Effects of revibration on early age retarded concrete

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Abstract

In this study, the influence of revibration on the compressive strength of retarded concrete is examined at late lag time intervals before and after the initial and final setting times. The time lag intervals ranged from about 2 hrs to 8 hrs and the retarder dosages of the used cement weight ranged from 0.5% to 1.5%. Results from this study indicate that the maximum compressive strength is achieved when the concrete is revibrated after 2 hrs 35 min with 0.5% of retarder dosage for any workability. Furthermore, higher dosages of the retarder do not reduce the compressive strength of the concrete when it is revibrated at late lag time intervals even near its final setting time. The use of setting retarder in high doses and revibration of the concrete reduces the air-voids in hardened concrete.
Keywords: revibration, retardation, workability, fresh concrete, compressive strength.

1 Introduction

It is essential to place concrete continuously to avoid cold joints in structures such as beam-column intersection and large constructions (bridge decks and turbine foundations). In these types of structures, micro transverse cracks could form in the fresh concrete because of the changes in deflection and rotation over supports during construction due to the dead weight of the concrete. Additionally, theses cracks might result from a lapse in time between revibration and the final setting of the earlier poured layers of concrete. (CCAA Report [1] and Krishna *et al.* [2]).

Previous studies indicate that revibration improves many of the qualities of hardened concrete since it is carried out within about 4 hours from the mixing time. Compressive strength increases approximately 14%. Water tightness and

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concrete density are greater and there is an improvement in the appearance of the formed surfaces [3, 4].

The primary chemical process that occurs in the first 2 hours after concrete placement is the formation of calcium hydroxide, which typically makes up 15 to 25 percent of the ordinary Portland cement concrete. The other major product of hydration is calcium silicate hydrate, which is approximately 50 percent of the ordinary Portland cement concrete and gives the concrete its hardness and durability. Calcium silicate hydrate forms quickly after several hours. Formation of the more brittle, weaker calcium hydroxide continues but falls behind the calcium silicate hydrate formation, which accelerates dramatically between initial set and final set. Therefore, revibration of concrete after the initial set has an advantage of momentarily liquefying the concrete again and break down some of the weaker calcium hydroxide that already formed. This allows freshly placed concrete adjacent to the revibrated concrete to form a monolithic concrete structure, rather than introducing a construction joint [5].

Concrete benefits from revibration when concrete is plastic enough to permit the vibrator to sink on its own. After the final set of concrete takes place, the vibrator takes 30-60 seconds to sink in the concrete. This delay in revibration may reduce the strength of hardened concrete [6, 7]. At this interval of time, the revibration effect on concrete strength has not sufficiently been investigated.

Retarded concrete remains in plastic phase much longer than plain concrete. Therefore, the delay between placement and revibration could increase. Also the retarder plasticizer improves the compressive strength of plain concrete revibrated at late period after placing [8, 9].

This study quantifies the change in compressive strength of concrete revibrated indirectly with a table vibrator using different parameters namely lag time intervals (2-8 hours) and retarder plasticizer doses (0.5 - 1.5%).

2 Experimental program

To study the effect of indirect revibration on compressive strength of retarded concrete using different retarder plasticizer dosages and time lag intervals. Sets of compressive strength tests on concrete cube specimens 150mm carried out; each set consisted of three specimens. Concrete of four different properties was used based on different retarder dosages (0.0%, 0.5%, 1.0%, and 1.5%). Six time lag intervals were used for revibration, namely, 0 hrs, 2 hrs 35 min (one hour before initial setting time), 3 hrs 35 min (at initial setting time), 5 hrs 40 min (one hour before final setting time), 6 hrs 40 min (at final setting time), and 7 hrs 40 min (after one hour from final setting time).

2.1 Materials

Cement: An ordinary Portland cement was used produced locally by Kirkuk Cement factory in accordance with Iraqi Specification [10]. Details of the chemical and physical properties are shown in Tables 1 and 2 respectively.

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Table 1: Chemical composition of the ordinary Portland cement (O.P.C.).

