EFFECT OF DIFFERENT RETEMPERING TECHNIQUES ON THE PERFORMANCE OF SELF CONSOLIDATING CONCRETE

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ABSTRACT: This paper evaluates the fresh and hardened properties of Self Consolidating Concrete (S.C.C.) when using water or superplasticizer for concrete retempering. To achieve this aim, a detailed experimental program was designed and conducted where more than one hundred and forty cubical specimens were cast and tested in compression and more than two hundred fresh tests were performed on S.C.C. while more than 400 fresh test results were collected. Four main mixes have been used to produce S.C.C. by means of viscosity agent or extra cement content and each were used twice to study the effect of water and superplasticizer retempering. Also the effect of silica fume on the retempering of S.C.C. has been studied. Water, the most economical retempering agent, produces significant loss in strength of concrete particularly for the superplasticized concrete. Superplasticizer, despite its cost and influence of increasing the rate of slump loss, is the best retempering agent that can be used without any loss in strength. Moreover, the mixes contain silica fume need more water content for retempering to achieve an acceptable limit of slump flow diameter of S.C.C. after retempering for both mixes which contain viscosity agent or extra cement content. Also, it is clearly shown that the overall behavior of the mixes which contain extra cement content to acquire S.C.C. having much higher compressive strength than the mixes containing viscosity agent to acquire S.C.C..

Keywords: Concretes; workability; retempering; slump loss; compressive strength; self consolidating concrete

INTROUDUCTION

Self-Consolidating Concrete (S.C.C.) was first developed in Japan about in the late eighties of the last century in order to reach durable concrete structures where it was found that poor compaction is one of the main causes for producing concrete with low durability[1-3]. Since then, several investigations have been carried out to achieve a rational mix design for a standard concrete, which is comparable to normal concrete. Self-Consolidating concrete is defined so that no additional inner or outer vibration is necessary for the compaction. S.C.C. is compacting itself alone due to its self-weight and is molded almost completely while flowing in the formwork. In structural members with high percentage of reinforcement it fills also completely all voids and gaps. S.C.C. flows like “honey” and has nearly a horizontal concrete level after placing [4-7].

Occasionally, however, delays occur in transport of the mix shapes prevent a timely discharge of the concrete. If a loss of slump occurs, the question arises as to whether the slump can be restored by means of addition of water coupled with remixing. Such an operation referred to as retempering. As retempering increases the original water/ cement ratio of the mix, it is arguable that it should not be permitted where the original water/ cement ratio was directly or indirectly specified. This is an appropriate stance under some circumstances but, at other times, a more flexible and sensible solution may be appropriate as long as the consequences of retempering are understood and appreciated[8]. The practice of retempering in hot-dry environments is frequently performed to increase slump beyond typical specification's limits (of 100 ± 25 mm) in order to cope with the need for expediting the casting operations and reducing the consolidation effort[9].

Water-reducing agents, such as superplasticizers, have been utilized effectively to increase workability and enhance the placement of concrete[10,11]. Environmental conditions and delays in the placement of concrete may cause loss in the workability of superplasticized concrete. The loss can be restored by retempering with water or superplasticizers. The use of water usually results in a reduction in strength. There is divergence of opinion on the engineering properties of the re-tempered concrete.

RESEARCH SIGNIFICANCE

Comparison between the effect of retempering with water and with superplasticizer on the fresh and hardened concrete properties was studied on self consolidating concrete with and without silica fume. Two strategies that will be disused later were used to achieve self consolidating concrete

EXPERIMENTAL DETAILS

Experimental program and mix proportions

In this study four mixes were used with different cement content and different silica fume replacement. The aim of this investigation is to study the effect of using water or superplasticizer in retempering S.C.C. To achieve this objective, a comprehensive experimental program was designed and conducted to investigate the fresh and hardened concrete properties for S.C.C.

Two strategies were used in this study to obtain S.C.C. The first strategy which was conducted in Mix (I) and Mix (II) is to use normal cement content (350kg/m^3), with viscosity agent and superplasticizer as needed. The second strategy which was conducted in Mix (III) and Mix (IV) is to use high cement content (500kg/m^3), with superplasticizer as needed but without using viscosity agent. Both strategies used an equal amount of coarse aggregate and fine aggregate, in addition to small size of coarse aggregate (Nominal Maximum Size = 20 mm)

Based on the strategies for obtaining S.C.C., the four mixes were designed using the absolute volume method, as shown in table (1). Taking into consideration the following assumptions:

- The weight of coarse aggregates = the weight of fine aggregates,
- The W/C for the mixes containing 350 kg and 315 kg of cement = 0.5,
- The W/C for the mixes containing 500 kg and 450 kg of cement = 0.4,
- Silica fume replacement = 0% and 10% by weight of cement content.

