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Effect of cement content and water to powder ratio on the self-compacted concrete casted and cured in hot dry weather

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الملخص العربى :

نظرا لازدياد الاستخدامات للخرسانة الذاتية الدمك فى العديد من المشروعات ومع التوسع فى التنمية العمرانية فى الصحراء ظهرت الحاجة الملحة لدراسة خواص الخرسانة ذاتية الدمك المصبوبة و المعالجة فى الجو الحار حيث ان الخرسانة ذاتية الدمك تتاثر تاثر كبير بدرجة الحرارة حيث ان لها تاثير كبير على الخرسانة الطازجة وكذلك على خواص الخرسانة المتصلبة مثل مقاومة الخرسانة للضغط.

فى هذا البحث تمت دراسة خواص الخرسانة ذاتية الدمك المصبوبة و المعالجة فى درجات حرارة 30 و 40 درجة مئوية و تمت مقارنة خواصها بالخرسانة المصبوبة فى الظروف العادية حيث درجة الحرارة 20 درجة مئوية و معالجة فى رطوبة 100% . المتغيرات التى تمت دراستها نسبة الاسمنت فى الخلطة ونسبة الماء الى المواد الناعمة

اتضح من نتائج الاختبارات التى تمت فى هذا البحث ان درجة الحرارة لها تاثير مباشر وكبير على الخرسانة ذاتية الدمك سواءا فى حالتها الطازجة او المتصلبة وذلك لجميع الخلطات المختبرة

اظهرت النتائج انه عند زيادة درجة حرارة الخلطة لابد من زيادة محتوى الاسمنت فى الخلطة بحيث لا يقل عن 450 كجم / متر مكعب درجة حرارة الخلطة فى الخرسانة الذاتية الدمك يجب الا تزيد عن 30 درجة مئوية

يراعى ادراج تاثير درجة الحرارة الى الكود المصرى للخرسانة ذاتية الدمك ووضع معاير لتاثير درجة الحرارة عند الخلط و المعالجة

Abstract

Due to the increasing uses of self-compaction concrete in many projects and with the expansion of urban development in the desert, the urgent need to study the properties of self-compaction concrete, cast and curing in hot weather, has emerged as self-compaction concrete is greatly affected by temperature as it has a great influence on fresh concrete as well as on the properties of hardened concrete such as the concrete's resistance to compression.

In this paper, self-compaction concrete properties were studied . the tested specimens were casted and cured at temperatures of 30 ^{o}C and 40 ^{o}C. Its properties were compared to concrete casted and cured in normal conditions, where the temperature is 20 ^{o}C and 100% humidity. The variables studied are the cement content in the mixture and the ratio of water to the total powder. It became clear from the results of the tests conducted in this research that the temperature has a direct and significant effect on the self-compaction concrete, whether in its fresh or hardened state, for all the tested mixtures.

The results showed that when the temperature of the mixture was increased, the cement content of mix should be increased. so that it was not less than 450 kg / m^3, the temperature of mixes in self-compaction concrete should not exceed than 30 ^oC

The effect of temperature is further taken into account to the Egyptian code for self-compaction concrete, and calibrators are set for the effect of temperature during mixing and curing.

1-Introduction

Self-consolidating or self-compacting concrete often abbreviated SCC, may be one of the most significant concrete technology developments in many years. SCC (Self Compacting Concrete) is concrete with a specific mix proportion with very good workability that could make the concrete self-compacted, fill the narrow gaps between the bars, and fill all the space in the mold without using an either manual or mechanical vibrator. The main benefit of using Self-Compacting Concrete (SCC) stems from the fact that it has high workability and can be placed into formwork without vibration SCC offers several advantages in technical, economic and environmental terms. When comparing traditional concrete or Vibrated Concrete (VC), SCC has a larger paste volume, higher mineral admixtures content, and ratio of coarse to fine aggregates close to 1 to 1. The disadvantages of SCC are its cost, associated to chemical admixtures and high volumes of Portland cement. One alternative to reduce the cost of SCC is the use of mineral additives such as limestone powder, pozzolans and ground granulated blast furnace slag (GGBFS), which are finely ground materials added to concrete as separate ingredients either before or during mixing. (1-7)

Deserts occupy most Arabic countries, and the most constructions are in this area as in the new administrative capital in Egypt. The desert is characterized by high temperature and lack of humidity in the air. And given the importance of using compaction concrete in this atmosphere, the properties of self-compaction must be understood in these conditions characterized by high temperature and lack of humidity which be harmful to the properties of SCC

This article focuses on the effects of the hot climate on the concrete characteristics and the procedures of hot weather concreting on the properties of fresh and hardened self-consolidated concrete. The tested variables in this study were

The cement content and the water powder ratio in all mixes, the coarse agg. /total volume of concrete was 40 %, Fine/total aggregate 40 %, and the superplasticizer to the cement content ratio was 2.8%. All tested mixes were cast and cured at three temperatures, 20 ^oC, 30 ^oC, and 40 ^oC. The test program consists of 12 blends. Every mixture was cast and cured at three temperatures 20 ^oC, 30 ^oC, and 40 ^oC.

2 EXPERIMENTAL PROGRAM

2.1 Materials

Locally produced ordinary Portland cement was used. The chemical compound composition of ordinary Portland cement was; 45.8% C3S, 29.6% C2S, 9.6% C3A, and 8.5% C4AF, with a Blaine fineness of 3550 cm^2/gm. The compressive strength of cement was 294 and 372 kg/cm^2 after 3 and 7 days, respectively. Local gravel and sand obtained from natural source, the gravel has a specific gravity, bulk density, and nominal maximum size of 2.52, 1.54 ton/m^3, and 20.0mm. The sand agrees with the Egyptian standard specification No.1109 (second zone). The specific gravity, bulk density, and fineness modulus of sand were 2.56, 1.74 ton/m^3, and 2.66 respectively. Silica fume (SF) with a 20000 cm2/gm fineness, The chemical composition and physical requirements show that the silica fume conforms to ASTM C1240 specifications. Silica fume has 96.5% of SiO2.