Property	Test result, %	Standard IQS, No. 5
1. Oxide composition		
Alumina, Al_2O_3	5.1	
Silica, SiO_2	21.89	
Ferric Oxide, Fe_2O_3	3.4	
Lime, CaO	63.11	
Sulphate Anhydride, SO_3	2.22	Max. 2.5%
Magnesia, MgO	3.04	Max. 4%
2. Compound composition		
C_3A	7.77	
C_2S	29.00	
C_3S	45.03	
C_4AF	10.34	

Table 2: Physical properties of the O.P.C.

Property	Test result	Standard IQS, No. 5
Fineness (Residue on sieve NO. 170)	-----	Max. 10%
Specific surface "Blaine," cm^2/gm	3348	2250
Initial setting time, min.	217	Min. 45 minutes
Final setting time, min.	400	Max. 10 hours
Compressive strength, MPa.		
At 3 days	26.79	15 MN/m^2
At 7 days	36.21	23 MN/m^2

Fine aggregate: River sand with a maximum size of 4.75 mm conforming to zone II of British Standards (BS 882: 1992) [11] was used, as detailed in Table 3**.**

Table 3: Characteristics of fine aggregate.

Sieve Size (mm)	% passing	Limits Zone II as per B.S 882, % passing
9.5	100	100
4.75	100	90-100
2.36	77.5	75-100
1.18	64.5	55-90
0.6	53.1	35-59
0.3	28.9	8-30
0.15	8.6	0-10
Fineness Modulus 2.67		

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Coarse aggregate: Normal river gravel was used (irregular almost rounded maximum size 20 mm) in accordance to BS 882: 1992 [11]. Their sieve analysis and grading are shown in Table 4.

Table 4: Characteristics of coarse aggregate.

Sieve Size (mm)	% Passing	Limits as per B.S 882 % passing
37.5	100	100
20	95	85-100
10	22.9	0-25
5	1.4	0-5
Fineness Modulus 6.81		

Water: Ordinary potable water was used for mixing and curing purposes.

Chemical admixture: Sika-retarder was used to meet a highly efficient set-retarding admixture, which properties are shown in Table 5.

Table 5: The properties of Sika retarder.

Type	Naphthalene formaldehyde sulphonate
Colour	Transparent liquid
Density	1.2 kg/l
Dosage	0.2-2.0% by weight of cement as retardation rate is required.

2.2 Mix Proportions and procedure

The mixes were prepared with four different retarder admixture ratios, 0%, 0.5%, 1% and 1.5% of cement weight. The cement and w/c ratios were kept constant at 400 kg/m^3 and 0.425 respectively for all of the tested mixes as shown in Table 6. The control mix was designed by ACI method [12].

All mixes were prepared in an electrical mixer. The mixing sequence consisted of homogenizing the coarse and fine aggregate and cement for an adequate time. The Sika retarder and water was mixed and added to admixture and mixed again properly until a uniform admixture was obtained [13]. Once the mix was prepared, the slump test was performed in a quick succession, according to ASTM C143/ C143M-05a [14], to determine the workability.

2.3 Casting and testing

Cube specimens of 150 mm x 150 mm x 150 mm were cast as per the standard procedure. Westerwork 300 mm x 600 mm balance vibrating table with 3000 rpm was used for initial vibrating and revibration of the concrete. The casting of the cubes was done in three layers. The first two layers were vibrated for 20 seconds and the last third layer vibrated for 40 seconds. In lag interval times the casted concrete was revibrated again for 40 seconds. The compressive strength of the specimens at the end of 28 days curing in water was tested using ADR 1500 ELE Testing Machine under strain rate control.

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Table 6: Mix characteristics of investigated concretes.

