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Evaluation of Superplasticizer Effects on the Properties of Workability and Water Absorption of Concrete Mixes

Randa Muddather Omar[1], Ali Eltoum Hassaballa[2], Mohammed Ahmed Ismaeil[3], Ayed Eid Alluqmani[4]

1Department of Civil Engineering, University of Gezira, Sudan

2Department of Civil Engineering, Jazan University, Jazan, KSA

3Department of Civil Engineering, University of Prince Mugrin, Madinah, KSA.

4Department of Civil Engineering, Islamic University in Madinah, Madinah, KSA

Corresponding Author: ahassaballa@jazanu.edu.sa

Abstract

In order to satisfy the needs of engineers and contractors, this research aims to examine the effects of superplasticizers on the qualities of workability and water absorption of concrete mixes when combined with local materials. The methodology used to accomplish the research's goals focuses mostly on data gathering from many sources, a thorough evaluation of prior studies, creating concrete mixes, and conducting several laboratory trials utilizing various ratios of superplasticizer with low water concentrations. By creating 12 cubes for each sample, the ratios of superplasticizer applied were 0.0 (as a reference mix), 0.4, 0.8, 1.2, and 1.5 liters/50 kg cement for concrete ages of 3, 7, and 28 days. Graded natural coarse and fine with local ordinary Portland cement (OPC) were used for all concrete mixes conducted in this research. The experimental findings showed that the ratio of superplasticizers with a reduction of 15% (w/c) to 50 kg of cement (0.8 liters) significantly improved the workability of concrete. Additionally, there has been great workability with the ratios of 1.5L per 50 kg of cement with a 30% reduction in water/cement and 0.4L per 50 kg of cement with a 10% reduction in water/cement. However, the absorption values exhibited no variations with respect to the SP or w/c content ratios that were utilized. According to the results, superplasticizers increase the workability of the concrete mix while lowering the water-cement ratio to improve its characteristics.

Keywords: Superplasticizer; workability; absorption; concrete mixes; (W/C) Ratio.

تقييم أثر الملدنات الفائقة على خاصيتي التشغيلية وامتصاص الماء للخلطات الخرسانية

رندا مدثر عمر[1]، علي التوم حسب الله[2]، محمد أحمد إسماعيل[3] وعايد عيد اللقماني[4]

1قسم الهندسة المدنية، جامعة الجزيرة، السودان.

2قسم الهندسة المدنية، جامعة جازان، جازان، المملكة العربية السعودية.

3 قسم الهندسة المدنية، جامعة الأمير مقرن، المدينة المنورة، المملكة العربية السعودية.

4قسم الهنسة المدنية، الجامعة الإسلامية، المدينة المنورة، المملكة العربية السعودية.

المؤلف المرسل: ahassaballa@jazanu.edu.sa

المستخلص

من اجل استيفاء متطلبات المهندسين والمقاولين، هدف هذا البحث لاختبار أثر الملدنات الفائقة على جودة التشغيلية وامتصاص الماء بواسطة الخلطات الخرسانية عندما تدمج بالمواد المحلية. المنهجية التي استخدمت للوصول لهدف البحث المنشود تركزت على الآتي: البيانات التي تم الحصول عليها من عدة مصادر، عبر تقييم الدراسات السابقة، عمل خلطات خرسانية، عمل عدة تجارب معملية بناءً على أخذ عدة نسب من الملدنات الفائقة وهي 0.0 (كنسبة مرجعية)، 0.4، 0.8، 1.2 و1.5 لتر لكل 50 كيلوجرام من الأسمنت ولخرسانة بعمر 3يوم، 7 يوم و28 يوم. في هذا البحث تم استخدام الركام المتدرج الخشن والناعم مع اسمنت بورتلاندي عادي. النتائج المعملية التي تم الحصول عليها أظهرت أن استخدام الملدنات الفائقة بنسبة تخفيض 15% من نسبة الأسمنت للماء لكل 50 كيلوجرام أسمنت (0.8 لتر)، تؤدي لتحسين تشغيلية الخرسانة بشكل ملحوظ. بالإضافة إلى أنه يوجد تشغيلية جيدة مع نسبة 1.5 لتر لكل 50 كيلوجرام من الأسمنت مع تخفيض بنسبة 30% من نسبة الماء للأسمنت و 0.4 لتر لكل 50 كيلوجرام من الأسمنت مع نسبة تخفيض 10% من نسبة الماء للأسمنت. مع ذلك فإن قيم الامتصاص لم تظهر أي تباين فيما يتعلق بالملدنات الفائقة أو نسبة الماء للأسمنت التي تم استخدامها. وفقاً لهذه النتائج يمكن القول إن الملدنات الفائقة تزيد من تشغيلية الخلطات الخرسانية بينما تقلل من نسبة الماء للأسمنت مما يحسن خصائصها.