Table1. Mix proportions used for each mix design.

Mix No.	**Cement content** (kg)	**Water content** (liter)	**Silica fume** (10% of cement content) (kg)	**Coarse aggregate** (kg)	**Fine aggregate** (kg)	**Viscosity agent** (lit/100 kg of cement)	**Super plasticizer** (lit/100 kg of cement)
I	350	175	-	936	936	1.75	9.9

II	315	175	35	934	934	1.75	9.9
III	500	200	-	798.5	798.5	-	3.3
IV	450	200	50	796	796	-	3.3

Figure (1) shows flow chart for the tested variables and the hardened and fresh S.C.C. tests using three different methods for measuring the workability of S.C.C. at different time intervals (5, 30, 60, 90, and 120min) before and after retempering.

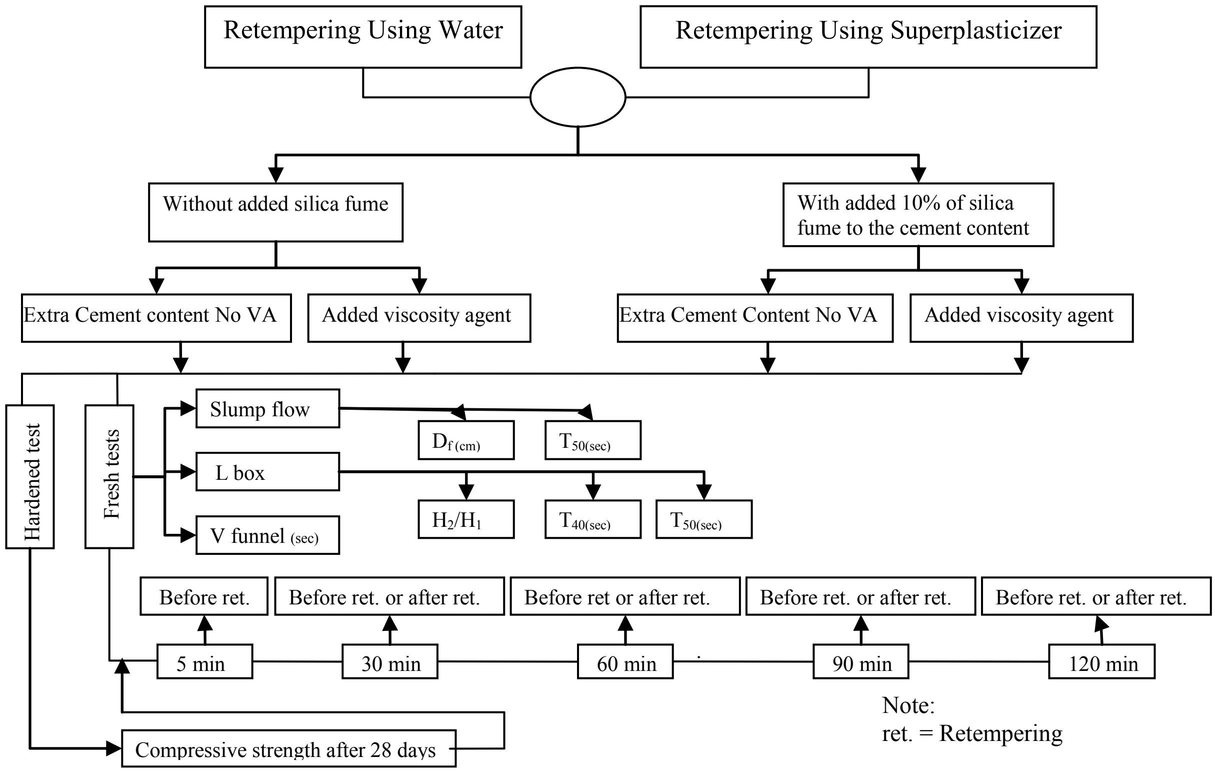

Figure1. Flow Chart for the experimental variables

The mixing procedure for S.C.C. mixes was performed using a tilting pan mixer by mixing fine and coarse aggregate with the cementations material, then water with an initial dosage of superplasticizer and viscosity agent was added. Each mix was adjusted to achieve S.C.C. by changing the amount of superplasticizer until the slump flow diameter achieved the allowable limits (60cm to 80cm). After 5 min from mixing water with the other constitutes, all the fresh properties of S.C.C. is measured using the three tests (The slump flow, V-funnel and L-box tests) then these tests were performed at time interval 30 min (after 30min, 60min, 90min, and 120min) before and after retempering if needed. During this period of time of 120 min the concrete mixer was kept running with the concrete and at each time interval a part of the concrete is discharged from the mixer to be used in fresh testing. The retempering process was conducted when the slump flow diameter decreased below the lower limit 60 cm. No retempering is needed for the time interval in which the measured slump flow is satisfying the pre-mentioned limits.

