EFFECT OF WATER CEMENT RATIO ON THE COMPRESSIVE STRENGTH OF REVIBRATED CONCRETE

AUTA, S. M. MAMUD, A. AND ABDULAZEEZ, Y.
Department of Civil Engineering, Federal University of Technology, Minna.
Corresponding Author: smahuta@yahoo.com

Abstract
Effect of water cement-ratio on compressive strength of re-vibrated concrete is presented. The mix proportion of 1:2:4 aggregates were considered to cast 39 cubes each as laboratory specimen with 0.65, 0.70 and 0.75 water-cement ratios. Each of these categories were revibrated at time lag intervals of 10minutes for 120 minutes period of revibration process and cured for 7, 21 and 28 days. When tested for their respective compressive strength, the result obtained shows that there is a gradual increase in compressive strength of the concrete specimen with increase in time and in water-cement ratio. The maximum compressive strength at 120th minute for ages of 28 days are 25.42, 26.67 and 40.44N/mm^2 for concrete with water-cement ratio of 0.65, 0.70 and 0.75 respectively. The maximum attained compressive strength for 28 days curing is 40.44N/mm^2 (for 0.75w/c) appears to be higher than 25.42N/mm^2 (for 0.65 w/c). Water-cement ratio has adversely enhanced the compressive strength of concrete when re-vibrated.

Keywords: Compressive strength re-vibrated concrete, re-vibration, time-lag intervals, water-cement ratio.

Introduction

Water/cement ratio is a major factor that affects the compressive strength of concrete, whether with or without admixtures or with partial replacement for cement as the case may be. It is the ratio of the amount of water to the amount of cement used in the cement paste. Concrete achieves its strength through a chemical process called hydration. Hydration is a complex process but in simple terms, is the reaction between water and the cement dust in the mixture. As in any chemical reaction, only a certain amount of water is needed for the reaction to reach completion (Lafe, 1986). The excess water used in the mix migrates to the surface of the concrete and evaporates. This leaves a network of flow channels called capillaries and as a result, a hardened finished product, which is less dense, and porous, however, capillaries provide the pathway for water to be absorbed.

Newman and Choo (2003) reports that fresh concrete must be protected from further vibrations due to blasting, piling or very close road or rail traffic once initial set has taken place from approximately 4hours to approximately one day. And further asserts that information is sparse on the level at which vibration becomes damaging, but indication is given by the peak particle velocity (ppv). The research work of Krishna et tal (2008) and Neville (1994) agree that re-vibration is beneficial rather than detrimental, provided that the concrete is again brought to a plastic condition. And that re-vibration may be accomplished by immersion- type vibrators, by form vibration or by transmission of vibration through the reinforcement system, enhances the compressive strength of the concrete (Sawyer and Lee 1956, Vollick 1958, Sheshadri and Rama, 1964, Everard and Bhagat, 1970). Introduction of re-vibration of the fresh concrete becomes very important and crucial to take care of the capillaries, pores and utilize excess water. Re-vibrating concrete momentarily liquefies the concrete again. The chemical process that occurs in the first two hours after concrete is placed is the formation of calcium hydroxide which typically makes to 15% to 25% of Ordinary Portland Cement concrete. The other major product of hydration is calcium silicate hydrate, which usually makes up about 50% of OPC concrete and gives the concrete its hardness and durability (Krishna et al., 2008). When re-vibration occurs after the initial set, it breaks down some of the calcium hydroxide that has already been formed, which allows freshly placed concrete adjacent to the re-vibrated concrete to join with it, rather than introducing a construction joint and again becomes a monolithic concrete. Re-vibration, if done at appropriate time, results in improvement of compressive strength.

Krishna et al (2008) suggests the optimal time-lag intervals of revibration for different w/c ratios when a minimum revibration time lag interval of 30minutes to 4 hours was adopted. However on the other hand an interval time lag of 30minutes was too much, because the effect was dynamic in nature (Auta, 2011). While other researchers look at the effect of water/cement ration on concrete without admixture (Marar and Eren, 2011, Garcia et al., 2008) and with admixtures (Omotola and Idowu, 2011) at the level of only initial vibration and compaction of concrete, this work intends to focus on revibration the concrete and observing the effect adopts a revibration time lag of 10 minutes successions for 120minutes period of revibration process to investigate possible influence of varied w/c ratio in the scope of 0.65 – 0.75 (i.e., 0.65, 0.70 and 0.75) on the compressive strength of the revibrated concrete for aggregate mix proportion of 1:2:4.