كلمات مفتاحية: الملدنات الفائقة، التشغيلية، الإمتصاص، الخلطات الخرسانية، نسبة الماء للأسمنت.

Introduction

Admixtures are defined as additional materials for concrete constituents, i.e., cement, aggregates and mixing water, these constituents are added to the batch immediately before or during mixing (ASTM 125, 1999).

Superplasticizers are used in concrete to improve some properties of fresh and hardened concrete. These properties include, but not limited to, workability improvement, curing time increasing or decreasing, and increasing concrete strength. Sometimes admixtures are used to change the cement color.

A study on the dosage effect of superplasticizer on self-compacting concrete was reported by Benaicha *et al*. (2019) one of several researchers who examined the impact of superplasticizer on the properties of concrete mixes (the correlation between rheology and strength). Slump flow, V-funnel, L-box, yield stress, and plastic viscosity were employed to measure rheology. in addition to compressive strength, mechanical tests. The study's findings indicate that the tests had a strong correlation.

To assess the performance of self-compacting concrete using 10% fly ash substitution for cement in addition to varied doses of superplasticizer, Dumne(2014) investigated the effect of superplasticizer on the fresh and hardened properties of the material. The study found that the combination of fly ash and superplasticizer improved workability and raised compressive strength.

In an effort to determine the ideal superplasticizer dosages to improve concrete's strength and workability, Alsadey(2015) made an effort to research the impact of superplasticizer on the fresh and hardened qualities of concrete. Improved workability and compressive strength are the results of the research.

Superplasticizer impact in mineral dispersal systems based on quarry dust was assessed by Smirnova (2018). The compatibility issue was examined when this admixture was used with microfillers made from quarry dust from rock crushing.

Additionally, studies on the impact of superplasticizers alone or in combination with other admixtures on concrete mixes were undertaken by Saeed Ahmad *and* Elahi, Ayub (2005); Mbadike (2011); E., Alsadey (2012); Gayathri (2014); Fadhil Nuruddin *et al*. (2011).

Materials Used and Method of Testing

Cement

Ordinary Portland Cement (OPC), which complies with British Standards (BS 1996) is utilized in this study. It was tested for its physical characteristics, including as its standard consistency, start and final setting times, and compressive strength. It was discovered that 29% of the cement's weight came from the water absorbed via the routine consistency test. The beginning and final setting times of cement were experimentally determined using this amount of water. Table 1 displays the findings of the physical characteristics and compressive strength of cement mortar cubes aged 2 and 28 days. These studies' findings demonstrate that the cement utilized in this study complies with British Standards (BS 1296).

Aggregates

For this study, concrete mixtures were made using natural aggregates (both coarse and fine). The grade of aggregates to be utilized in concrete mixtures was investigated using sieve analysis tests. According to British Standards BS (1992); 882:1992 and (BS, 1992) 812-103, these tests were conducted. Tables (2) and (3), respectively, give the results for coarse and fine aggregate. The grading of coarse aggregate met BS 812-103.1 (882:1992), as shown in Table (2) and Fig. 1, whereas the grading of fine aggregate met BS 882:1992 and BS 812-103, as shown in Table (3) and Fig. 2.

Admixture used

The superplasticizer caplast super-special, which complies with ASTM C494 Type F (ASTM, C494) and BS 5075 Part III (BS, 1985) was utilized in this study as a water reducer. Utilizing this kind of admixture aims to decrease mixing water, provide excellent workability, and greatly boost compressive strength.