Two cubes (with dimensions 100 mm * 100 mm *100 mm) were cast after 5 min from mixing, and then another two cubes were cast at each time interval. If the S.C.C. need retempering at any time interval then another two cubes were cast. All cubes were cured for 28 days age then tested in compression.

Each mix is designated by a code name. Figure (2) shows the key to this code.

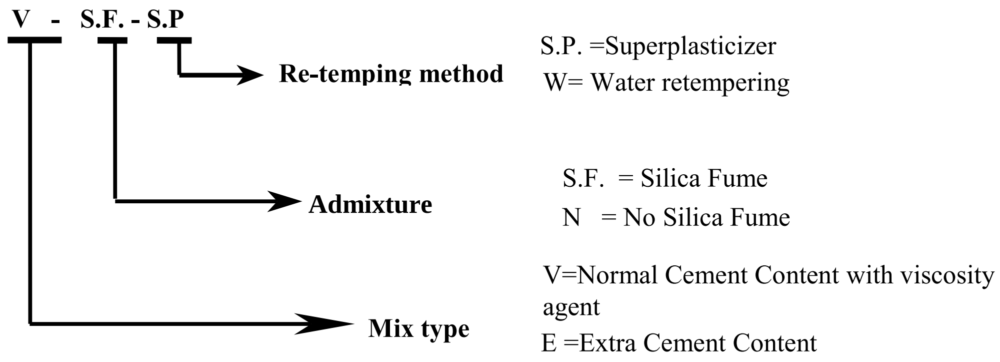

Figure2. Mixes Code Name

Materials

Ordinary Portland cement (CEM 1) satisfies the Egyptian specification (ES 4756/1 - 2007) was used in this investigation. The fine aggregate used was natural siliceous sand, free of clay, silt and organic materials. The grading of the sand was performed according to ASTM and ESS requirement. The fine aggregate specific gravity = 2.7 and its unit weight =1.79 t/m^3. One size of pink limestone was (5-20 mm). The nominal maximum size of coarse aggregate is 20 mm; the aggregate grading curve is within the acceptable limits according to Egyptian specification, the coarse aggregate specific gravity = 2.61 and its unit weight =1.38 t/m^3

Superplasticizers or high range water reducing admixtures "Sikament 136M" conforming to EN 934-2 was used in this study to increase workability; the admixture should bring about the required water reduction and fluidity but should also maintain its dispersing effect during the time required for transport and application. Viscosity modifying agent "Sika-Viscocrete 5-400" is used to modify the cohesion of the S.C.C. without significantly altering its fluidity and alter mix segregation. The silica fume which used in this study was obtained from Egyptian Alloy Company and used in this study as a 10% replacement of cement by weight.

Testing of Fresh Properties for Self Consolidating Concrete

S.C.C. is designed with very high flowability. Standard concrete test methods are not appropriate to measure flow, stability and "blocking" resistance of very high slump concrete. All the apparatus used for measuring fresh properties of S.C.C. are locally manufactured according to ASTM C1611 specifications. Then the fresh concrete properties were measured using three different methods to measure the S.C.C. flowability, filling ability, passing ability, and resistivity to segregation at different time intervals (5, 30, 60, 90, and 120min) before and after retempering as follow:

1- ***Slump flow test:*** The "Slump Flow Test" has been developed for use in S.C.C. to measure slump flow diameter and flow rate over time as shown in figure (3). S.C.C. slump flow typically reaches a spread diameter of between 600 and 800 mm and measured the time which the S.C.C. was taken it to reach 50 cm on a specially marked board

Figure3. Flowability of concrete

2- V- Funnel Test: This test method give an indication of S.C.C. viscosity by monitoring the time it takes for the S.C.C. to flow through an orifice under its own weight. The time taken for S.C.C. to flow through V-Funnel apparatus is recorded. The V-Funnel test is used in the field and is sometimes used as acceptance test. The locally made V-funnel is shown in Figure (4).

