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Effect of Concrete Retempering Methods on Fresh and Hardened Concrete Properties for Normal and High Strength Concrete

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Abstract: Concrete retempering is the procedure that is used to restore the lost workability in ready mixed concrete. Adding an extra amount of water for retempering concrete is the common practice but adding an extra amount of water without exact calculation in mixture proportions makes compressive strength affects harmfully. As a result of delivery delaying or concreting in conditions of hot weather, abnormal slumps loss is expected, therefore, it is usual to modify the normal concrete placing and finishing procedures consequently. This research aims to evaluate different concrete retempering methods and their effect on concrete characteristics which gives the user the ability to choose the suitable method according to the expected concrete properties. In this research the experimental program was carried out to investigate the influence and the effect of retempering time (with 15 min time interval ranging between 0 up to 120 min) without any additions, retempering with adding water, superplasticizer and extra amount of cement paste on slump test and the mechanical properties of Normal Strength Concrete (NSC) and High Strength Concrete (HSC).

Key words: Retempering, normal strength, high strength, workability, mechanical properties

INTRODUCTION

ACI 116 defined the concrete retempering process as "Water adding and remixing of concrete or mortar which has lost significant workability to become unplaceable" (Alhozaimy, 2007). Many researchers and engineers adopted the ACI definition and added water to concrete to restore the original workability, when concrete placing has been delayed or when water batched initially with insufficient content. Higher rate of evaporation in hot weather concreting, especially when it is combined with a delay in delivery of ready-mixed concrete may lead to undesirable field practices and the retempering process may be the only method to accept the concrete batch.

While adding water for retempering concrete is the usual procedure but the addition of water without proper adjustment in mixture proportions adversely affects mainly the compressive strength of concrete. If abnormal slumps loss is expected by way of hot weather concreting conditions or by way of delay in delivery, it is usual to modify the normal concrete placing and finishing procedures accordingly.

Researchers not only used the classical method of retempering with water addition but also, they used different procedures for concrete retempering. The most used methods are retempering using superplasticizer and retempering using an extra amount of cement and water.

Studies on concrete retempering with addition of extra amount of water carried out by Erdogdu (2005), Gonnerman and Woodworth (1929), Cook (1943) Anderson and Carrasquillo (1993) and Yaligar *et al*. (2013) showed that the decrease in concrete strength is parallel to the amount of retempering water that means that the greater amount of free water in concrete results in greater reduction in the strength of concrete. While Gassman *et al.* (2001) studies concluded that mixing beyond 30 min reduces the compressive strength of concrete and retempering with up to 20% extra water reduced the strength by 35% at 28 days but the reduction was only 15% at 90 days. Therefore, they concluded that up to an extra 20% of water for retempering has no adverse effect on the design compressive strength of concrete.

Using superplasticizer as a retempering agent in the studies by Kirca *et al.* (2002), Erdogdu (2005), Ghasemi *et al.* (2019) and Mustafa and Zregh (2014) showed that retempering with a superplasticizer would be beneficial in terms of the strength loss experienced. Sobhani *et al*. (2012) stated that the observed increase of

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compressive strength in the retempered specimens could be mainly attributed to increasing workability which led to better compaction and adequate time for the water absorption of aggregates.

By Kirca *et al*. (2002), Almeida *et al*. (2018), Shetty and Chand (2010), Abdel-Aziz and Sayad (2002) and Erdogdu (2005) investigations showed that adding water without adding cement, increases the water-cement ratio which lowers strength and durability of concrete. Therefore, adding a small amount of cement may be required for appropriate retempering. A small quantity of extra cement sometimes is also added while retempering to obtain the desired slump provides the designed water/cement ratio is not exceeded.

The purpose of this paper is to study the effect of using different retempering procedures on the properties of the produced normal and high strength concrete mixtures and recognize the best retempering procedure to restore lost workability and adjusting strength in studied concrete mixes. Fresh concrete slump and hardened concrete compressive strength, indirect tensile strength and flexural strength tests were executed on retempered concrete samples.

MATERIALS AND METHODS

Cement: The used cement was ordinary Portland cement CEM I N 52.5. Its chemical and physical characteristics satisfy the egyptian standard specification for ordinary Portland cement (Anonymous, 2009).