2.1.1Test Methods

Slump-flow and T_{50} time test for self-compacting concrete was performed according to The European Guidelines for Self Compacting Concrete (8) For each concrete mixture, the compressive strength was determined on three cubes at 7and 28 days. The mean value of the three cube strength at a particular age was multiplied by 0.97 and considered as the strength. Table 1 show the constants of the tested mixes .

2.2. Preparation, Casting and Curing of Test Specimens:

All the concrete mixtures were mixed for 5 min in a laboratory counter – current mixer. Tests were conducted on fresh concrete mixtures to determine slump flow, flow time T_{50} and The test was performed within 10 min for all mixes. From each concrete mixture nine cubes 100x100 x100 mm, were cast for the determination of compressive strength after 7and 28 days

Table 1 The tested mixes

Mix no	Mix symbol	Cement content	Water/powder ratio
1	C1	400	0.4
2	C2	450	
3	C3	500	
4	C4	550	
5	WPR5	400	0.35
6	WPR6	450	
7	WPR7	500	
8	WPR8	550	
9	WPR9	400	0.3
10	WPR10	450	
11	WPR11	500	
12	WPR12	550	

3.. RESULTS AND DISCUSSION

3.1. Fresh concrete properties

3.1.1 Spread Flow Test

The slump-flow test judges the capability of concrete to deform under its own weight against the friction of the surface with no external restraint present. Because of the viscous nature of some SCC mixtures, the slump-flow measurements were carried out. There was no discernable movement of the concrete, approximately 60 seconds after removing the slump cone. The slump-flow values of the SCC mixtures were measured between 50 and 75 cm, which refers to the mean spread diameter of concrete following the removal of slump cone as specified by ERMCO [8].

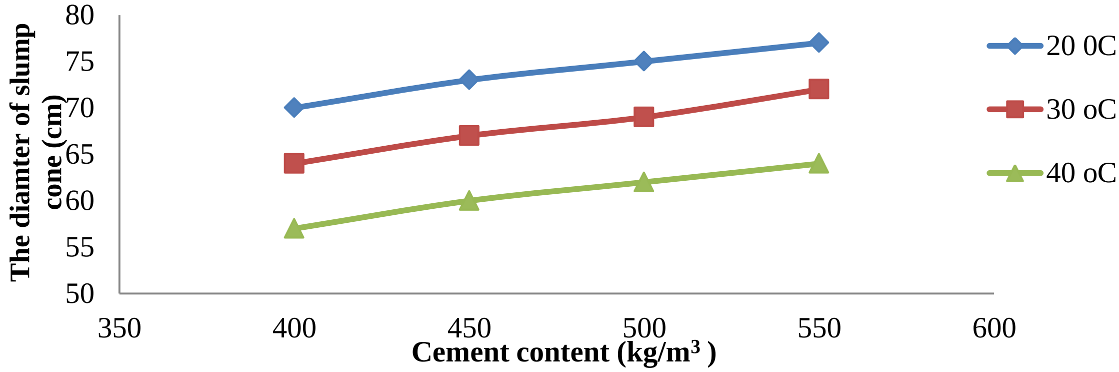

Figure6. The effect of cement content on the slump diameter at different temperatures.

From figure 1 it is clear that the cement content has a considerable effect on the SCC properties. This effected is reflected on the diameter of the slump. The relationship between the cement content and the diameter of the slump cone is a direct relationship at all the temperatures at which the mixers were tested. At temperature of 20 ^{o}C the diameter of slump cone was about 70 cm when cement content increased by 50 kg /m^{3} the diameter of slump cone increased by about 3 cm. The relation between cement content and the diameter is approximately is linear relation. When the temperature of the mixture is raised to 30 ^{o}C, the relationship continues between the cement content and the diameter of slump cone. But in mixes have the same cement content the diameter was lesser.When the temperature of the concrete mixture increases, the diameter of slump is decreases. The rate of decrease in the diameter of the cone increases as the cement content increases. The higher the temperature of the mixes, the lower the cone diameter for mixes containing the same cement content. The higher the temperature of the mixture, the decrease in the diameter of the slump cone is greater .The higher the cement content, the rate of the decreasing in the cone diameter is greater for the same temperature difference. The decrease in slump cone diameter is more pronounced in cement-rich mixtures at high temperatures. When the temperature of mixes increased from 20 ^{o}C to 30 ^{o}C the decrease of the slump diameter were 6,6,6 and 5 cm for mixes have 400, 450, 500 and 550 kg/m^3 cement content respectively . For the mixes have temperature of 40 ^{o}C , The decreases of the slump diameter were about 13 to 11 cm for mixes have cement content of 400 and 550 kg/m^3 respectively . It is clear that the lack of the SCC workability with the increase in the temperature of the mixture and also with the increase of the cement content due to the increase in the speed of the interaction between the cement and the water, which causes the release of hydration heat, which leads to the rapidity of water evaporation and the lack of workability Another important note is that the mixture at a temperature of 40 °C, which contains cement 400 kg / m^3, does not meet the standard cone diameter required in the Egyptian Code for self-compaction. Therefore, the cement content must be not less than 450 kg / m^3 when pouring self-compaction concrete with a ratio of water to powders of not less than 0.4 at high temperature more than 30 °C. The same effect are clear on the T_{50} too.as shown in table 2 .