Figure 4. V-funnel Apparatus

3 - *L-Box Test:* This test, as shown in figure (5), simulates the casting process by forcing an S.C.C. sample to flow through obstacles under a static pressure. Then H_2/H_1 for the L-box is recorded; where H_2 taken at the end point of the L-box and H_1 is taken at the gate of the L-box. The times (T_{40} and T_{80}) is recorded where the T_{40} and T_{80} are the time for S.C.C. to reach 40 cm and 80 cm respectively measured from the gate of the l-box. These measured times provide indication for the segregation resistance of S.C.C. as well as its ability to flow through reinforcements. This is used in the field as acceptance test method.

Figure 5. The S.C.C. after opening the gate and recording T40 and T80 in L-Box test

RESULTS AND DISSCUSSION

Fresh Properties of S.C.C

To attain self consolidating concrete, it was decided that the slump flow diameter (D_f) results must be in between 60 cm as a minimum limit to 80 cm as a maximum limit as a main condition to pass this test [5]. In this study two comparisons were performed, the first is between the mix No.(I) which include normal cement content and viscosity agent and the mix No.(III) which contain the extra cement content with no viscosity agent. This is done in two different cases of retempering; first retempering with water and retempering with superplasticizer. These comparisons is done for mixes without adding silica fume while these same comparisons is performed between the mix No.(II) which contain the viscosity agent and the mix No.(IV) which contain the extra cement content in case of retempering with water or super plasticizer but with 10 % silica fume replacement of cement content by weight.

Self Consolidating Concrete Retempering Using Water; Four mixes were examined using water retempering, and the three tests for measuring the flowability, filling ability, passing ability, and resistivity to segregation have been conducted on each mix after 5 min from mixing and every 30 min till 120 min. If the concrete mixture achieves the acceptable S.C.C. limits (flow diameter 60-80cm) then no need to add water for retempering. The amount of water needed to attain the S.C.C. pre-mentioned limits is added to the mix to satisfy the S.C.C. fresh properties requirements.

For both extra cement content mixes (E-N-W, and E-SF-W), it was found that the S.C.C. need retempering to achieve the S.C.C. limits after 30 min only, while the mixes contain viscosity agent needed water retempering after 90 min and 120 min for V-SF-W and V-N-W respectively but with different amount of water. This indicates that the use of viscosity agent allows S.C.C. to preserve its flowability, filling ability, and passing ability for a longer period than using extra cement content as an extra powder. On the other hand, the mixes containing silica fume needed more percentage of water for retempering to achieve the allowable flow diameter for both mixes which contain viscosity agent or extra cement content as shown in Figure 6 and Table 2.

Figure 6 shows the increase of total water to cement ratio for the four mixes at different time stages due to water retempering which indicate that in spite of the S.C.C. using viscosity agent does not need any retempering water until 90 min and 120 min from mixing for mixes (V-SF-W, and V-N-W) it uses relatively high water to cement ratio comparing to the S.C.C. using high cement content to reach the S.C.C. specification limits. On the other hand, S.C.C. using extra cement content needed retempering with water every 30 min to reach the S.C.C. condition but the water to cement ratio is lower than S.C.C. using viscosity agent. This dramatically increases in water: cement ratio for mixes contain viscosity agent will defiantly effect in loss of concrete strength.

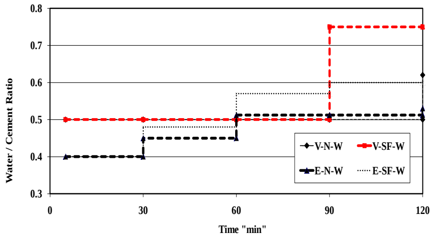

Figure 6. The change in water to Cement ratio versus retempering duration

It can be seen from figure 6 that, to maintain self consolidating condition for 120 min both mixes with silica fume (V-SF-W) and (E-SF-W) needed retempering with an increase for the water to cement ratio of 50%, while the other two mixes without silica fume (V-N-W) and (E-N-W) needed retempering with an increase in water to cement ratio of 24% and 32% respectively. This indicates that S.C.C. mixes containing silica fume generally needs more water retempering than mixes without silica fume to maintain S.C.C. conditions. This may be related to the high surface area of silica fume compared with replaced amount of cement

Table (2) shows all the fresh properties of S.C.C. tests and the water to cement ratio for retempering at different time stages.