Silica fume: A waste by-product of the production of silicon and silicon alloys industry consisting mainly of non-combustible amorphous silica (SiO_2) particles. The used silica fume was produced by Egyptian Ferro Alloys Corporation (EFACO). The used silica fume met the requirements of (ASTM C 1240-05, 2005).

Water: The clean drinking freshwater used for mixing and curing was free of impurities. It meets the requirements of ECP 203/2007 (Anonymous, 2007).

Superplasticizer: Sika Viscocrete 3425 supplied by Sika Egypt company which meets the requirements of superplasticizer according to ASTM-C-494, types G and F is used. The used superplasticizer has 1.08 kg/L density, 4.0 pH value and 0.6% solid content (by weight).

Fine aggregate: The fine aggregate used was natural siliceous sand with characteristics satisfy the egyptian standard specification for aggregate (Anonymous, 2008). It was clean and nearly free from impurities with a specific gravity 2.6 t/m^3 and a fineness modulus of 2.7.

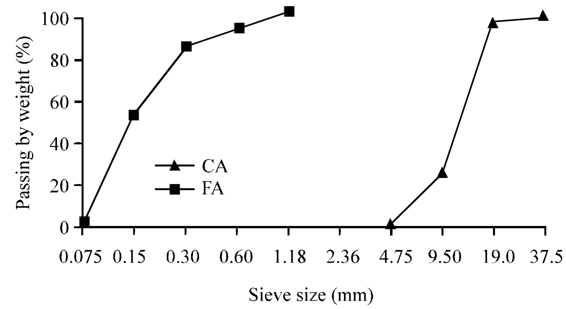

Fig. 1: The grain size distribution for used aggregate

Coarse aggregate: Crushed dolomite is used as coarse aggregate and satisfy the egyptian standard specification for aggregate (Anonymous, 2008). The specific gravity, maximum nominal size and water absorption of the coarse aggregate are 2.65 t/m^3 12.5 mm and 0.6%, respectively. Grading of the used fine and coarse aggregate is shown in Fig. 1.

Mixtures proportions: Normal Strength Concrete (NSC) mix was designed and cast using a fine to Coarse Aggregate ratio (CA/FA) = 2, Water to Cement (W/C) ratio of 0.5, cement content of 350 kg/m^3. High Strength Concrete (HSC) mix was designed and cast using a fine to Coarse Aggregate ratio (CA/FA) = 2, Water to Binder (W/B) ratio of 0.3, cement content of 550 kg/m^3, silica fume 5% by weight of cement and Superplasticizer to Bender (SP/B) ratio 0.7%.

Concrete samples: Specimens in this research cast to explore the main properties of the different 29 concrete trails. The main aim of the concrete retempering is to restore the original slump of the concrete mix. Slump test was carried out in accordance with Anonymous (2007). The Compressive Strength (CS), the indirect Tensile Strength (splitting method) (TS) and Flexural Strength (FS) tests were done in accordance to Anonymous (2007) standard cubes of dimensions 100×100×100 mm, cylinders of 100 mm diameter and 200 mm height and prism molds of 100×100×500 cm dimensions were used to measure the compressive strength, indirect tensile strength and flexural strength of the studied concrete mixes.

Nomenclature for specimens: The mixes were divided into two main groups. The first group (normal strength concrete) has first letter (N) while the second group (high strength concrete) has first letter (H). The second part of the name divided into three main groups, the first group (RW0-RW5-RW10, ...,) refers to retempering using water and the number refers to the adding percentage (ranging between 0-30% for NSC and between 0-15% for HSC), the second group (RWC3-RWC5-RWC7-RWC10) refers to retempering using extra amount of cement and water while the number refers to the adding percentage (ranging between 0-10%), the third group for HSC mixes only was (RW1S2-RW1S4, ...,) refers to retempering using water and superplasticizer while first number refers to the adding water percentage (ranging between 1-5%) and second number refers to the adding superplasticizer percentage (0.2, 0.4). Adding percentages ware measured as a percentage of cement content for NSC and as a percentage of binder materials (cement and silica fume) for HSC.

RESULTS AND DISCUSSION

Test results of fresh and hardened concrete are analyzed to investigate the effect of retempering time and retempering with adding water, superplasticizer and an extra amount of cement on the properties of normal and high strength concrete samples.