Results and Discussion

In this study, intensive laboratory tests were carried out to investigate the effects of the superplasticizer on the properties of fresh concrete (workability) and the water absorption of the concrete mix. Preliminary tests for local ordinary Portland cement and aggregate used in the research have been carried out. The ratios of superplasticizer added were 0.0 (as a reference mix), 0.4, 0.8, 1.2, and 1.5 liters/50 kg cement for concrete ages of 3, 7, and 28 days by preparing 12 cubes for each sample. The fresh concrete mixes were cast in standard test molds of 150 mm cubes,

whereas a standard slump cone of 300 mm high and 150 mm in diameter was used for measuring concrete slumps. The results of these experiments are shown in the following tables and figures:

Preliminary Tests Results of Cement

The results of the cement paste's physical characteristics and compressive strength are displayed in Table 1.

Table (1): Results of Preliminary Cement Tests

Test	**Results**	**Requirements of BS 12 1996**
Consistency	29.0%	26% -32%
Setting Time		
a. Initial setting time (min)	60	Not less than 60 min
b. Final setting time (hr)	3.17	Not more than 10 hrs.
Compressive Strength		
a. 2 days		
Sample-1	17.6 N/mm^2	Equal or Greater than 10 N/mm^2
Sample-2	17.2 N/mm^2	
Sample-3	17.32 N/mm^2	
b. 28 days		
Sample-1	45.6 N/mm^2	Equal or Greater than 42.5 N/mm^2
Sample-2	44.1 N/mm^2	
Sample-3	46.2 N/mm^2	

Results of Aggregate Tests

Natural fine aggregate was created in accordance with BS 5075-1:1982, while natural uncrushed coarse aggregate was created in accordance with British Standards BS (882:1992). The outcomes of the sieve analysis test for coarse aggregate conducted in accordance with BS 812-103 (BS 812-103.1: 1992) are displayed in Table 2. The greatest aggregate, which can be determined from Table (2), is 20 mm, and the sample appears to be well-graded, as Fig. 1's vivid illustration makes evident. The outcomes of the fine aggregate sieve analysis are displayed in Table 3 and Fig. 2.

Table (2): Results of Sieve Analysis of Coarse-Aggregate

B.S Sieve (mm)	Retained					%Age Passing	BS 812-103
	Sample (1)		Sample (2)		Average		
	Wt. (g)	(%)	Wt. (g)	(%)	(%)		
25	0	0	0	0	0	100	100
19.5	0.129	6.45	0.131	6.55	6.5	93.5	85 to 100
12.5	1.113	55.6	1.265	63.25	59.425	34.075	0 to 70
9.5	0.567	28.35	0.450	22.5	25.425	8.65	0 to 25
4.75	0.185	9.25	0.155	7.75	8.5	0.15	0 to 5
pan	**0.006**	**0.3**	**0.0**	**0**	**0.15**	**0**	**-**