Table2. Fresh S.C.C. properties and the change in w/c due to water added for retempering at different time

	Time (min)	**5**	**30**	**30**	**60**	**60**	**90**	**90**	**120**	**120**
		Before	Before	After	Before	After	Before	After	Before	After
V-N-W	% Increase over the initial W:C ratio (0.5)	0	0	0	0	0	0	0	0	***24%***
	FD D_f (cm)	69	64	64	62	62	60	60	55	***75***
	Test T50(sec)	1	2	2	2	2	2.5	2.5	4	1
	VFunnel	3	3.5	3.5	4	4	5	5	7	2
	Lbox H_2/H_1	0.8	0.75	0.75	0.75	0.75	0.7	0.7	0	0.9
	Test T40 (sec	1.5	3	3	4	4	5	5	20	1
	T80 (sec	5	10	10	12	12	15	15	0	3
	% Increase over the initial W:C ratio (0.5)	0	0	0	0	0	0	***50%***	50%	50%

V-SF-W	FD	Df (cm)	69	65	65	60	60	40	***70***	65	65
	Test	T50(sec)	1	2	2	4	4	10	1	1	1
	VFunnel		3	4	5	6	6	8	2	3	3
	Lbox	H2/H1	0.9	0.8	0.8	0.75	0.75	0	0.9	0.85	0.85
	Test	T40	3	4	4	6	6	20	2	3	3
		T80	6	7	7	9	9	40	5	6	6
E-N-W	% Increase over the initial W:C ratio (0.4)		0	0	***20%***	20%	***28%***	28%	28%	28%	***32%***
	FD	Df(cm)	73	50	***62***	50	***72***	60	60	50	***60***
	Test	T50(sec)	1	3	2	3	1	2	2	3	1
	VFunnel		3	7	4	7	3	4	4	7	4
	Lbox	H2/H1	0.95	0	0.8	0	0.95	0.75	0.75	0	0.8
	Test	T40	1	20	3	20	1	3	3	20	2
		T80	3	40	6	40	4	9	9	40	5
E-SF-W	% Increase over the initial W:C ratio (0.4)		0	0	***20%***	20%	***42%***	42%	***50%***	50%	50%
	FD	Df(cm)	65	50	***61***	50	***60***	50	***60***	55	65
	Test	$T_{50(sec)}$	1	2.3	2.3	5	4	5	4	4	2
	$V_{Funnel\ (sec)test}$		3	3.5	3.5	5.5	3.5	5.5	5	7	3
	Lbox	H_2/H_1	0.8	0.75	0.75	0	0.75	0	0.75	0	0.9
	Test	$T_{40\ (sec)}$	1.5	2	2	20	3	20	3	20	1.5
		$T_{80\ (sec)}$	5	10	10	40	15	40	14	40	4

Self Consolidating Concrete Retempering Using Super Plasticizer Retempering; The results of the four mixes retempered using superplasticizer indicate that the overall behavior of these mixes is similar to those retempered using water as shown in Figures 6 and 7. From figure 7, it can be seen that the mixes containing viscosity agent showed a prolonged mixing behavior and maintained self consolidating conditions for longer period than those using extra cement content which lost their ability to flow as measured using slump flow test at the first interval after only 30 min of mixing. On the other hand, the mixes containing silica fume (V-SF-SP) and (E-SF-SP) generally needed more percentage of superplasticizer for retempering to achieve the desired flow measured as slump flow diameter than both mixes (V-N-SP) and (E-N-SP) without silica fume which contain viscosity agent or extra cement content.

The initial amount of superplasticizer in both mixes contain viscosity agent was (9.9 liter/100 kg cement) which is much higher than the initial amount of superplasticizer of the other two mixes containing extra cement content (3.3 liter/100 kg cement) to achieve the same S.C.C allowable limits.

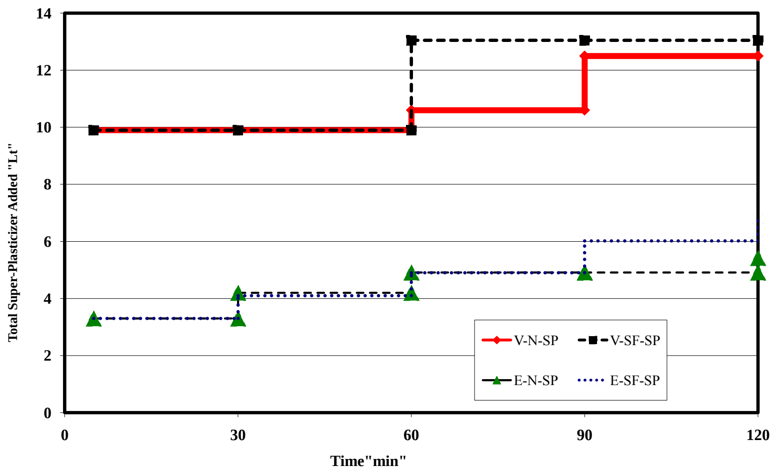

Figure 7. Change in superplasticizer dosage for retempering versus time

Table (3) shows all the fresh concrete workability tests and the doze of superplasticizer added for retempering at different time stages.

