in agreement that Naphthalene-based superplasticizers showed lower strength at early ages and a similar strength at ninety days [40]. From the above result and the comparison between S1 "SP= 1 %" and S2.5 "SP= 2.5 %", we found that the optimum dosage of the admixtures is 1000 ml/100 kg of cement because it has a higher value in the late days at 28, 90 day, although its value lower than in 3,7 days.

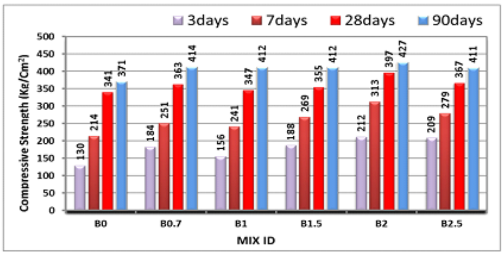

Fig.7: Comparison between compressive strength of various mixes with and without superplasticizer (NSF) by using SR cement at constant w/c ratio at 3, 7, 28, and 90days.

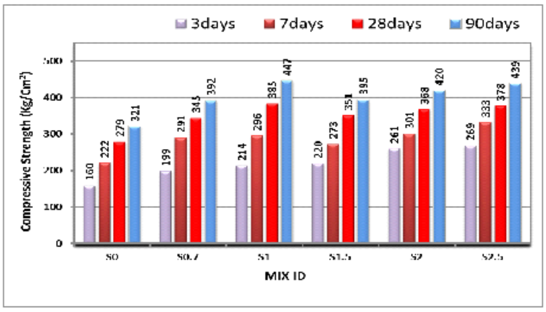

Fig.8: Comparison between compressive strength of various mixes with and without superplasticizer (NSF) by using SR cement at a variable w/c ratio at 3, 7, 28, and 90days.

Table10: Compressive strength of concrete at various percentages of SP dosage and the w/c ratio is constant at 0.54%

ID Mix	SP Dosage (%)	w/c	AV. Comp. Strength(kg/cm²)			
			3 days	7 days	28 days	90 days
B0	0	0.54	130	214	341	371
B0.7	0.7	0.54	183	250	363	413
B1	1	0.54	156	241	346	412
B1.5	1.5	0.54	187	269	355	411
B2	2	0.54	212	313	396	426
B2.5	2.5	0.54	209	279	366	411

Table11: Compressive strength of concrete at various percentages of SP dosage and the w/c ratio variable.

ID Mix	SP Dosage (%)	w/c	AV. Comp. Strength (kg/cm²)			
			3 days	7 days	28 days	90 days
S0	0	0.60	159	222	279	321
S0.7	0.7	0.56	199	290	344	392
S1	1	0.54	213	295	384	446
S1.5	1.5	0.52	219	273	351	394
S2	2	0.50	261	301	368	419
S2.5	2.5	0.48	268	333	377	439

3.4. IR spectrophotometric analysis

Fig. 9 shows the FTIR spectrum of the FTIR spectra of SNF condensate was used and its structure was confirmed by Mattson gensis, FTIR spectrometer in the range 400 – 4000 cm–1.

The main band characterizing the condensation process is the CH2 linkage, which appears as stretching vibration band at 2922 cm–1 and bending (scissors) vibration band at 1499 cm-1. Also, IR spectrum contains aromatic C–H stretching band at 3053 cm-1, aromatic ring modes at 1625 and 1596 cm–1 as well as sulfonate group bands at 1190, and 1031 cm–1. The other bands show: S=O stretching vibration band at 1347 cm–1, S–O group at 677 cm–1, C=C aromatic groups at 2366 cm–1.

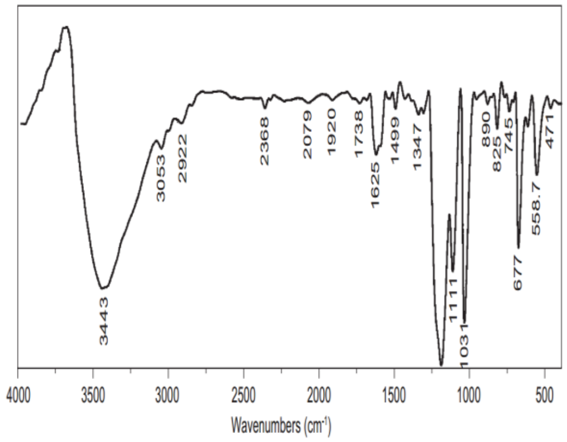

Fig.9: FTIR spectra of SNF

The FTIR spectra of cement paste specimens (B0, B1and B2.5) and (S0, S1, and S2.5) of different SNF dosages at the water to cement ratio (w/c) of concrete was maintained 0.54 % and variable for 90 days, respectively are illustrated in Fig. 10(a, b).