Materials and Methods

The materials used for this study include: Ordinary Portland cement which satisfies BS ; locally sourced crushed granite as coarse aggregate that passed 20mm mesh to those retained on 4.75mm mesh according to BS 882 (1992); fine aggregate (river sand) also locally sourced which passed through 2.36mm mesh to those retained on the pan; and a portable clean water was sourced from a bore hole in FUT Minna Main Campus. These materials were used to achieve the mix proportion of 1:2:4 with water to cement ratios of 0.65, 0.70 and 0.75.

For each category of water/cement ratio (0.65, 0.70, 0.75) thirty nine concrete cubes specimen (150mm×150mm×150mm) were prepared and cast (BS 1881: Part 108, 1983) to make a total of one hundred and seventeen cubes (39x3=117cubes), cured (BS 1881: Part 111, 1983) and tested (BS 1881: Part 116, 1983) at ages of 7days, 21days and 28days in accordance with the standards as indicated. Tests such as sieve analysis (BS 812: Part 103.1, 1985), moisture content (BS 812: Part 109, 1990), specific gravity (BS 812: Part 107, 1995), bulk density(BS 812: Part 2, 1995) , absorption test (BS 812: Part 107, 1995), workability/compacting factor test of fresh aggregate (BS 1881: Part 103, 1993), slump test (BS EN 12350-2, 2000) and finally the compressive strength test (BS 1881: Part 116, 1983) after curing for 7days, 21days and 28 days were carried out in accordance with British Standard for each category of water cement ratio of 0.75, 0.70, 0.65 as so indicated. To achieve compaction and revibration of these concrete cubes, a table vibrator was used at time lag interval of 10 minutes successively to a re-vibration time lag period of 120minutes (2 hours).After de-moulding, the cubes were placed in curing tank for the specified days of curing, namely 7 days, 21 days and 28 days. The compressive strength test was then carried out immediately after each aging set of cubes in accordance with BS (BS 1881: Part 115 & 116, 1983).

Results and Discussions. The results of all tests such as sieve analysis, moisture content, specific gravity, bulk density, absorption test, void ratio of aggregate, porosity of aggregate, workability/compacting factor test of fresh aggregate, slump test and finally the compressive strength test after curing are presented in summary on Figures 1 and 2, Tables 1, 2, 3 and 4. Figures 1 and 2 represent the result of sieve analysis test of fine and coarse aggregates graphically presenting the cumulative percentage passing according to the sieves used as indicated. On the other hand, the characteristics of fine aggregate; coarse aggregates and the concrete used are presented on Tables 1, 2 and 3 respectively.

The result of the particle size distribution carried out in accordance with standard (BS 812: Part 103.1 1985) gave rise to the graphical presentations in Figures 1 and 2. Those retained on 150µm, 300µm, 600µm, 1.18mm and 2.36mm were recorded as fine aggregate to also compute for the fineness modulus (FM) of 3.1 which according to BS 882 (1992) is finely graded. Even though smaller sieves than 5mm sieve were not used for coarse aggregate sieve analysis 100% will also be retained on these standard smaller sieves specified. They were therefore used in calculating the FM of the coarse aggregate (granite) which was found to be 5.8 uniformly graded.