Absorption Ratio % = (1002-1000)/1000 = 0.2%

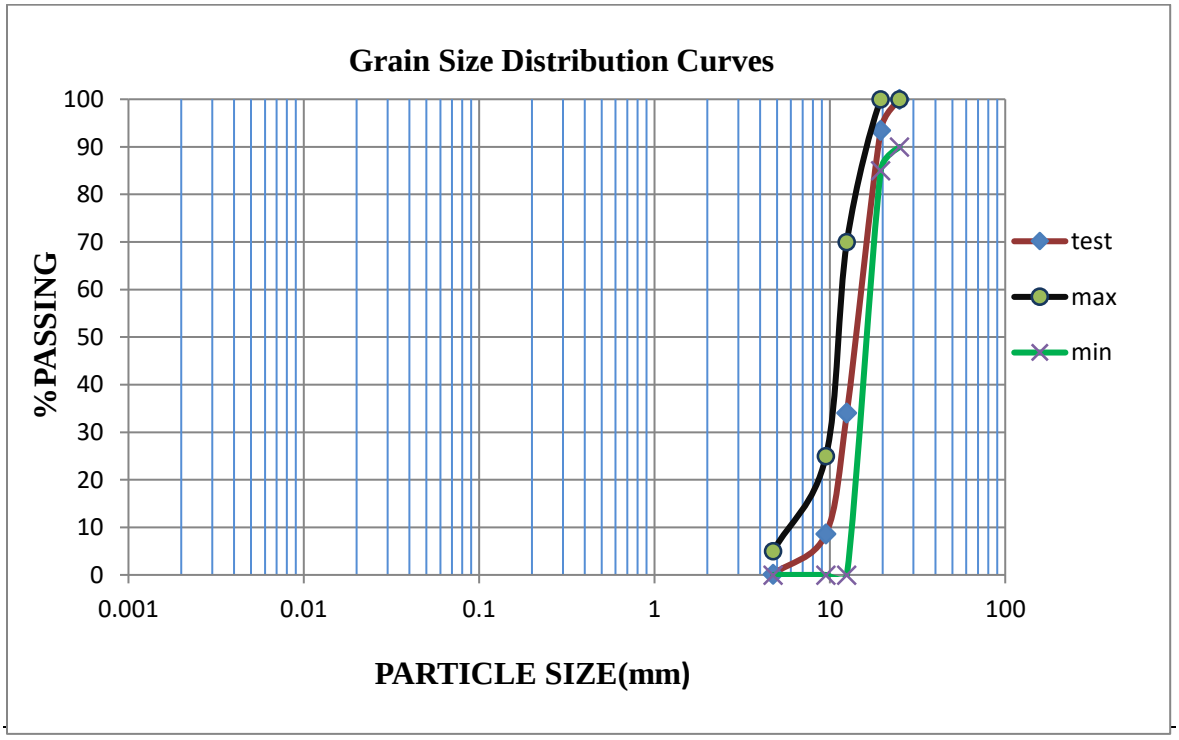

Figure (1): Grain Size of Coarse-Aggregate Test

From Figure (1), the distribution curves resulted in well-graded coarse aggregate.

Table (3): Results of Sieve Analysis of Fine-Aggregate Test

B.S Sieve (mm)	Retained					%Age Passing	BS 812-103
	Sample (1)		Sample (2)		Average		
	Wt. (g)	(%)	Wt. (g)	(%)	(%)		
4.75	0.016	1.6	0.019	1.9	1.75	98.25	89 to 100
2.36	.029	2.9	0.031	3.1	3	95.25	60 to 100
1.18	.0052	5.2	0.052	5.2	5.2	90.05	30 to 100
0.600	.0158	15.8	0.161	16.1	15.95	74.1	15 to 100
0.300	.0626	62.6	0.656	65.6	64.1	10	5 to 70
0.150	.0096	9.6	0.062	6.2	7.9	2.1	0 to 15a
0.075	0.023	2.3	0.019	1.9	2.1	0.4	-
pan		00	00	00	00	**00**	**00**