Workability results and discussion: Recorded slump values are shown in Table 1 and 2, respectively. They are presented and discussed in the following sections. The slump test results show that workability as measured from slump test, decreased as the retempering time increased. This is due to the fact that as the retempering time increases the evaporation of concrete water takes place from mass and also concrete starts losing its plasticity, thereby reducing workability. Also, it was noticed that workability is increased by increasing the percentage of added retempering water this is because adding extra water will help in keeping the concrete in plastic state for additional time.

For the NSC the initial slump (at zero time) could be achieved by adding 5% water till 15 min. While for 10% retempering water, it could be achieved till about 45 min. When adding retempering water 15-25% it satisfied the initial slump of the control mix for all time interval till 120 min. However, upon adding 30% of retempering water segregation was happened till 30 min then the concrete transformed to self compacting concrete. The initial slump could be achieved by adding 3% an extra amount of cement and water till 15 min. For 5, 7 and 10% an extra amount of cement and water it could be achieved till about 30 min. The addition of an extra amount of cement and water was found to correlate well with the increase in slump.

For the HSC it is noticed that concrete slump was very sensitive to adding a percentage of excess water then the chosen adding percentage of water was ranging between 0-15% of bender materials. Thus, it was observed that using small amounts of additional water improve the workability where the initial slump (at zero time) could be achieved by adding 1% water till 90 min and for 3% retempering water it could be achieved till about 105 min. For retempering water more than 3%, it could be found that retempering with 5% of water led to collapsing in concrete slump till 30 min and for retempering with 7% of water led to segregation then collapsing in concrete slump till 60 min. While for retempering with 10 and 15% led to segregation then collapsing in concrete slump till 75 min.

When retempering with additional water and superplasticizer, the workability improved and the initial slump (at zero time) for HSC could be achieved by adding 1, 3 and 5% water combined with 0.2 or 0.4% of superplasticizer for all time intervals till 120 min. Thus, addition of water and superplasticizer within the used

Table 1: The slump of retempered NSC

	Slump (mm)										
Retempering time (min)	NRW0	NRW5	NRW10	NRW15	NRW20	NRW25	NRW30	NRWC3	NRWC5	NRWC7	NRWC10
Ho	50	60	70	115	150	178	Seg	53	55	60	63
15	50	58	70	115	150	166	Seg	50	55	57	60
30	45	45	70	110	145	157	Seg	47	50	55	58
45	20	26	60	90	120	134	Self	23	28	30	35
60	10	12	38	80	110	126	Self	10	15	18	21
75	10	12	32	80	100	121	Self	10	13	18	20
90	8	10	27	77	100	114	Self	7	10	15	17
105	6	9	25	75	98	109	Self	5	7	12	16
120	0	7	24	70	88	106	Self	0	3	8	10

Table 2: The slump of retempered HSC

Retempering time (min)	HRW0	HRW1	HRW3	HRW5	HRW7	HRW10	HRW15	HRW1S2	HRW3S2	HRW5S2	HRW1S4	HRW3S4	HRW5S4	HRWC3	HRWC5	HRWC7	HRWC10
0	70	120	190	Col	Seg	Seg	Seg	Self	Self	Seg	Self	Seg	Seg	75	77	81	84
15	55	120	175	Col	Col	Seg	Seg	Self	Self	Seg	Self	seg	Seg	61	63	66	68
30	30	100	140	Col	Col	Seg	Seg	Self	Self	Seg	Self	Self	Seg	38	40	45	60
45	15	95	110	220	Col	Col	Col	Self	Self	Seg	Self	Self	Self	19	22	30	35
60	10	88	100	170	Col	Col	Col	145	160	Self	170	Self	Self	15	17	21	27
75	0	70	95	155	205	Col	Col	145	135	Self	165	Self	Self	5	7	15	20
90	0	70	190	125	185	195	220	100	130	Self	150	Self	Self	5	5	13	15
105	0	55	76	95	110	170	190	100	120	Self	200	Self	Self	3	5	10	15
120	0	20	50	77	85	135	155	90	115	160	200	Self	Self	0	5	7	10

Seg means: by visual identification segregation was occurred; self means: slump flow satisfies self-compacting concrete requirements; col means: collapse slump failure limits was found to correlate well with the concrete slump. Retempering with an extra amount of cement and water slightly improved the concrete workability.