3.2 Effect of the water powder ratio on fresh properties of the SCC mixes.

To study the effect of the water powder ratio on fresh properties of the SCC mixes. Many mixes were tested. the tested mixes have three w/p ratio and have 0.4, 0. 35 and 0.30 water powder ratios as shown in table 2

Table 2 show the components of the tested mixes

Mix no	Mix symbol	Cement content	Water/powder ratio	The diameter of slump (cm) and D_{50} (second) of SCC at different temperatures					
				T=20 ^{o}C		T=30 ^{o}C		T=40 ^{o}C	
				D	T	D	T	D	T
1	C1	400	0.4	70	2.5	64	3.5	57	6.9
2	C2	450	0.4	71	2.5	64	3.6	61	3.6
3	C3	500	0.4	74	2.1	67	3.0	60	3.9
4	C4	550	0.4	77	2.1	66	2.6	62	3.5
5	WPR5	400	0.35	66	2.6	62	2.8	56	4.3
6	WPR6	450	0.35	68	2.7	63	3.1	54	5.1
7	WPR7	500	0.35	71	2.4	66	3.1	59	6.5
8	WPR8	550	0.35	73	2.1	67	2.7	60	3.3
9	WPR9	400	0.3	61	3.1	53	6.1	48	-
10	WPR10	450	0.3	63	3.2	55	5.7	51	5.8
11	WPR11	500	0.3	67	3.5	61	3.8	53	5.7
12	WPR12	550	0.3	70	3.1	63	3.7	55	6.1

of water to powder When the mixture temperature is increased to 30 ^{o}C and 40 ^{o}C, the linear proportionality does not continue and the relationship line decreases downward . When the temperature of the mixture is increased to 30 ^{o}C and 40 ^{o}C, the linear proportionality does not continue, and the relationship line decreases to the bottom, meaning that the rate of increase in the diameter of the cone becomes less with the increase in temperature, and this means that the efficiency of increasing the water becomes lower at higher temperatures. . The effect of w/p ratio with different temperature with cement content of 400 kg/m^3 shown in table 2 and illustrated in figure 2.

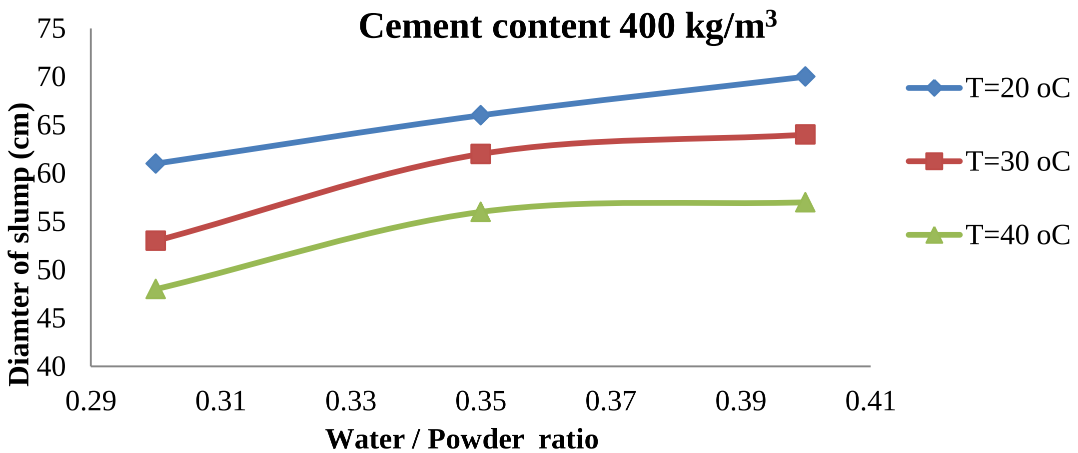

Figure 7. The effect of w/p ratio with different mixes temperature with cement content of 400 kg/m^3.

The figure shows that increasing the ratio of water to powder leads to an increase in the diameter of the cone. In all mixtures and in all mixtures to have different temperatures. The rate of the increase in the diameter of the cone was different depending on the ratio of water to the powder, the temperature of the mixture, and the cement content .Figure 2 shows the relationship between the diameter of the cone and the ratio of water to powder content for mixtures containing kg per cubic meter at different temperatures. And it is clear that the effect of increasing the ratio of water to powders is clearly visible in the mixture that has a temperature of 20 °C. The diameter of the cone is almost linearly proportional to the water powder ratio of all mixes .