S. No	Mix particulars	Retarder/cement ratio			
		0%	0.5%	1%	1.5%
1	Mix proportio by weight C : FA : CA	1:1.575:2.925	1:1.575:2.925	1:1.575:2.925	1:1.575:2.925
2	Materials per m of concrete, kg				
	Water	170	170	170	170
	Cement	400	400	400	400
	Fine aggregate	630	630	630	630
	Course aggregate	1170	1170	1170	1170
	Sika retarder	0	2	4	6
3	Revibration tim hrs:min	0:0, 2:35, 3:35 5:40,6:40,7:40	0:0, 2:35, 3:3 5:40,6:40,7:40	0:0, 2:35, 3:3 5:40,6:40,7:40	0:0, 2:35, 3:3 5:40,6:40,7:40
4	Slump, mm	43	68	88	162

3 Results and discussion

3.1 Initial and final setting time

The influence of Sika retarder doses on the initial and final setting times of concrete is illustrated in Figure 1. It can be seen that Sika retarder doses increases the initial and final setting times. This figure also shows that the initial setting time is more affected with increasing the retarder ratio than the final setting time. Even though both of the initial and final setting times were closely related and highly affected. The maximum increases in the initial and final setting times are observed to be 414% and 238% respectively.

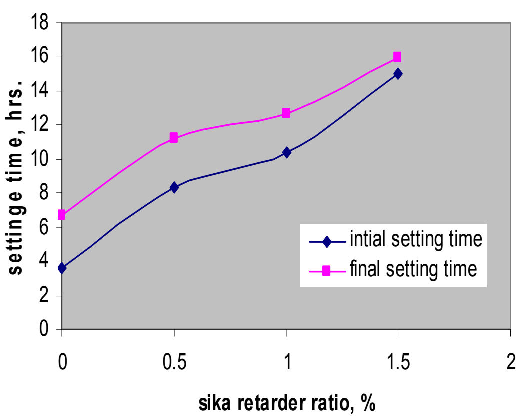

Figure 1: Effect of Sika retarder plasticizer on initial and final setting time.

3.2 Workability

The relationship between the workability and Seka retarder dosages are plotted in Figure 2. The results show that the slump values have a normal linear increase for retarder ratios up to 1% of the cement weight. A significant increase in the workability is observed for dosages greater than 1% of the retarder. At the same time, this high increase in the workability was accompanied with a decrease in compressive strength at 28 day age. Therefore, the 1% ratio is the optimum effective dosage suggested to be used.

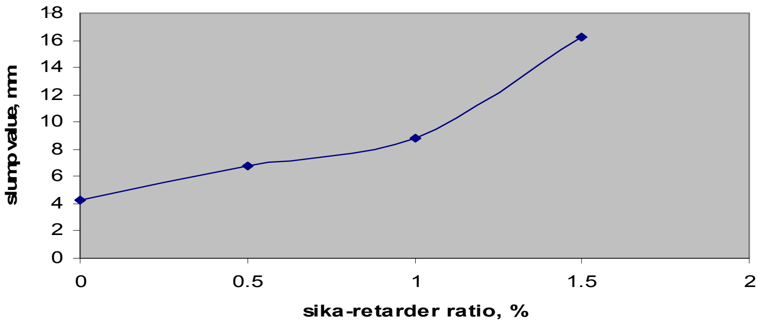

Figure 2: Effect of Sika retarder plasticizer on concrete workability.

3.3 Compressive strength

The compressive strength of concrete for different time lag intervals of revibration and different dosages of Sika retarder are plotted in Figures 3 and 4 respectively. A comparison of maximum percentage increase in compressive strength at a certain time lag interval for different dosages of Sika setting retarder is illustrated in Table 7 and plotted in Figure 5. From Figure 3 it can be seen that the 28 day compressive strength is slightly affected by using different dosages of Sika retarder. In general, it is known that the early age compressive strength must decrease when setting retarder is added to the mixture. This decease is related to the delay of final setting time, which is clearly noticed in figure 1, and finally delays the hardening of the concrete.