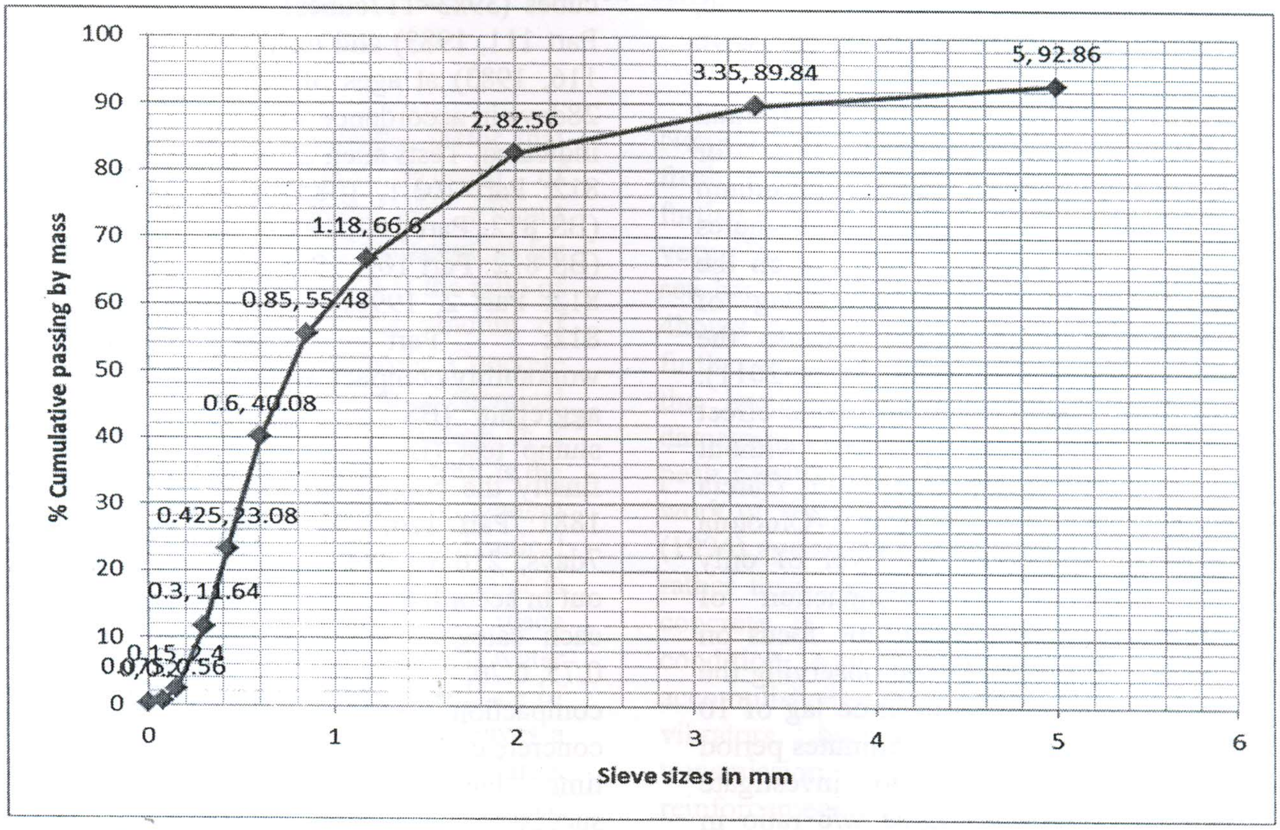

Figure 1. Laboratory result for sieve analysis of fine aggregate.

The specific gravity obtained for fine aggregate was 2.71 and that of coarse aggregate is 2.62 which are found to be within the standard range of 2.6 –3.0 and 2.4–2.8 respectively falling within the range required by BS 812: Part 107 (1995).

The average moisture content obtained for fine aggregate from is 5.98% and that of coarse aggregate is 1.76%. Both are found to be within the standard range of 5–15% and 1–5% respectively required by BS 812: Part 109 (1990).

The average water absorbed by the coarse aggregate was 0.66% which is within the standard range of 0.5–5% (BS 812: Part 107, 1995).

The average bulk density obtained for fine aggregate was 1690.2kg/m³ while that of coarse aggregate was 1600.0kg/m³, which fall within the standard range of 1500 – 1700kg/m³ and 1300–1800kg/m³ respectively (BS 812: Part 2, 1995).