Table (3) Fresh S.C.C. properties and the quantity of superplasticizer added for retempering at different retempering times

	Time		**5** Before	**30** Before	**30** After	**60** Before	**60** After	**90** Before	**90** After	**120** Before	**120** After
V.N.SP	Dosage of admixture L\100kg cement		9.9	0.00	0.00	0.00	**0.70**	0.00	**1.90**	0.00	**1.03**
	FD Test	Df(cm)	65	61	61	50	**60**	50	**60**	55	**65**
		$T_{50(sec)}$	1	2.3	2.3	5	4	5	4	4	2
	$V_{Funnel\ (sec)test}$		3	3.5	3.5	5.5	3.5	5.5	5	7	3
	Lbox Test	H_2/H_1	0.8	0.75	0.75	0	0.75	0	0.75	0	0.9
		$T_{40\ (sec)}$	1.5	2	2	20	3	20	3	20	1.5
		$T_{80\ (sec)}$	5	10	10	40	15	40	14	40	4
V.SF.SP	Dosage Of admixture L\100 cement		9.9	0	0	0	**3.15**	0	0	0	0
	FD Test	Df(cm)	64	61	61	50	**65**	62	62	60	60
		$T_{50(sec)}$	1	2	2	5	1	2	2	3	3
	$V_{Funnel\ (sec)test}$		3	4	4	6	2.5	2.5	2.5	4	4
	Lbox Test	H_2/H_1	0.9	0.8	0.8	0	0.9	0.8	0.8	0.75	0.75
		$T_{40\ (sec)}$	2	3	3	20	1	3	3	4	4
		$T_{80\ (sec)}$	7	9	9	40	4	9	9	10	10

E.N.SP	Dosage of admixture L\100kg cement		3.3	0	**1**	0	**0.71**	0	0	0	**0.51**
	FD Test	Df (cm)	70	55	**65**	52	**71**	60	60	45	**65**
		$T_{50(sec)}$	1	3	2	4	1	2	2	10	1
	$V_{Funnel\ (sec)test}$		2	5	4	5	2	3	3	5	3
	Lbox	H_2/H_1	0.9	0	0.8	0	0.95	0.8	0.8	0	0.85
	Test	$T_{40\ (sec)}$	2	20	4	20	2	5	5	20	4
		$T_{80\ (sec)}$	4	40	7	40	4	8	8	40	7
E.SF.SP	Dosage of admixture L\100kg cement		3.3	0	**0.805**	0	**0.88**	0	**1.036**	0	**0.85**
	FD Test	Df	65	50	**62**	51	**63**	51	**63**	40	**64**
		$T_{50(sec)}$	1	5	3	4	2	4	2	10	1
	$V_{Funnel\ (sec)test}$		3	7	5	7	3	7	3	7	3
	Lbox	H_2/H_1	0.9	0	0.8	0	0.85	0	0.85	0	0.95
	Test	$T_{40\ (sec)}$	3.5	20	4	20	4	20	4	20	3
		$T_{80\ (sec)}$	8.5	40	8	40	7	40	7	40	9

Properties of hardened S.C.C. "concrete compressive strength"

Comparison between water Retempering vs. superplasticizer Retempering; All the compressive strength test results for different S.C.C. mixes are presented in figure (8) and (9). Form these results, it can be seen that there is a significant loss in compressive strength after retempering using water. This is due to the increase in water cement ratio with retempering leading to reduction in compressive strength as shown in figure (8) and (9). Moreover it is noticed that the loss in compressive strength due to water retempering decrease with the time between retempering. On the other hand, it can be noticed that there is no loss in concrete compressive strength before or after retempering using superplasticizer. This is due sustaining the level of water to cement ratio and gaining the flowability by the use of superplasticizer only. Moreover, it can be noticed that some increase in compressive strength take place when using superplasticizer retempering, this may be related to evaporation of water with the prolonged time.