Mechanical properties results and discussion: For NSC the compressive strength test results are shown in Fig. 2-5 and the indirect tensile strength and flexural test results are shown in Fig. 6-9. Results show that NSC compressive, tensile and flexural strength decrease with respect to retempering time within the studied interval (0-120 min) and for all the adding percentages (0-30%) of the retempering water. Also, it is noticed that the compressive, tensile and flexural strength were decreased with respect to increasing of retempering water percentage. The reduction is slightly decreased at the beginning til 10% Retempering Water (NRW10) then decreased rapidly up to 30% (NRW30). The average reduction of compressive strength for NRW 5 was about 6% and for NRW10, NRW15, NRW20, NRW25, NRW30 the compressive strength reduced by about 11, 18, 45, 49, 54%, respectively.

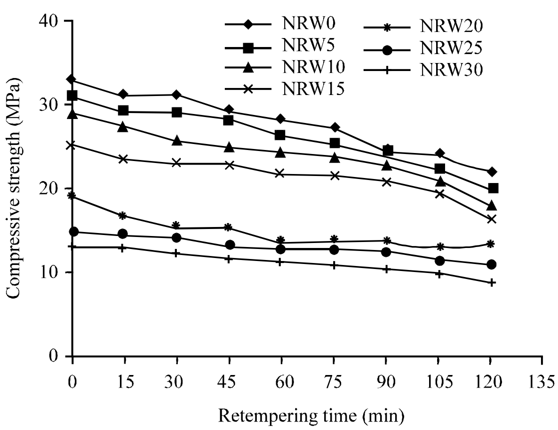

Fig. 2: 7 days CS for NSC retempered using water

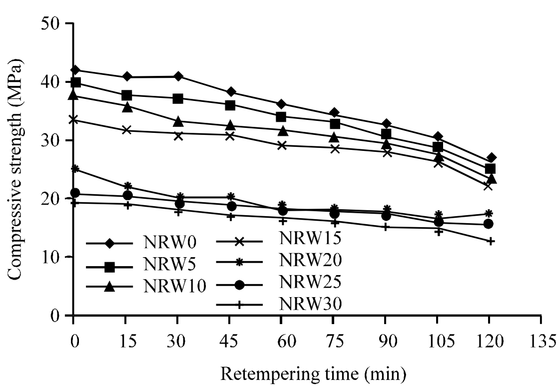

Fig. 3: 28 days CS for NSC retempered using water

It is noticed that the compressive, tensile and flexural strength gave an increase when retempering with 3 and 5% extra amount of cement and water then it decreases for 7 and 10% extra amount of cement and water. The average increase of compressive strength for NRWC3 and NRWC5 was about 4.8 and 5.6, respectively and the average reduction for NRWC7 and NRWC10 was 3.1 and 8.3%, respectively.