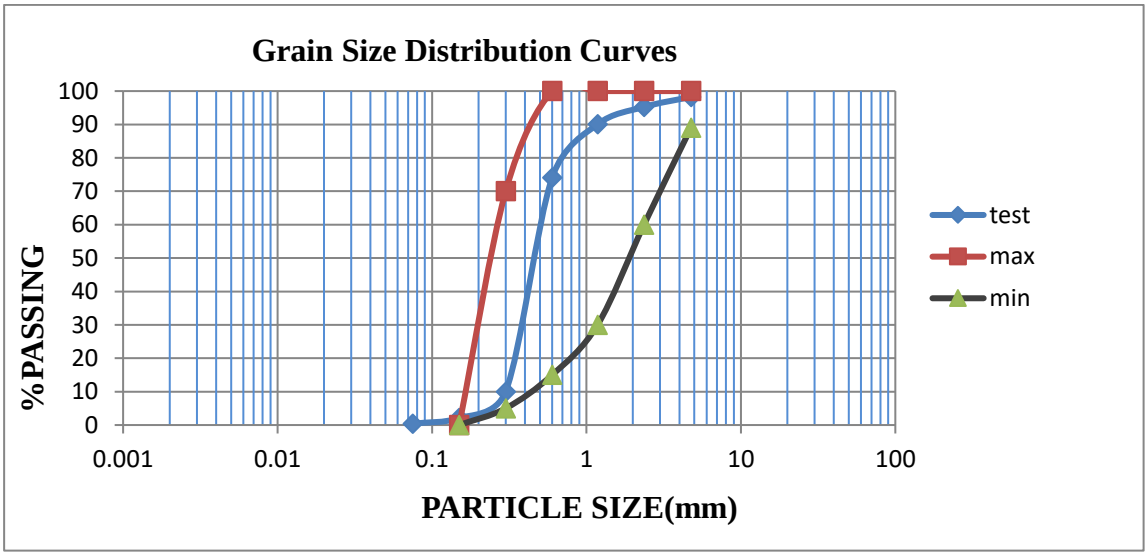

Figure (2): Grain Size of Fine-Aggregate Test.

Table (4): Fine Aggregate Silt Content

Sample	Sample 1	Sample 2
Total weight (g)	1000	1000
Weight after washing (g)	992	991
Silt and clay (%)	0.8	0.9

Results of Workability (Slump) for Fresh Concrete Tests

The equipment for the slump test is indeed very simple. It consists of a tamping rod and a truncated cone, 300mm in height, 100mm in diameter at the top, and 200mm in diameter at the bottom. To conduct a slump test, first moisten the slump test mold and place it on a flat, nonabsorbent, moist, and rigid surface. Then hold it firmly to the ground by foot supports.

Next, fill 1/3 of the mold with the fresh concrete and rod it 25 times uniformly over the cross section. Likewise fill 2/3 of the mold and rod the layer 25 times, then fill the mold completely and rod it 25 times. If the concrete settles below the top of the mold, add more. Strike off any excessive concrete. Remove the mold immediately in one move. Measure and record the slump as the vertical distance from the top of the mold to average concrete level.

Table (5): Results of Slump Improved by Superplasticizer (SP) Ratios and Water Reduction

Superplasticizer (SP) (Litre/50-kg Cement)	**0.0**	**0.4**	**0.8**	**1.2**	**1.5**
Water Reduction (%)	0	10	15	20	30
Slump (mm)	40	90	180	190	185

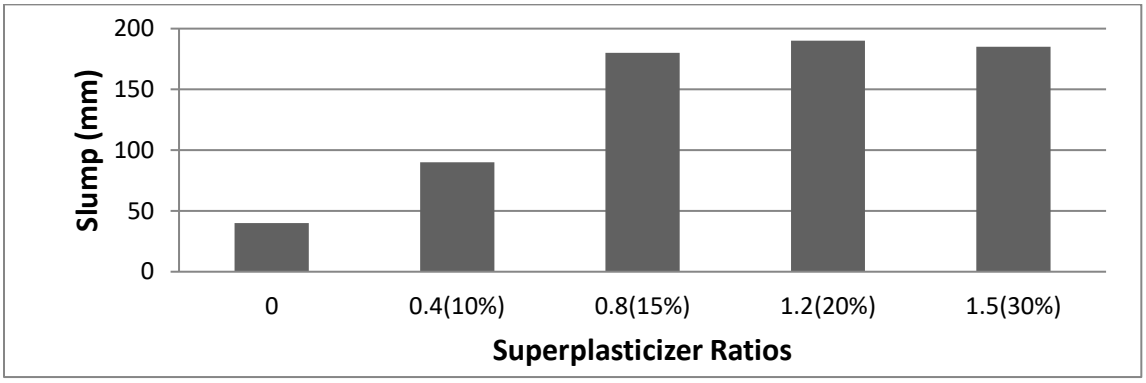

Figure (3): Relationship between Results of Slumps and Superplasticizer Ratios and Water Reduction

Table (5): Results of Slumps Improved by Superplasticizer Ratios with Water and Cement Reduction

Superplasticizer (Litre/50-kg Cement)	0.0	0.4	0.8
Water Reduction (%)	0	10	15
Cement Reduction (%)	0	10	15
Slump (mm)	40	50	85