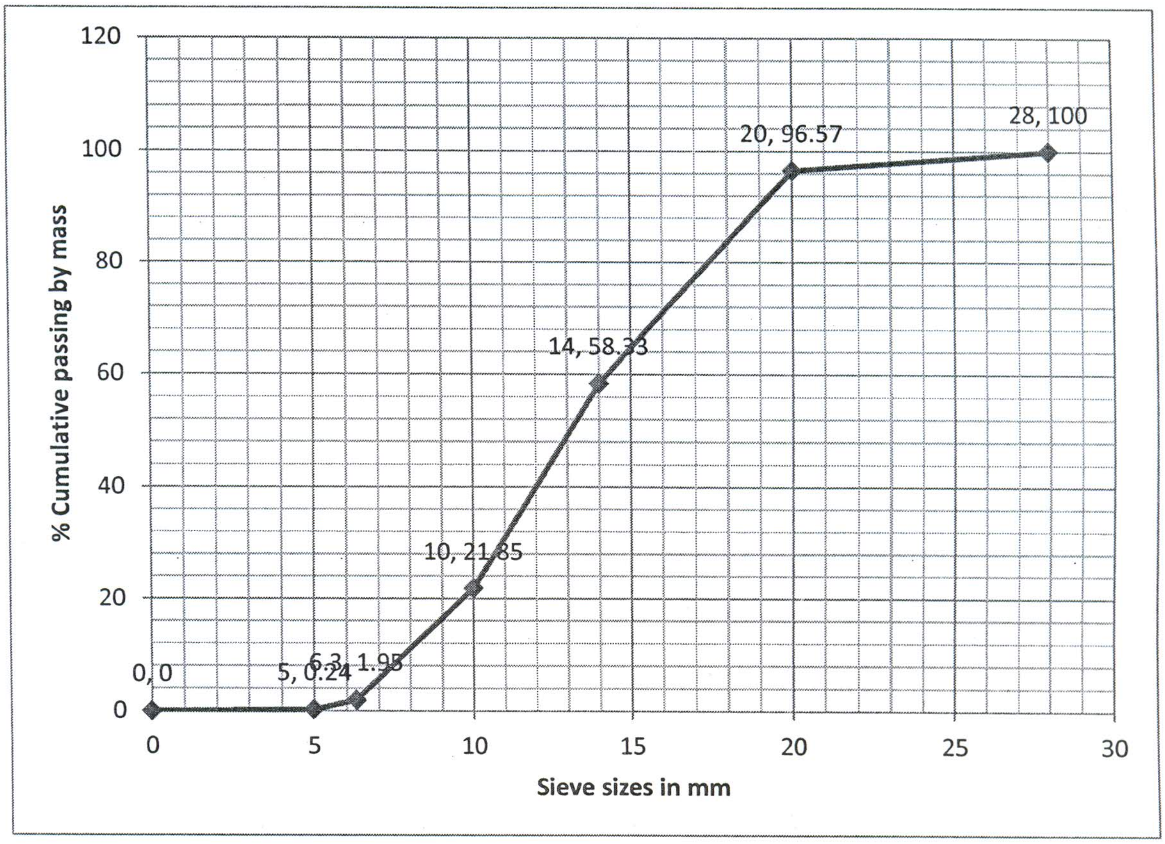

Figure 2 Laboratory result for sieve analysis of coarse aggregate.

The summary of the characteristics of Fine aggregate, coarse aggregate and the concrete are presented on Tables 1, 2 and 3 respectively.

Table 1. Characteristics of Fine Aggregate

S.No.	Test	Result	BS requirement
1	Specific Gravity	2.71	2.6 – 3.0 (BS 812: Part 107, 1995)
2	Bulk Density (kg/m^3)	1690.2	1500 – 1700 (BS 812: Part 2, 1995)
3	Moisture Content (%)	5.98	5 – 15 (BS 812: Part 109, 1990)
4	Fineness Modulus (FM) from standard sieves only.	3.1	2.0 – 3.3 (BS 882:1992)

Table 2. Characteristics of Coarse Aggregate

S.No.	Test	Result	BS requirement
1	Specific Gravity	2.62	2.4 – 2.8 (BS 812: Part 107, 1995)
2	Bulk Density (kg/m^3)	1600.00	1300 – 1800 (BS 812: Part 2, 1995)
3	Moisture Content (%)	1.76	1 – 5 (BS 812: Part 109, 1990)
4	Water absorption (%)	0.66	0.5 – 5 (BS 812: Part 107, 1995)
5	Fineness Modulus (FM) from standard sieves including those lower than 5mm sieve.	5.80	BS 882:1992

Table 3. Characteristics of Concrete

S.No.	Test	Water – cement ratio (w/c)	Control	Result
1	Mix Proportion, cement: fine aggregate: coarse aggregate	0.75	1:2:4	1:2:4
		0.70	1:2:4	1:2:4
		0.65	1:2:4	1:2:4
2	Slum in (mm)	0.75	35	35
		0.70	40	40
		0.65	44	44
3	Number of cubes cast	0.75	3	36
		0.70	3	36
		0.65	3	36
4	Maximum compressive strength after 7days curing (N/mm^2)	0.75	16.00	24.88
		0.70	13.33	22.84
		0.65	12.36	19.20
5	Maximum compressive strength after 28days curing (N/mm^2)	0.75	19.56	40.44
		0.70	17.78	26.67
		0.65	15.82	25.42

The compressive strength of concrete at 7days, 21days and 28 days of curing are presented on Table 4. From Table 4, it can be observed that the compressive strength of the concrete with w/c ratios from 0.65 to 0.75 at the time lag intervals up to 2 hours is higher than the compressive Strength of concrete without re-vibration.