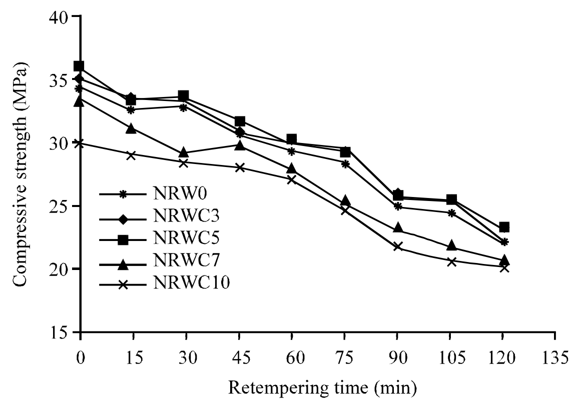

Fig. 4: 7 days CS for NSC retempered using extra amount of cement and water

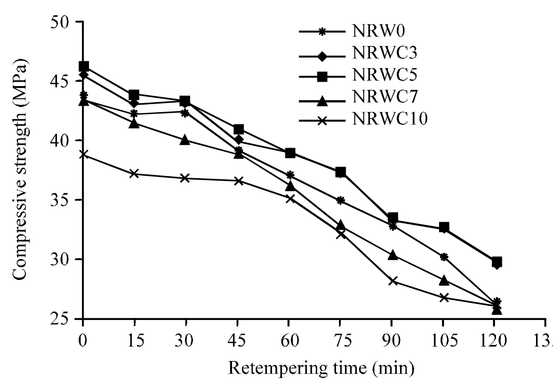

Fig. 5: 28 days CS for NSC retempered using extra amount of cement and water

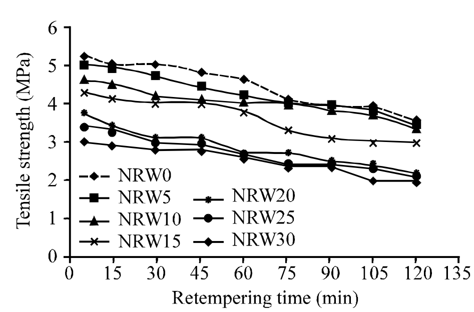

Fig. 6: 28 days TS for NSC retempered using water

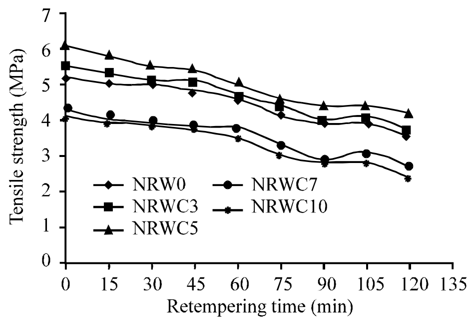

Fig. 7: 28 days TS for NSC retempered using extra amount of cement and water

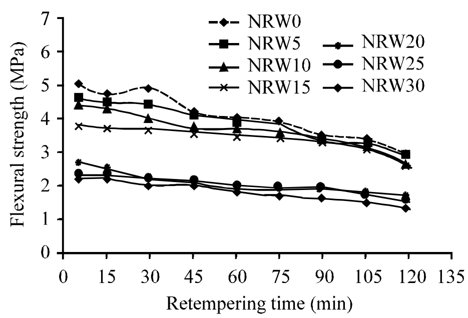

Fig. 8: 28 days FS for NSC retempered using water

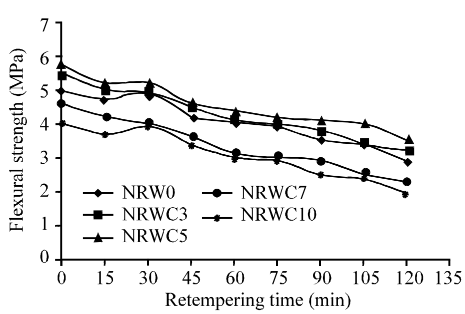

Fig. 9: 28 days FS for NSC retempered using extra

The compressive strength of the concrete retempered by adding 5% extra amount of cement and water is higher than that retempered by 5% water only by about 10%. While for retempering using 10% extra amount of cement and water gave higher compressive strength than retempering with 10% water only by about 4%.

For HSC the compressive strength test results are shown in Fig. 10-18 and the indirect tensile strength and flexural test results are shown in Fig. 19-25. For HSC retempered without any additions with adding water only and with adding an extra amount of cement and water it was clearly noticed that the