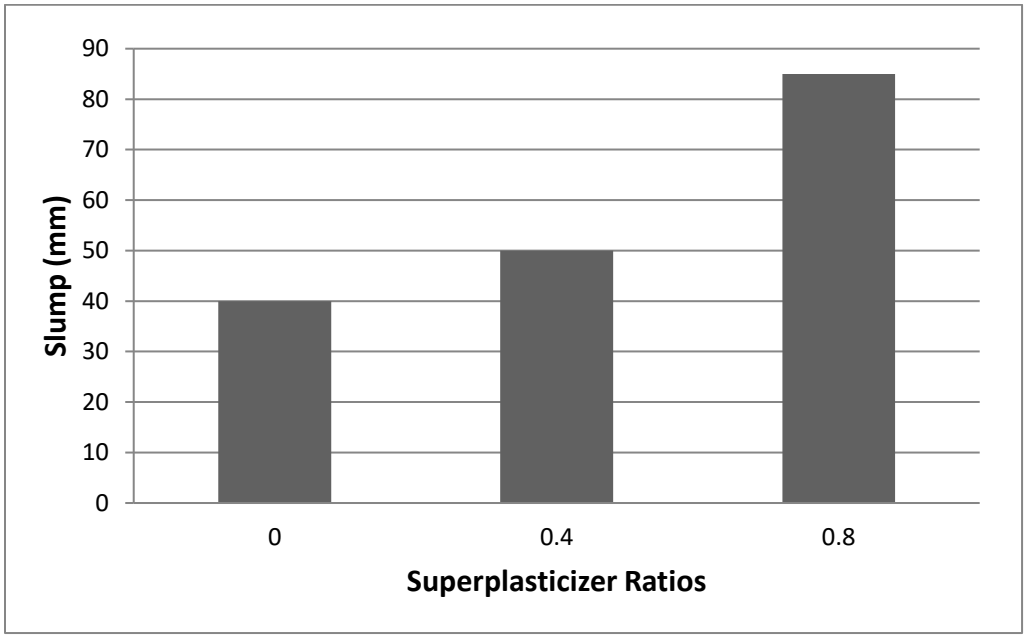

Figure (4): Relationship between Results of Slumps and Superplasticizer Ratios and Water & Cement Reduction.

Results of Concrete Water Absorption Tests

Drying the produced specimens until the mass was constant (WO). The specimens were then submerged for 28 days in clean water. The specimens were removed when the necessary immersion time had passed, the surfaces were swiftly cleaned with water, and they were then immediately weighed (W1), as shown in Tables 7–14. The following formula can be used to determine the rate of water absorption:

Water Absorption (%) = {(W1 – WO)/WO} *100.

Table (7): Results of Absorption after 28-Days: Control Mix

Cube No.	Initial Weight	Final Weight	Differences	Absorption
1	8.002	8.347	0.345	**3.42%**
2	8.021	8.251	0.23	
3	8.088	8.337	0.249	
Mean Weight	**8.037**	**8.312**	**0.275**	

Table (8): Result of Absorption after 28-Days: Superplasticizer Ratio = 0.4L/50-kg of Cement and 10% Water Reduction.

Cube No.	Initial Weight	Final Weight	Differences	Absorption
1	7.954	8.320	0.366	**3.33%**
2	8.283	8.492	0.209	
3	8.167	8.405	0.238	
Mean Weight	**8.135**	**8.406**	**0.271**	

Table (9): Result of Absorption after 28-Days: Superplasticizer (SP) Ratio = 0.8L/50-kg of Cement and 15% Water Reduction

Cube No.	Initial Weight	Final Weight	Differences	Absorption
1	8.032	8.333	0.301	**3.62%**
2	8.039	8.318	0.279	
3	8.203	8.501	0.298	
Mean Weight	**8.091**	**8.384**	**0.293**	

Table (10): Result of Absorption after 28-Days: Superplasticizer (SP) Ratio = 1.2L/50-kg of Cement and 20% Water Reduction.