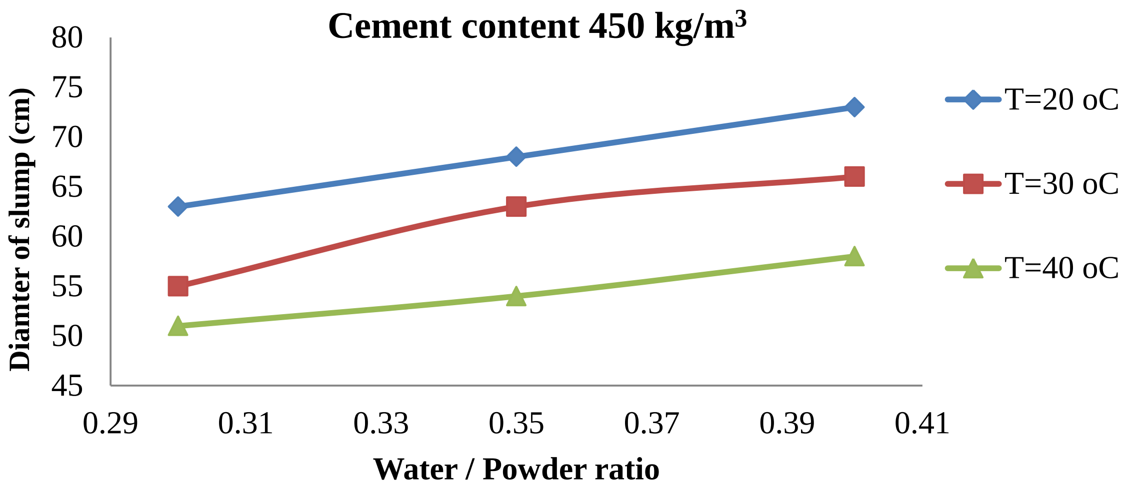

Figure 8. The effect of w/p ratio with different mixes temperature with a cement content of 450 kg/m^3.

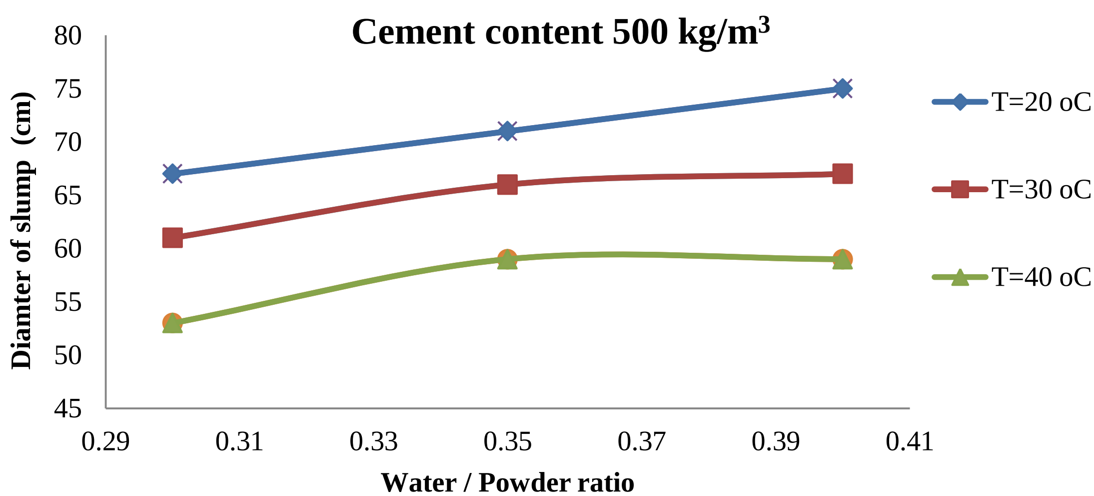

Figure 9. The effect of w/p ratio with different mixes temperature with a cement content of 500 kg/m^3.

This phenomenon appears clearly as the cement content increases in the mixture, the higher the temperature of the mixture, and Figures 2, 3 and 4 illustrate this phenomenon. Whereas, with increasing temperature and cement content, free water becomes less involved in pioneering workability as the mixture loses a greater part by evaporation when the temperature rises.

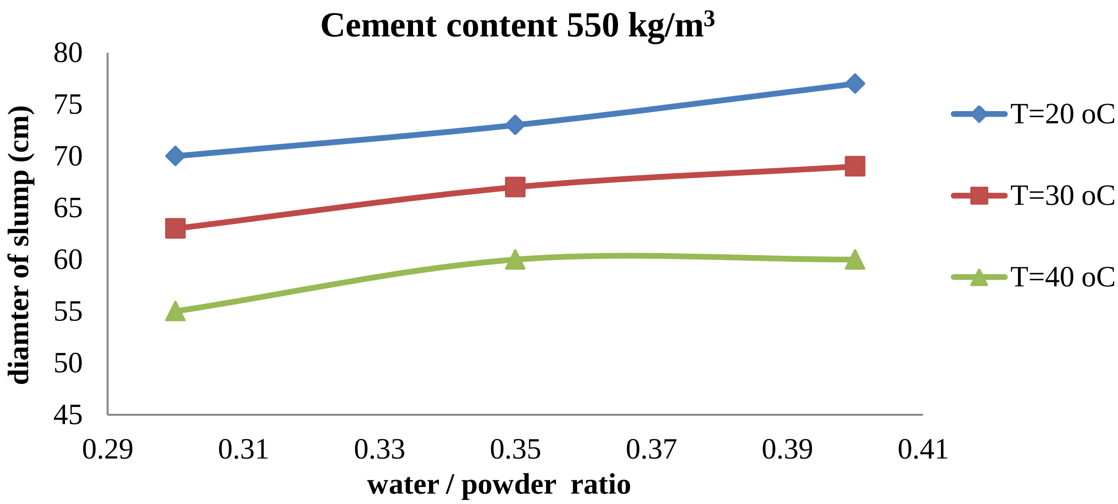

Figure 10.The effect of w/p ratio with different mixes temperature with a cement content of 550 kg/m^3.

We arrive at this point to conclude that the higher the temperature of the mixture, its properties become less efficient. Therefore, attention must be paid to the need not to raise the temperature of the mixture to obtain natural properties, especially when increasing the cement content in SCC.