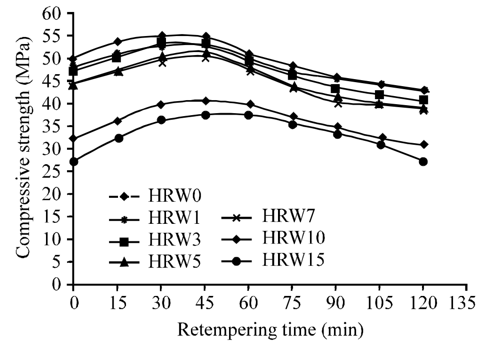

Fig. 10: 7 days CS for HSC retempered using water

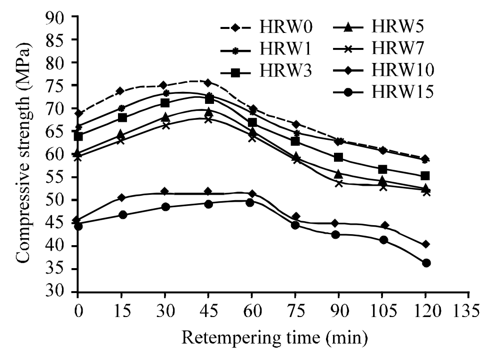

Fig. 11: 28 days CS for HSC retempered using water

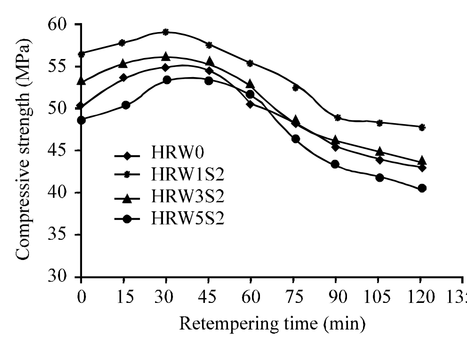

Fig. 12: 7 days CS for HSC retempered using water and 0.2% superplasticizer

compressive, tensile and flexural strengths were increased with respect to retempering time up to 60 min where the compressive strength increases rapidly for time interval (0-45 min) then it slightly increased for time interval (45-60 min). The compressive, tensile and flexural strengths were decreased from 60-120 min retempering time. When retempering with water combined with superplasticizer the compressive, tensile and flexural strength were increased with respect to retempering time up to 45 min then were decreased from 45-120 min.

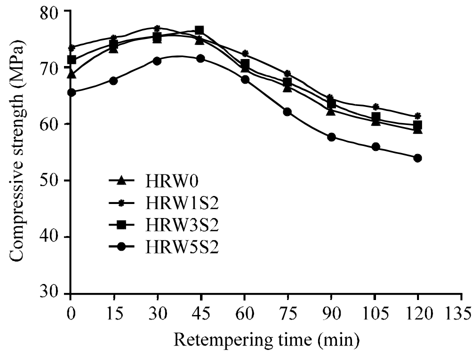

Fig. 13: 28 days CS for HSC retempered using water and 0.2% superplasticizer

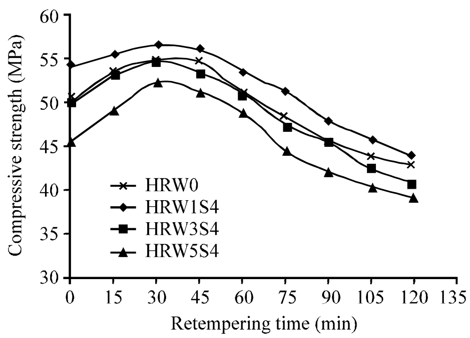

Fig. 14: 7 days CS for HSC retempered using water and 0.4% superplasticizer

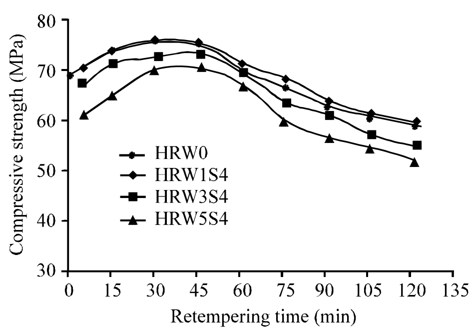

Fig. 15: 28 days CS for HSC retempered using water and 0.4% superplasticizer

It is observed that retempering with 1, 3 and 5% water combined with 0.2 or 0.4% superplasticizer gave higher compressive, tensile and flexural strength of concrete than retempering with 1, 3 and 5% water only by about 5%. The compressive strength of the retempered concrete with adding 3% extra amount of cement and water higher than that retempered by 3% water only by about 7% and higher than that retempered with 3% water combined with 0.4%