Cube No.	Initial Weight	Final Weight	Differences	Absorption
1	8.326	8.624	0.298	**3.78%**
2	8.347	8.679	0.332	
3	8.365	8.683	0.318	

Mean Weight	**8.346**	**8.662**	**0.316**	

Table (11): Results of Absorption after 28-Days: Superplasticizer (SP) Ratio = 1.5L/50-kg of Cement and 30% Water Reduction

Cube No.	Initial Weight	Final Weight	Differences	Absorption
1	8.187	8.374	0.187	**2.21%**
2	8.352	8.548	0.196	
3	8.220	8.401	0.181	
Mean Weight	**8.253**	**8.441**	**0.188**	

Table (12): Result of Absorption after 28-Days: Superplasticizer (SP) Ratio = 0.4L/50-kg of Cement and 10% Water Reduction and 10% Cement Reduction

Cube No.	Initial Weight	Final Weight	Differences	Absorption
1	8.489	8.782	0.293	**3.95%**
2	8.220	8.545	0.325	
3	7.951	8.308	0.357	
Mean Weight	**8.220**	**8.545**	**0.325**	

Table (13): Result of Absorption after 28-Days: Superplasticizer (SP) Ratio = 0.8L/50-kg of Cement and 15% Water Reduction and 15% Cement Reduction

Cube No.	Initial Weight	Final Weight	Differences	Absorption
1	8.529	8.653	0.124	**1.44%**
2	8.391	8.518	0.127	
3	8.667	8.787	0.12	
Mean Weight	**8.529**	**8.653**	**0.124**	

Table (14): Effect of Superplasticizer (SP) Ratios on Absorption of Concrete Mixes for 28-Days of Age

No.	Dosage	Water Reduction (%)	Absorption (%)	Difference (Relative to Control Mix)	% Age Difference
1	0.0	0.0	3.42	3.42-3.42 =0	0
2	0.4	10.0	3.33	3.33-3.42 =-0.09	3 (decrease)
3	0.8	15.0	3.62	3.62-3.42=0.20	6 (increase)
4	1.2	20.0	3.78	3.78-3.42 =0.36	11 (increase)
5	1.5	30.0	2.21	2.21-3.42 =-1.21	35 (decrease)

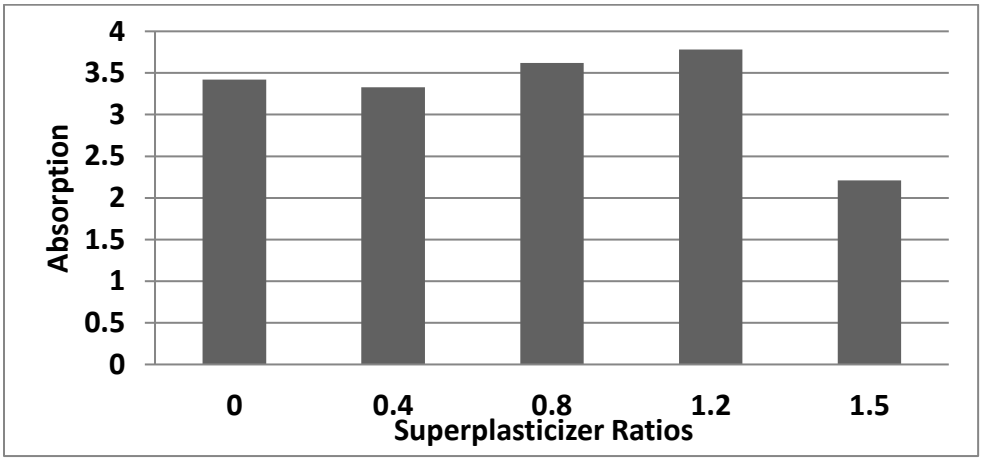

Figure (5): Relationship between Superplasticizer (SP) Ratios and Absorption of Concrete Mixes for 28-Days of Age

Table (15): Effect of (0.4 and 0.8) L/50-kg of Cement Superplasticizer, (10 and 15%) Water Reduction and (10 and 15%) Cement Reduction on Absorption of Concrete Mixes for 28-Days of Age.