It is also observed from the result that the compressive strength of the concrete cubes decreases with decrease in water-cement ratio. However, the compressive strength was observed to increase with increase in the number of curing days. The increase is due to re-arrangement of coarse aggregate and mortar in the concrete under the plastic condition which is usually not explored at the initial compaction and vibration of fresh concrete. During the process of re-vibration the pores and capillaries which are usually responsible to a less dense concrete are refilled liquefied concrete in plastic state. Hence the quantity of water still unused is utilized.

Thus, water-cement ratio becomes one of the main determinants of crushing strength of the concrete cubes.

Conclusions

This paper has considered the effect of water cement ratio on the compressive strength of a re-vibrated concrete. Thus, 0.65, 0.70, 0.75 water cement ratios were considered for this study at successive revibration time lag interval of 10minutes up to 120minutes period of revibration process. Re-vibration resulted in an increased compressive strength of concrete within the studied range of 0.65 to 0.75 w/c.

Depending on the mix ratio of water to cement in the concrete mixture, the compressive strength observed at the 120th minute revibration time-lag interval is higher than that at the control.

Table 4. Compressive strength of the re-vibrated concrete

S. No.	Mode of revibration	Interval of revibration	Compressive strength, N/mm^2								
			7 days curing			21 days curing			28 days curing		
			0.65	0.70	0.75	0.65	0.70	0.75	0.65	0.70	0.75
1	Non-revibrated (control)	0	12.36	13.33	16.00	13.69	14.00	16.89	15.82	17.78	19.56
2	revibrated	10	12.67	15.42	16.62	14.22	14.31	17.78	16.67	18.22	20.00
3	revibrated	20	13.07	15.56	17.60	14.40	15.42	18.13	17.69	20.00	20.00
4	revibrated	30	13.24	15.56	19.11	14.58	15.56	20.09	18.49	20.22	20.44
5	revibrated	40	13.91	15.64	19.91	14.67	16.00	20.36	19.02	20.00	24.44
6	revibrated	50	14.44	16.09	21.07	14.76	16.22	21.69	20.27	20.22	24.89
7	revibrated	60	14.98	17.51	21.42	15.11	17.33	24.44	21.07	20.44	27.56
8	revibrated	70	15.73	18.00	22.22	15.56	17.78	25.33	21.73	21.56	28.00
9	revibrated	80	16.09	18.27	23.11	15.73	18.27	30.58	22.09	22.22	28.89
10	revibrated	90	16.71	18.31	24.44	16.09	19.78	31.11	22.93	23.33	32.89
11	revibrated	100	17.60	19.47	24.88	16.18	21.78	32.44	23.82	24.22	33.78
12	revibrated	110	18.18	20.17	29.33	16.71	21.96	33.33	24.84	25.33	35.56
13	revibrated	120	19.20	22.84	29.78	16.98	23.11	33.78	25.42	26.67	40.44

Being the principal focus of this work, the compressive strength of the concrete with 0.65 water cement ratio (25.42N/mm^2) is found to be lower than that of 0.70 (26.67N/mm^2) and 0.75(40.44N/mm^2) respectively at age of 28 days. Indicating that increasing the water cement ratio higher than 0.65 for a mixture of 1:2:4 can result in a higher compressive strength and still higher than that of control with a revibration time lag interval of 10minutes up to 120minutes, accounting for the reason that the unused water awaiting evaporation in the concrete is further utilized in plastic formation status of the re-vibrated concrete.

Recommendations: Revibration can be done for water cement ratio lower than 0.65 and higher than 0.75 in the range of 0.35 to 0.85 for a mix proportion of 1:2:4 re-vibrated concrete at the interval of 10 minutes revibration time lag interval up to 4 hours to obtain the true optimal compressive strength and the optimal water – cement ratio for such concrete.

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