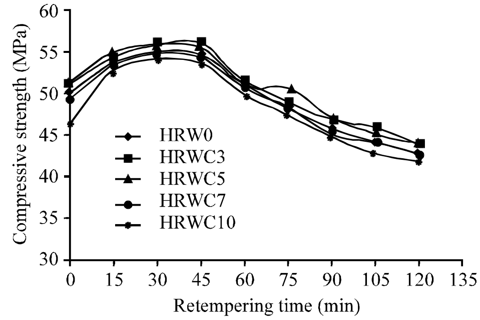

Fig. 16: 7 days CS for HSC retempered using extra amount of cement and water

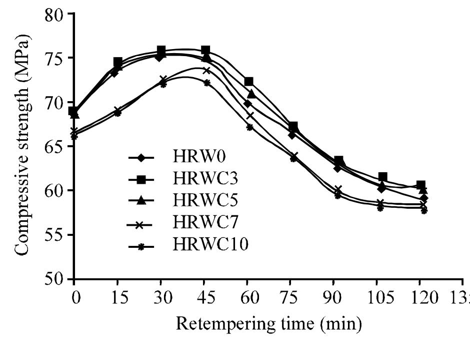

Fig. 17: 28 days CS for HSC retempered using extra

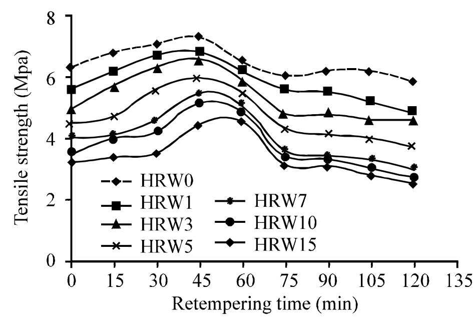

Fig. 18: 28 days TS for HSC Retempered using water

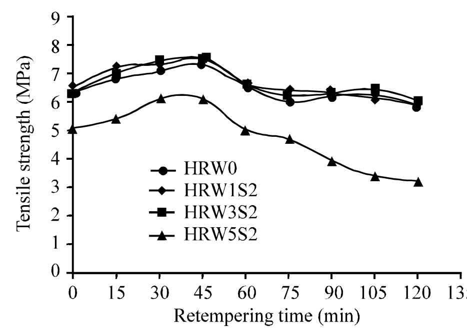

Fig. 19: 28 days TS for HSC retempered using water and 0.2% superplasticizer

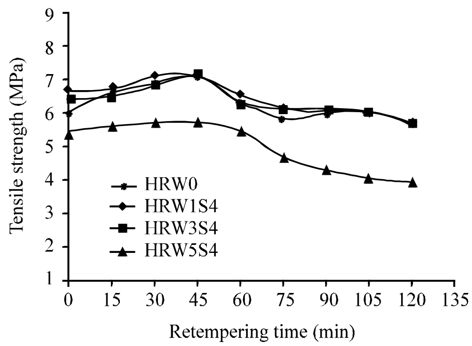

Fig. 20: 28 days TS for HSC retempered using waterand 0.4% superplasticizer

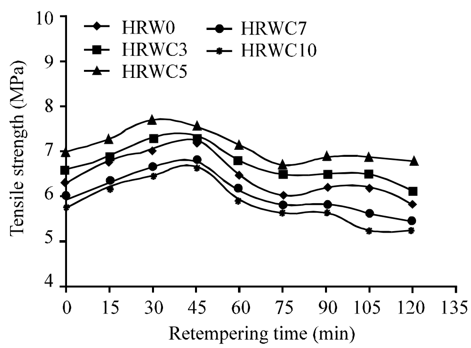

Fig. 21: 28 days TS for HSC retempered using extra amount of cement and water

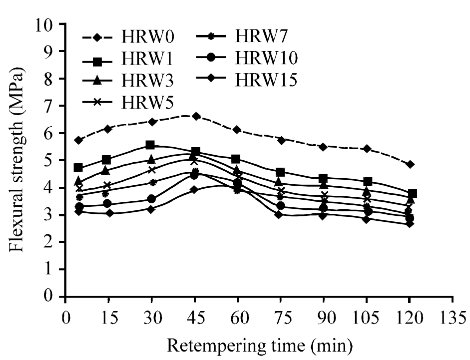

Fig. 22: 28 days FS for HSC Retempered using water

superplasticizer and almost convergent to that is retempered with 3% water combined with 0.2% superplasticizer. While for using 5% retempering with an extra amount of cement and water gave higher compressive strength as compared to the concrete retempered with 5% water only by about 11% and higher than that is retempered with 5% water combined with 0.2 or 0.4% superplasticizer (HRW5S2 or HRW5S4)