No.	Dosage	Water Reduction (%)	Cement Reduction (%)	Absorption	Difference(Relative to control mix)	% Age Difference
1	0.0	0.0	0.0	3.42	3.42-3.42 = 0	0
2	0.4	10.0	10.0	3.95	3.95-3.42 = 0.53	15 (increase)
3	0.8	15.0	15.0	1.44	1.44-3.42 = -1.98	58 (decrease)

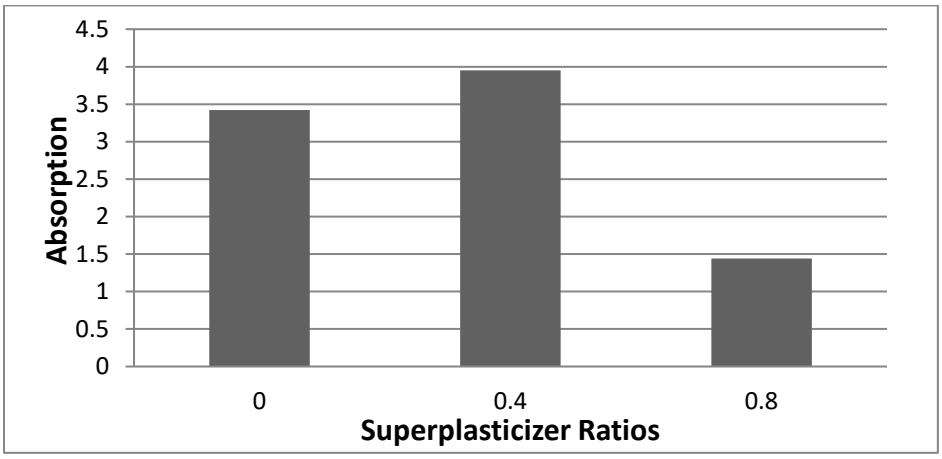

Figure (6): Absorption Concrete Mixes after 28-Days: Superplasticizer (0.4 and 0.8)L/50-kg of Cement, (10% and 15%) Water Reduction and (10% and 15%) Cement Reduction

Discussion of the Results:

Preliminary results of concrete constituents:

To ensure that the primary components of concrete (cement and aggregates) are sufficient and adhere to BS (British Standards) code requirements, laboratory tests were carried out. According to Table 1, which summarizes the findings of these preliminary tests, the cement utilized in this study conforms with BS 1296. Tables (2) and (3), respectively, give the results for coarse and fine aggregate. The grading of coarse aggregate met BS 812-103.1 (882:1992), as shown in Table (2) and Fig. 1, whereas the grading of fine aggregate met BS 812-103 and 882:1992, as shown in Table (3) and Fig. 2.

Workability

When admixtures were added to a common reference mix with a w/c ratio of 0.48, the slump test was utilized as a gauge of consistency. Slump values for standard reference mixes are 40 mm, while they are 90 mm, 180 mm, 190 mm, and 185 mm for mixes containing 0.4, 0.8, 1.2, and 1.5 L of superplasticizer per 50 kg of cement and reduced water by 10%, 15%, 20%, and 30%, respectively. A reduction in the slump in the proportion of 1.5 as a result of a significant reduction in the proportion of w\c compared with other ratios presented in Table (5) and Fig (3).

As indicated in Table 6 and Figure 4, slumps of mixes comprising (0.4 and 0.8 liters of superplasticizer per 50 kg of cement) reduced cement by 15% and water by 10%, respectively. While the workability of mixes combining admixtures and decreased cement was lower than that of blends containing only admixtures, it was still significantly greater than that of the common reference mix.

Water Absorption

Table (14) demonstrates that the values of absorption vary regardless of superplasticizer ratios or water reduction rates. Table (15) demonstrates that as superplasticizer ratios increased (0.4% and 0.8%) and cement and water contents reduced, absorption values decreased.

Conclusion

This investigation was done to find out how superplasticizer (SP) affected the characteristics of freshly-poured and hardened concrete.

Compressive strength and workability (slump) were the qualities that were examined. The study's findings lead to the following conclusions:

- In all ratios of this admixture added to concrete mixtures, superplasticizer had a substantial impact on the characteristics of fresh concrete.
- The slumps of mixes including ratios of SP with reduced water content were observed to range from 90 mm to 190 mm, which is significantly greater than the slump of the standard reference mix (40 mm) and almost twice as high as that of mixes containing SP with reduced water and cement (slumps reached up to 85 mm). However, very high doses of SP have a tendency to make concrete less cohesive.
- With regard to the applied ratios of SP or w/c contents, it was found that the absorption values did not exhibit any steady state alterations.

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