3.2.1 Effect of water powder ratio on the compressive strength of SCC casted and cured in normal and dry hot weather having 400- 550 kg/m^3 cement content

The results showed that the samples cured in hot dry weather reduce The compression strength of concrete, since for mixtures with a cement content of 400 kg / m^3, the compressive strength after 7 days was 92% and 84% of the specimens compressive strength cured at 20 °C for samples cured at 30 °C and 40 °C respectively. After 28 days. The compressive strength was 92% and 72% for mixtures in which the ratio of water to powder = 0.4. For mixtures in which the ratio of water to powders = 0.35 and the same content of cement = 400 kg / m^3, the compressive strength was achieved by 88% and 84% after 7 days when cured at 30 ^{o}C and 40 ^{o}C respectively, and after 28 days of curing the compressive strength was achieved. 84% and 68% of concrete strength under normal conditions. For mixtures in which the ratio of water to powders = 0.3 and the same content of cement = 400 kg / m^3, the resistance achieved 89% and 75% after 7 days when treated at temperatures of 30 ^{o}C and 40 ^{o}Celsius, respectively.

Table 3 the compressive strength of SCC at age of 7and 28 days of mixes have cement content of 400 kg/m^3 and different water powder ratio .the specimens were casted and cured at different temperature

W/P	T=20 °C				T=30 °C				T=40 °C			
	7day	+%	28 day	+%	7day	+%	28 day	+%	7day	+%	28 day	+%
W/P 0.4	302	100	372	100	278	100	342	100	254	100	265	100
Relative Fc %	100		100		92		92		84		72	
W/P 0.35	346	114.5	394	106	295	6.1	361	105.6	269	6	276	104.1
Relative Fc %	100		100		85.3		91,4		77.7		70	
W/P 0.3	379	109.5	446	119	311	5.4	402	111.2	276	2.7	285	103.3
Relative Fc %	100		100		82		90		73		68.5	

+% the relative strength % of fc at 20 °C temperature.

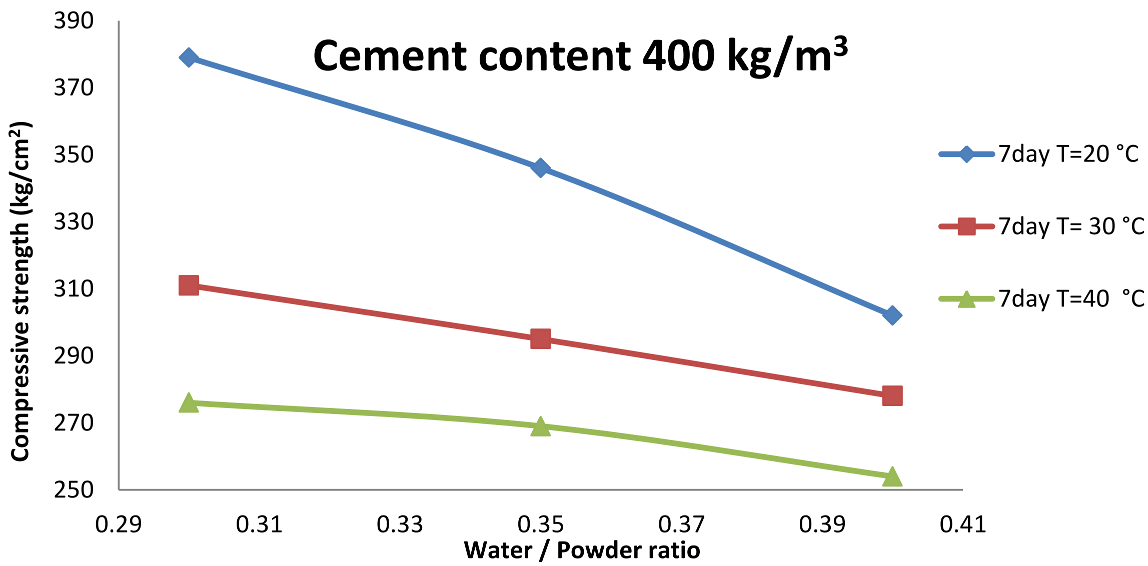

Figure 6. the effect of the water powder ratio on7 day age compressive strength of SCC at age of 7day, having 400 kg/m^3 cement content at different temperature

Table 4. The compressive strength of SCC at age of 7and 28 days of mixes have cement content of 450 kg/m3 and different water powder ratio .the specimens were casted and cured at different temperature

W/P	T=20 °C				T=30 °C				T=40 °C			
	7day	+%	28 day	+%	7day	+%	28 day	+%	7day	+%	28 day	+%
w/p 0.4	322	100	427	100	268	100	376	100	268	100	285	100
Relative FC %	100		100		83		88		83		66.7	
w/p 0.35	371	115	456	106	328	122	384	102	291	109	312	
Relative FC %	`100		100		88		`84		84		68	
w/p 0.3	411	111	498	109	368	112	402	107	310	107	334	107
Relative FC %	100		100		89		81		75		67	

+% the relative strength % of fc at 20 °C temperature.