Figures 4 and 5 demonstrate that with a low retarder ratio (0.5%) the compressive strength of the revibrated concrete increases for all revibration time intervals considered in this study. With retarder ratios more than 0.5%, the compressive strength starts to decrease. This decrease in the compressive strength may be attributed to the excessive delay in setting time caused by the retarder. It is noted, however, that the compressive strength of revibrated concrete at late time intervals (at the final setting and one hour later) retains its tendency to increase with the maximum retarder ratio (1.5%) used. This increase may be seen more clearly when the concrete is tested at late ages, i.e. more than 28 days. The optimum revibration time lag intervals for obtaining maximum possible percentage increase in compressive strength with retarder dosage ratios are given in Table 7.

Table 7: Increase in compressive strength and optimum time for different retarder dosages.

S. No	Retarder dosage, %	Maximum increase in compressive strength, %	Optimum time lag interval, hrs:min
1	0.0	2.86	2:35
2	0.5	12.34	2:35
3	1.0	4.65	2:35
4	1.5	7.55	7:40

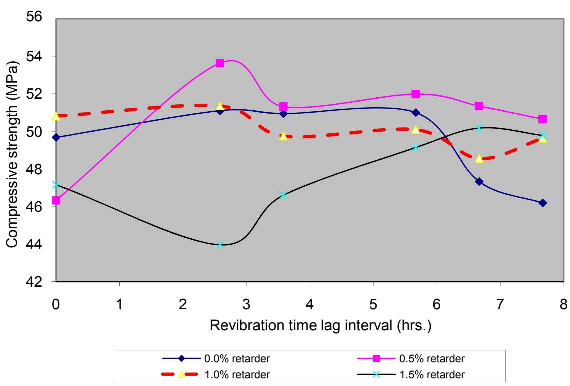

Figure 3: Compressive strength versus revibration time lag.

The additional bleeding and resettlement of revibrated concrete may occur at lag time intervals up to 3 hrs and 35 min, i.e., before the initial setting time, with 1% and 1.5% of the retarder. The bleeding and resettlement of concrete increases its compressive strength.

Figure 5 shows that the compressive strength of concrete without the retarder agent decreases by about 7% when revibrated at late time interval i.e. one hour after the final setting time of the used cement.

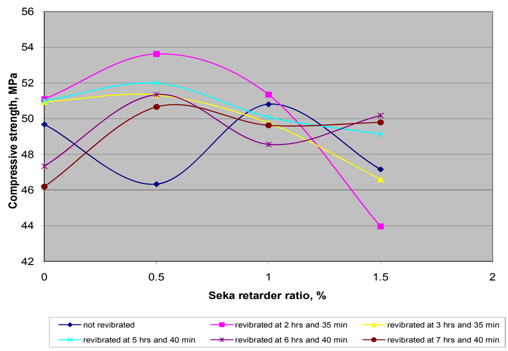

Figure 4: Effect of retarder ratios on compressive strength at different revibration time lags.

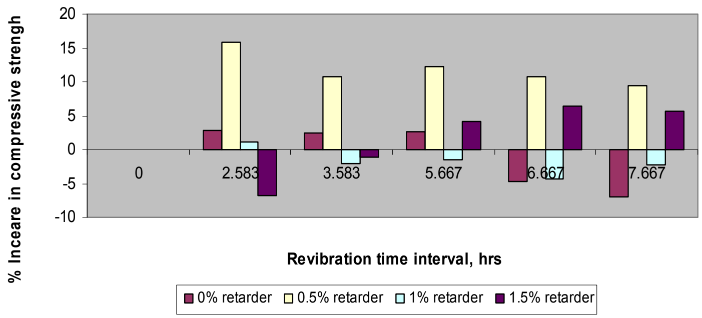

Figure 5: Effect of revibration time on compressive strength.

4 Conclusions

Based on the experimental results of this study, the following basic conclusions can be drawn:

1. The revibration of concrete can be performed at late lag time intervals with different dosages of setting retarder. The lag of time may reach the final setting time of the used cement.
2. The compressive strength of retarded concrete does not improve significantly by revibration.
3. By revibration of concrete the air-voids reduce noticeably in size and number.

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