The small band at 3642 - 3643 cm-1 is attributed to the –OH group of Ca(OH)2. This band is very useful for diagnosis of the initiation of the hydration process [41] and follow-up the hydration kinetics.

Its intensity decreases with SNF dosage, due to the retardation effect of SP, which acts as chelating agent and reacts with Ca+2, holding their action via the chelation process [42]. This is illustrated by the fig. 10(a,b).

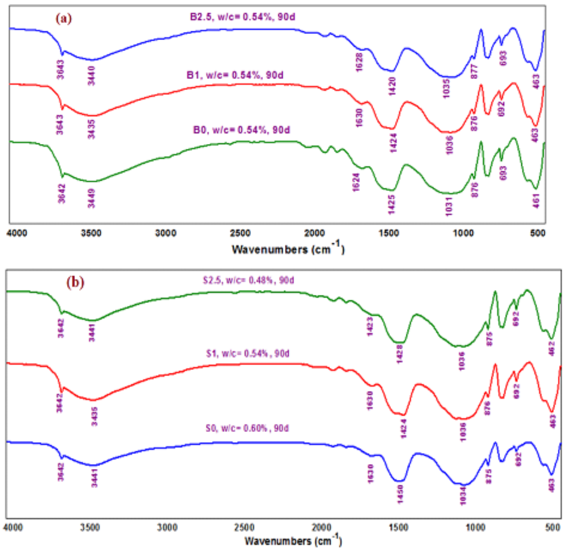

Fig. 10: FTIR spectra of concrete specimens (B0, B1and B2.5) and (S0, S1, and S2.5) of different SNF dosages at the water to cement ratio (w/c) of concrete was maintained 0.54 and variable for 90 days, respectively.

The broad band around 3400cm-1 and that observed at 1624 - 1630 cm-1 are assigned to the stretching and bending vibration of water-bound (H2O) in the hydration products [43], and by comparing the admixture dosages effect on the combined water content and compressive strength, it is evident that as the dosage of SNF increases, the combined water content decreases and the strength improvement enhances. This is confirmed by the results observed in fig. 10(a,b), when compared with the spectrum of B0, S0 "mixture without SP" with the spectrum of B1, B2.5 and S1, S2.5 in fig. 10(a,b), respectively, the spectra of B1, B2, and S1, S2 showed a decrease then increase in the intensity of absorption bands related to stretching vibration mode of O-H group at 3440-3449 cm-1 and 3435-3441 cm-1, respectively, this means that, the dosage of SNF increases, the compressive strength increase then decrease corresponding to the results of the compressive strength in the Tables10 and 11 and Figs 7 and 8 .

The C-O peaks at 875 and around 1400 cm–1 are occurring in all the samples as expected, and they are attributable to the presence of carbonates [44]. The intensity of that band decreases with SNF dosage, this is confirmed by the results from Fig. 10a, this band at 1425 - 1420 cm-1 of B0, B1and B2.5, respectively at (w/c) is constant at 0.54 and the band at 875 - 876 cm-1 of S0, S1and S2.5, respectively at (w/c) is variable.

The bands around 1031-1086 cm−1 are attributed to asymmetric stretching vibrations of the sulfonate group (SO42−) in gypsum which combined with C3A to form ettringite compound through CAH hydration which increased by the addition of NSF so that by increasing hydration strength increase.

The observed band at 450-492 cm-1 is due to bending vibration of Si–O bond in SiO4 tetrahedral [45], the intensity of that band increases with SNF dosage, due to the addition of NSF reaction and the formation of additional hydrated silicates. This is evident from the fig. 10(a,b).

4.Conclusions

This study investigated the effects of superplasticizer (SP) on the properties of fresh and hardened sulfate resisting Portland cement concrete. Concrete mixes were prepared without and with different SP (SNF) at constant and variable w/c ratios. The results revealed:-

- From the results of this study, the workability of concrete can be increased by the addition of a superplasticizer. However, very high dosages of SP tend to impair the cohesiveness of concrete.
- The measured value for initial and final setting time indicates that the control mix has the lowest value when compared with their corresponding mixes that contain SP.
- The results showed that all the concrete mixes with presences SP admixture exhibited improvement in

compressive strength compared with their corresponding mix that does not contain SP.

- The rate of the increase of compressive strength is improved by superplasticizer (SNF). Especially, its ultimate strength is higher than the early characteristic strength

5. Conflicts of interest

The authors declare that they have no conflicts of interest.

6. Recommendation

- The following are a few recommendations that can be done to further enhance the usefulness of the experiment:
- Since SP help to improve the properties of concrete, several factors should be taken into consideration:-
- Choose the type of superplasticizer admixtures well according to the desired improvement in the properties of the concrete.
- Knowing the type and analyses (chemical, physical) of the cement used.
- Conducting several experiments with different doses of the chemical admixtures and then deducing the best concentration of this chemical admixture that gives the best results for concrete.

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