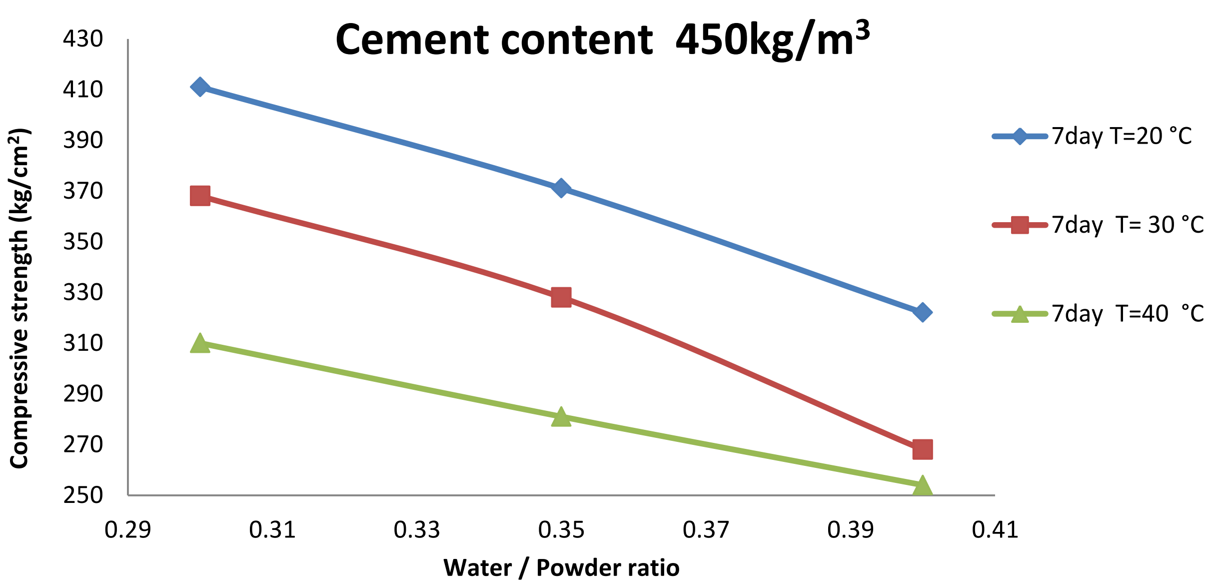

Figure 11. the effect of the water powder ratio on the compressive strength 0f SCC at age of 7 day , having 450 kg/m^3 cement content at different temperature

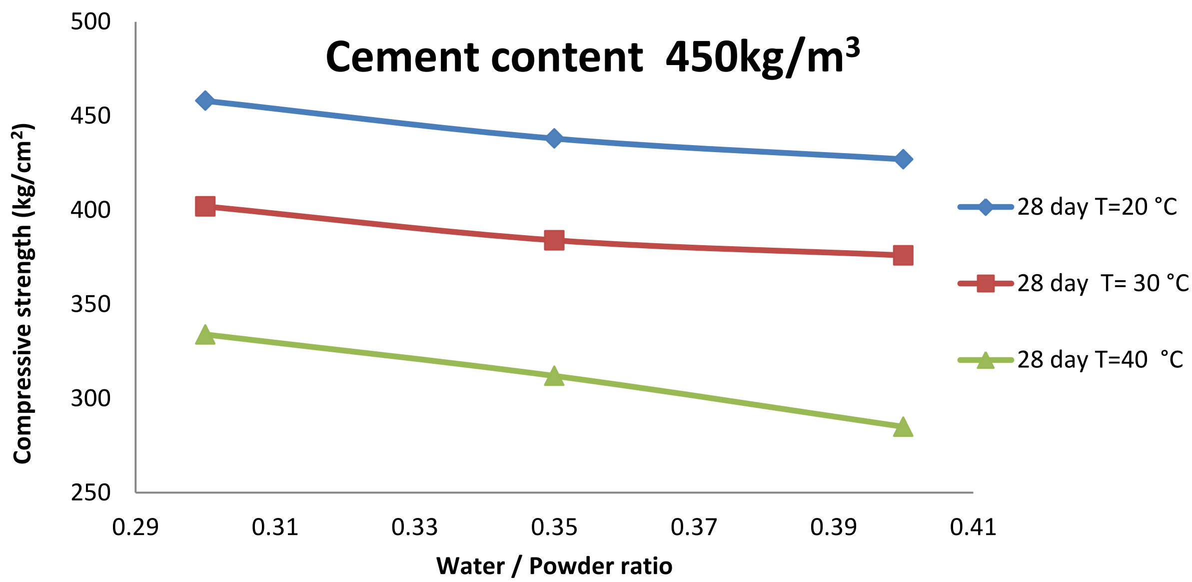

Figure 8. the effect of the water powder ratio on the compressive strength 0f SCC at age of 28 day , having 450 kg/m^3 cement content at different temperature

Table 5 the compressive strength of SCC at age of 7and 28 days of mixes have cement content of 500 kg/m^3 and different water powder ratio .the specimens were casted and cured at different temperature

w/p	T=20 °C				T=30 °C				T=40 °C			
	7day	+ %	28 day	+%	7day	+%	28 day	+ %	7day	+ %	28 day	+ %
0.4	353	100	411	100	324	100	351	100	283	100	309	100
Relative FC %	100		100		91		85		89		75.2	
0.35	414	117	487	115.2	361	111	412	117	303	107	332	107
Relative FC %	100		100		87		84		73		68	
0.3	469	114	561	115	423	117	481	117	343	113	392	118
Relative FC %	100		100		90		85		73		70	

+% the relative strength % of fc at 20 ^{o}C temperature.