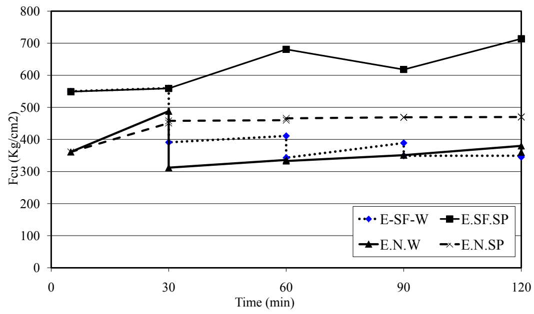

Figure 8. Effect of retempering on S.C.C. compressive strength for extra cement content mixes

Also it is well clarified; comparing figure (8)and (9) that the difference between the compressive strength for mixes re-tempered using water or superplasticizer decrease for both mixes used viscosity agent to achieve S.C.C. rather than mixes used extra cement content to achieve S.C.C.

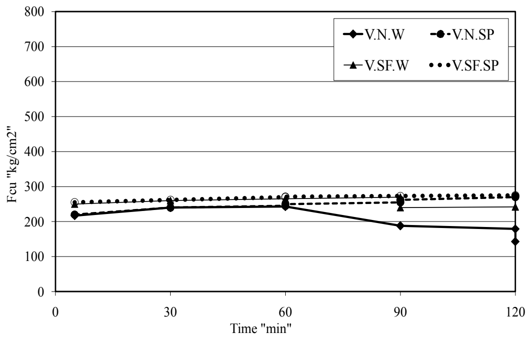

Figure 9. Effect of retempering on S.C.C. compressive strength for mixes with viscosity agent

Comparison between hardened properties of S.C.C. using viscosity agent vs. S.C.C. using extra cement content; As shown from figure 10, by comparing the four mixes with silica fume the average cube compressive strength for the mix containing extra cement content (E.SF.SP) is more than the other mix containing viscosity agent (V.SF.SP) by 130% for mixes containing silica fume. On the other hand, comparing between the same mixes but without silica fume is 80% as shown in Figure 11. Based on this results it is clearly shown that the overall behavior of the mixes that used extra cement content to acquire S.C.C. resulted in much higher compressive strength than the mixes used viscosity agent and normal cement content to acquire S.C.C. This can be attributed to the use of high cement content and the lower cement ratio in these mixes, which can be considered the main factors affecting the compressive strength. Also it is shown that retempering using superplasticizer did not show any adverse affect the cube compressive strength in both mixes that contain viscosity agent or for mixes that contain extra cement content as shown in Figures 10 and 11.

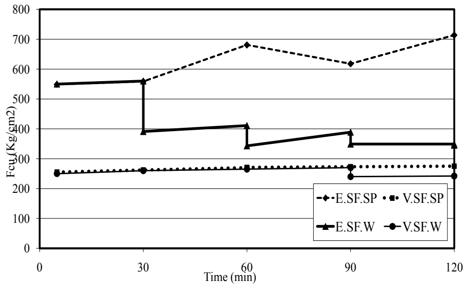

Figure 10. Effect of retempering on S.C.C. compressive strength for mixes with silica fume

As shown in figure (11), In spite of the concrete compressive strength of the mixes containing extra cement content is higher than mixes containing viscosity agent , the decrease in strength is very significant than viscosity agent

As shown in figures 10 and 11, it was noticed that there is reduction in compressive strength in all mixes retempered with water for both mixes containing extra cement content or viscosity agent. Also, it is clearly shown that all the mixes containing extra cement content showed much higher compressive strength than mixes containing normal cement content and viscosity agent, this related to the higher cement content and lower water cement ratios for those mixes.

Figures 10 and 11 also show that the reduction in compression strength due to water retempering is more pronounced in mixes containing extra cement content than in mixes containing viscosity agent and normal cement content, this may be attribute to the sensitivity for the mixes containing higher cement content to the increasing in water to cement ratio than those mixes containing normal cement content and viscosity agent. Moreover it can be concluded from figures 10 and 11 that the reduction in compressive strength due to water retempering is reduced with repetitive retempering process as shown for mixes containing extra cement content, this may be related to the reduction in the overall water to cement ratio after repetitive retempering process. This effect was not shown in the mixes containing normal cement content and viscosity agent.