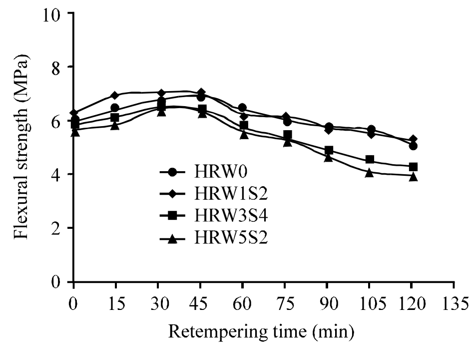

Fig. 23: 28 days FS for HSC retempered using water and 0.2% superplasticizer

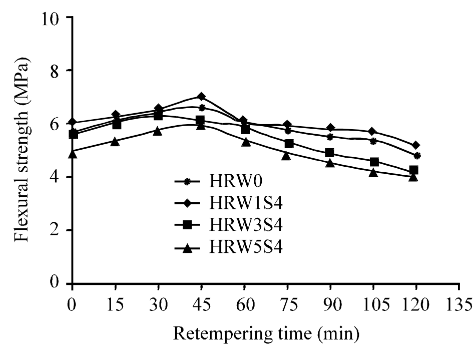

Fig. 24: 28 days FS for HSC retempered using water and 0.4% superplasticizer

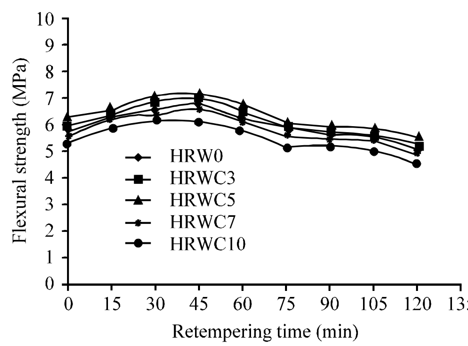

Fig. 25: 28 days FS for HSC retempered using extra amount of cement and water

by about 10%. While for using 7% retempering with an extra amount of cement and water it gave higher compressive strength as compared to the concrete retempered with 7% water only by about 10%. Retempering with 10% extra amount of cement and water gave higher compressive strength than concrete retempered with 10% water only by about 27%.

CONCLUSION

Based on the results obtained from the current research, the following main conclusions can be summarized:

Retempered normal strength concrete: The initial slump can be restored by adding 10% retempering water till about 45 min. Adding retempering water 15-25% satisfies the initial slump of the control mix for all time intervals till 120 min while when adding 30% of retempering water segregation takes place till 30 min then the concrete transformed to self compacting concrete. The initial slump could be achieved by adding 5, 7 and 10% extra amount of cement and water till 30 min. The compressive strength decreases with respect to retempering time within the studied interval (0-120 min) and for all the adding percentages (0-30%) of the retempering water.

Adding a percentage of retempering water to the concrete at different times reduces the compressive strength, tensile strength, flexural strength by the same amount of addition up to 15% and the reduction is almost double for percentages (20-30%) of retempering water. The compressive strength of the concrete retempered by adding an extra amount of cement and water higher than that is retempered by water only.

Retempered high strength concrete: HSC was very sensitive for excess water addition. The highest strength gained for HSC was achieved at 45 min from the beginning of HSC mixing. The initial slump of the control mix could be achieved by adding 3, 5, 7, 10% extra amount of cement and water for all time interval till 120 min. Adding of 1% retempering water to the concrete at different times led to a slight decrease in the compressive strength, although, it has a good effect on the workability. While for 3, 5 and 7% retempering water the reduction is almost double. Whereas using 10 and 15% reduce the compressive strength >30%.

Retempering with 1, 3 and 5% water combined with 0.2 or 0.4% superplasticizer gave higher compressive, tensile and flexural strength of concrete than retempering with 1, 3, 5% of water only by about 5%.

The compressive strength of the concrete retempered by adding 3% extra amount of cement and water higher than that is retempered by 3% water only by about 7% and higher than that is retempered with 3% water combined with 0.4% superplasticizer and almost convergent to that is retempered with 3% water combined with 0.2% superplasticizer. The compressive strength of the concrete retempered by adding 5% extra amount of cement and water gave higher compressive strength as compared to the concrete retempered with 5% water only by about 11% and higher than that is retempered with 5% water combined with 0.2 or 0.4% superplasticizer by about 10%.

The compressive strength of the concrete retempered by adding 7% retempering with an extra amount of cement and water gave higher compressive strength as compared to the concrete retempered with 7% water only by about 10%. While for using 10% retempering with an extra amount of cement and water gave higher compressive strength as compared to the concrete retempered with 10% water only by about 27%

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