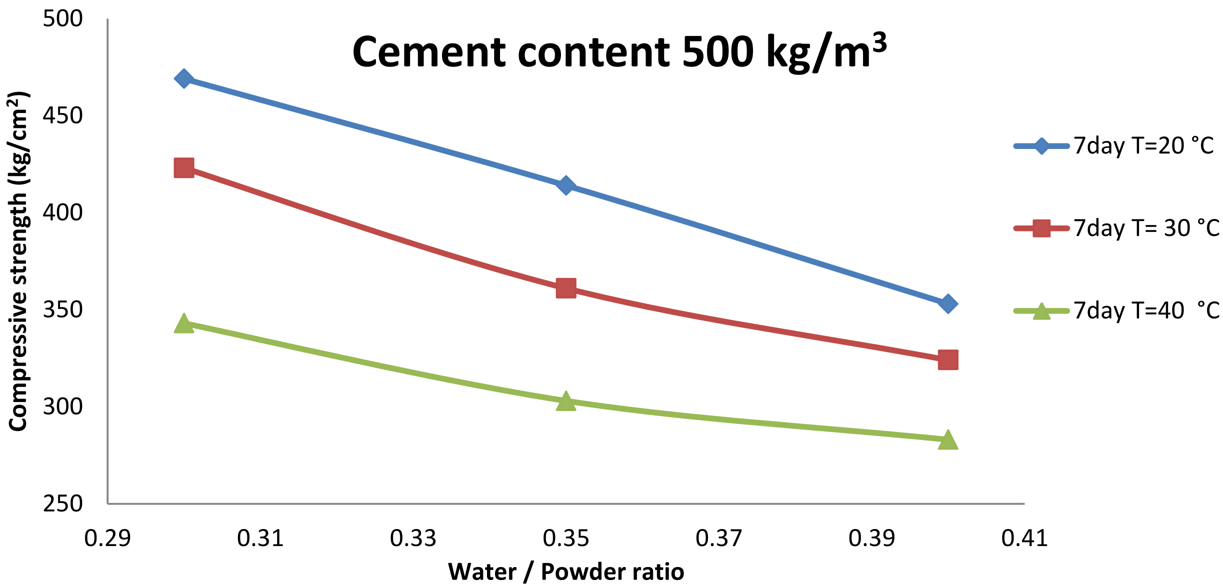

Figure 9. the effect of the water powder ratio on the compressive strength of SCC at age of 7 day , having 500 kg/m^3 cement content at different temperature.

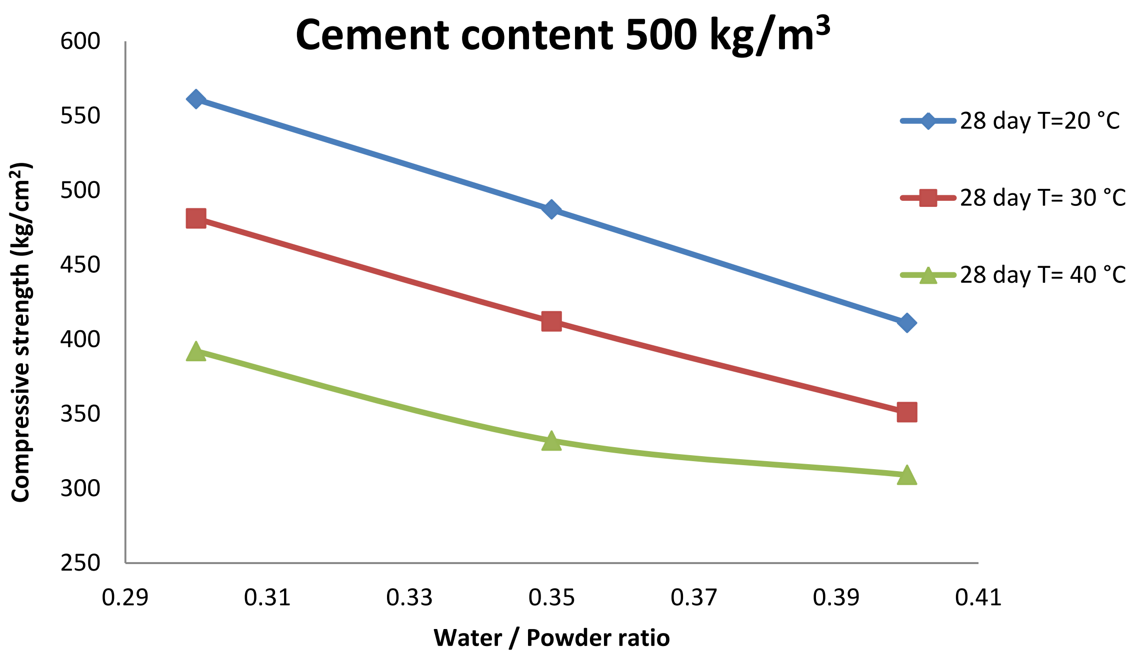

Figure 10. the effect of the water powder ratio on the compressive strength of SCC at age of 28 day , having 500 kg/m^3 cement content at different temperature

Table 6 the compressive strength of SCC at age of 7and 28 days of mixes have cement content of 550 kg/m^3 and different water powder ratio .the specimens were casted and cured at different temperature

	T=20 ^{o}C				T=30 ^{o}C				T=40 ^{o}C			
W/p ratio	7days	+%	28 days	+%	7days	+%	28 days	+%	7days	+%	28 days	+%
0.4	356	100	476	100	321	100	389	100	295	100	297	100
Relative FC %	100		100		90		82		82		62	
0.35	411	115	532	112	361	112	416	107	314	106.5	336	113
Relative FC %	100		100		87		78		76		63	
0.3	482	117	597	112.3	396	109.7	456	109.7	342	108.9	362	107.7
Relative FC %	100		100		82		76		71		61	

+% the relative strength % of fc at 20 ^{o}C temperature or w/p=0.4

In Tables 6, the compression strength of specimens cured in hot dry weather at temperatures of 30 °C and 40 °C to resistivity kept at 20 °C was calculated.