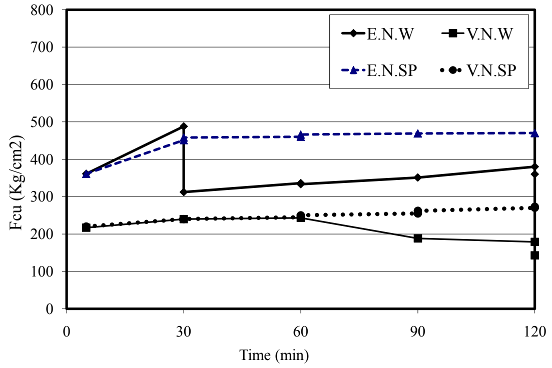

Figure 11. Effect of retempering on S.C.C. compressive strength for mixes without silica fume

Effect of silica fume on the self consolidating concrete properties; Adding silica fume to the S.C.C. enhanced the overall concrete compressive strength for all mixes using different retempering types, as shown in figure 12 and 13, it can be shown that this effect of silica fume is significant for S.C.C. having extra cement content rather than S.C.C. containing viscosity agent. From figure 13, it is noticed that the presence of silica fume when retempering with water for mixes containing normal water content and viscosity agent reduce the adverse effect of water retempering on compressive strength.

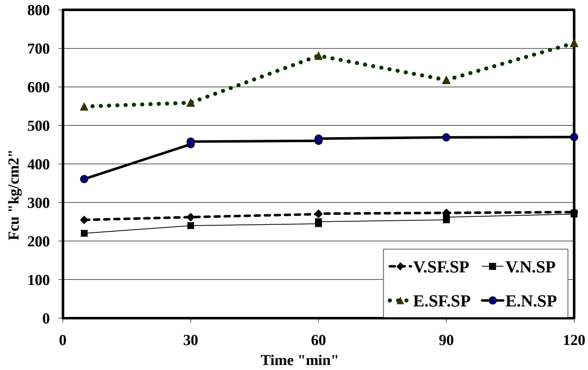

Figure 12. Effect of superplasticizer retempering on S.C.C. compressive strength

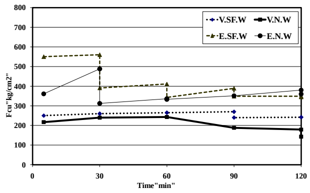

Figure 13. Effect of water retempering on S.C.C. compressive strength

CONCLUSIONS

In this study a comprehensive experimental program to study the effect of different types of retempering on the fresh and hardened properties of self consolidating concrete was designed and conducted. To acquire the hardened S.C.C. properties, more than 140 cubical specimens were cast and tested in compression, while more than 400 fresh test results were collected to study the fresh properties of S.C.C. (such as flowability, filling ability, passing ability and segregation resistance). The fresh properties were measured using three different tests which are the slump flow, the V funnel and the L box tests while the hardened concrete properties were measured through the cube compressive strength testing at 28 days age. The parameters studied in this research is the effect of using water or superplasticizer for retempering on S.C.C. fresh and hardened properties, the effect of adding silica fume to S.C.C. as a replacement of cement and the effect of the method of obtaining S.C.C. Four different mixes were used in this study; two of these mixes used viscosity agent and normal cement content while the other two mixes used high cement content and all mixes used superplasticizer as needed. The four mixes were used twice, once when retempering with water and the other retempered using superplasticizer.

Based on the results of this study, it was concluded that the use of viscosity agent allows S.C.C. to preserve its flowability, filling ability, and passing ability for a longer period than the S.C.C. mixes using extra cement content as an extra powder. On the other hand, S.C.C. using extra cement content needed retempering with water every 30 min to reach the self consolidating condition but the added water needed for retempering was found to be lower than retempering water dosages needed for S.C.C. mixes using viscosity agent. Also it was found that the mixes containing silica fume generally needed adding more percentage of water for retempering to achieve self consolidating conditions than that mixes that does not contain silica fume. A similar result can be concluded for superplasticizer retempering where the mixes containing silica fume generally needed more percentage of superplasticizer for retempering to achieve the desired flow measured as slump flow diameter than mixes without silica fume which contain viscosity agent or extra cement content.

Generally, from the results of this research it was found that the mixes using viscosity agent and normal cement content needed much higher dosages of superplasticizer than these mixes containing extra amount of cement content in spite of the lower water to cement ratio used in these mixes.

Based on the results of the hardened concrete properties, it can be concluded that the overall behavior of the mixes that used extra cement content to acquire S.C.C. resulted in much higher compressive strength than the mixes used viscosity agent and normal cement content to acquire S.C.C. Moreover, it was found that there is a significant loss in compressive strength for all S.C.C. mixes when retempered with water but this loss in strength decrease with the repeating of the retempering process. On the other hand, it was noticed that there is no loss in concrete compressive strength before or after retempering using superplasticizer on the contrary some increase could be seen to take place when using superplasticizer retempering. Also it was shown that the presence of silica fume enhanced the concrete compressive strength when superplasticizer retempering. This effect was more pronounced for S.C.C. mixes having high cement content rather than S.C.C. mixes containing viscosity agent and normal cement content.

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