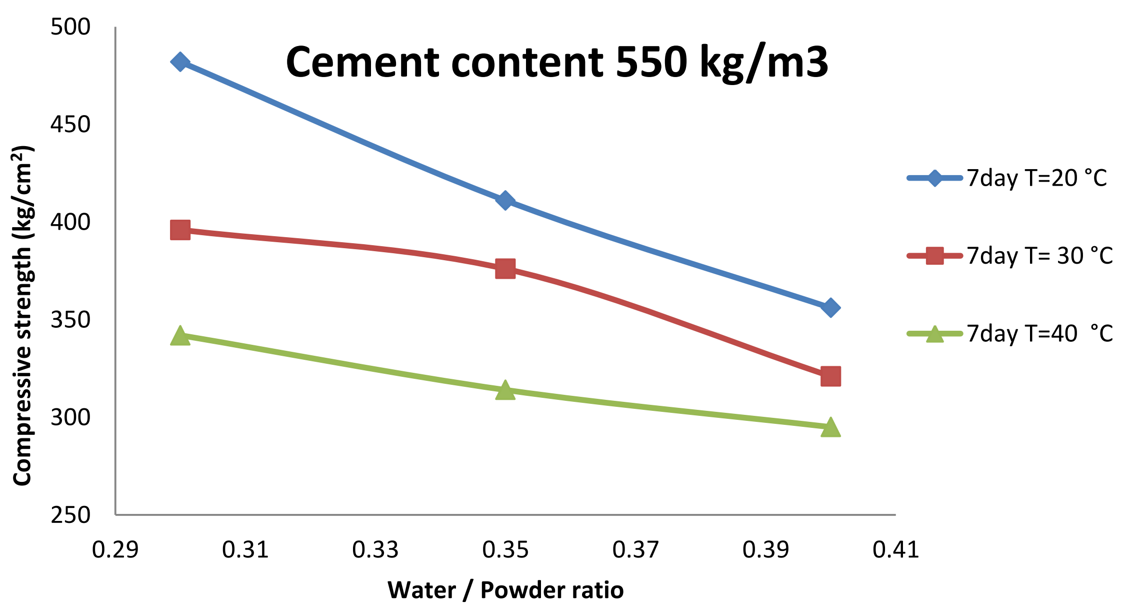

Figure 11. the effect of the water powder ratio on the compressive strength of SCC at age of 7day, 550 kg/m^3 cement content at different temperatures.

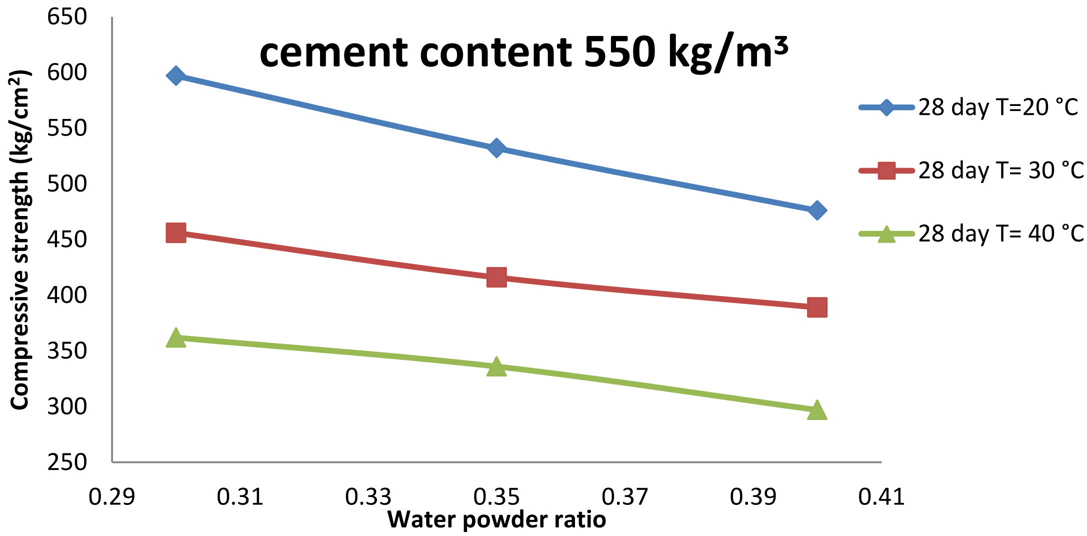

Figure 12 . the effect of the water powder ratio on the compressive strength 0f SCC at age of 28 days, 550 kg/m^3 cement content at different temperatures.

After 28 days of curing in hot dry weather the compressive strength was achieved. 81% and 67% of concrete strength under normal conditions. From the rest of the tables that show the resistance of concrete to mixes that contain higher percentages of cement, it became clear that the high temperature of pouring and curing has a more pronounced effect. It was found that in mixtures containing 550 kg / m^3, the resistance was achieved only 71% and 61% after 7 And 28 days, respectively, in mixtures with water to powders content = 0,3 when treatment at 40 °C.

4. Conclusions

This study presents an extensive database of the effect of cement content and the water-powder ratio of the SCC mixes. The effect of hot dry weather on the properties of the SCC was tested too experimental results for SCC casted and cured in normal and hot dry weather were shown. Based on the results presented in this work, the following conclusions can be drawn:

The mixing temperature has a great influence on the mixing properties of the self-compaction concrete as the temperature of the self-compaction concrete increases, the workability of the mixture decreases. The cement content of self-compaction concrete in hot weather must be not less than 450 kg/m^3 to achieve the require properties of SCC.

The water content to the powder should be at least 0.4.
The temperature of self-compaction concrete should be monitored no higher than 30 °C

Curing concrete at a high temperature and low humidity greatly evaporates resistance, and therefore care must be taken to prevent water from evaporating by capping or continuing spraying with water to obtain good resistance to self-compaction concrete.

Care must be taken to compensate for the lost water with evaporation for self-compaction in dry weather, or to preserve the water inside the concrete and prevent water evaporation from it so as to make hydration continue with the presence of water.

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