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ВЛИЯНИЕ ПОВТОРНОЙ ВИБРАЦИИ НА ПРОЧНОСТЬ ПРИ СЖАТИИ БЕТОНА С ЗОЛОЙ РИСОВОЙ ШЕЛУХИ В КАЧЕСТВЕ ЧАСТИЧНОГО ЗАМЕНИТЕЛЯ ЦЕМЕНТА

EFFECT OF REVIBRATION ON THE COMPRESSIVE STRENGTH OF CONCRETE WITH RICE HUSK ASH AS PARTIAL REPLACEMENT FOR CEMENT

Рассматривается влияние эффекта повторной вибрации на прочность при сжатии бетона с 20 % золы рисовой шелухи в качестве частичного заменителя цемента. Лабораторные образцы подвергались повторной вибрации с интервалом 10 мин в течение 120 мин. Прочность образцов на сжатие испытывалась после 7, 14 и 28 суток твердения. Результаты испытаний показывают, что прочность образцов на сжатие постепенно растет с увеличением времени повторной вибрации. Чтобы прочность на сжатие бетона с золой рисовой шелухи сравнялась с прочностью на сжатие обычного бетона требуется не менее 90 мин повторной вибрации.

Ключевые слова: прочность на сжатие, зола рисовой шелухи, повторная вибрация, частичная замена, водоцементное соотношение.

The paper examines the effect of revibration on the compressive strength of concrete containing 20 % rice husk ash as a partial replacement for cement. Laboratory specimen cubes were subjected to successive revibration with 10 minute intervals for a period of 120 minutes. They were cured for 7, 14 and 28 days and tested respectively for their compressive strength. The result obtained shows that there is a gradual increase in compressive strength of the concrete specimen with increase in revibration time and it requires revibration during at least 90 minutes to achieve the compressive strength equivalent to or higher than that of normal concrete without cement replacement at 7, 14 and 28 days of curing respectively.

Keywords: compressive strength, rice husk ash, revibration, partial replacement, water-cement ratio.

1. Introduction

To meet the rising demand for cement and concrete, the use of mineral cement replacement materials (MCRM) must be explored. Substantial energy and cost savings can result when industrial by-products are used as a partial replacement for the Portland cement [1]. According to Sampaio et al. [2], the cement production rate of the world is expected to grow exponentially to about 3.5 billion tons per year by 2015. Sampaio suggests that the approach of using MCRM is necessary to prevent the possible ecological disaster from global warming. The presence of MCRM in concrete is known to impart significant improvements in workability and durability. High performance concretes with good workability and high durability can be made using MCRM and appropriate concrete mix proportions. Such materials include silica fume, rice husk ash (RHA), fly ash and slag. Rice husk ash (RHA) is produced by burning the rice husks under controlled temperature and atmosphere, and a highly reactive rice husk ash is formed [3]. Rice husk ash consists of non-crystalline silica producing a cellular structure that is responsible for the high surface area of the material even when the particles are not small in size [4–6]. Researchers have made this assertion of the possibility to replace cement in full or partially without compromising the standards guiding usage of such indigenous cementious material as rice husk ash which has been recently in use as a partial replacement for cement [1, 2, 7–20].

Revibration, on the other hand, has shown to have enhanced the compressive strength of concrete [21–24] and recently its effect has been found to be dynamic in nature [25].

Revibration is beneficial, provided the already placed & compacted concrete can regain plastic state under reverberations. Generally speaking, concrete will benefit from revibration, provided the concrete is sufficiently plastic to permit the running vibrator to sink of its own weight. The major benefit of revibration is the improved bond between successive lifts of concrete as trapped water gets removed during revibration. Revibration, if done at appropriate time, also results in improvement of compressive strength.

RHA percentage replacement for cement has been considered by researchers from 10 to 40 % without revibration. In this work, however, 20 % replacement is considered and adopted to study the effect of revibration on the compressive strength of this kind of concrete.

2. Materials and Methodology

The materials used for this research work are: Dangote Portland cement, fine aggregates, coarse aggregates, rice husk ash obtained from Kutugi in Kacha Local Government Area of Niger State. And the water used was collected at Gidan Kwano borehole, main campus of Federal University of Technology Minna, Niger State, Nigeria.

The aggregates features such as their physical properties and strength were determined by conducting several tests which include: sieve analysis, specific gravities, bulk density of the aggregates, moisture content, as well as compressive strength test at ages of 7 days, 14 days and 28 days.

Rice husk collected was burnt to ashes and the ash collected was sieved using a 75um sieve to make it finer as required by standard. Water-cement ratio of 0.65 was used. For each aggregate mix proportion (1:2:4), 20 % of rice husk ash was measured and added to every 20 % removal of the cement sample. A total of thirty nine (39) cubes with mould sizes of 150 mm × 150 mm × 150 mm were cast. The concrete cubes were then revibrated at interval of 10 minutes for 2 hours on a vibration machine, after which they were taken to the curing tank for 7 days, 14 days and 28 days of curing respectively.

All of the tests and their procedures were conducted according to the BS [26–35] and ASTM [36]. The compressive strength test was also carried out immediately after each aging set of cubes in accordance with BS [33–35].

3. Results and Discussions

The results of all tests performed are summarized in Tables 1–9.

While Tab. 1 and Tab. 2 represent the sieve analysis test of fine and coarse aggregates, the characteristics of fine aggregate, coarse aggregates, rice husk ash (RHA) and the concrete used are presented in Tab. 3–6, respectively. The compressive strength of concrete at 7 days, 14 days and 28 days of curing is presented in Tab. 7, 8 and 9, respectively.

The result of the particle size distribution carried out in accordance with standard [29] is presented in Tab. 1 and Tab. 2. Those retained on pan, 150 μm, 300 μm, 600 μm, 1.18 mm and 2.36 mm were recorded as fine aggregate.

Table 1

Sieve analysis for fine aggregate

Sieve size	Percentage retained (%)	Cumulative percentage retained (%)	Cumulative percentage passing (%)
10 mm	0.00	0.00	100
6.30 mm	0.28	0.28	99.72
5.0 mm	0.28	0.56	99.44
3.35 mm	1.29	1.85	98.15
2.0 mm	2.25	4.10	95.90
1.18 mm	4.64	8.74	91.26
850 μm	4.14	12.88	87.12
600 μm	12.32	25.20	74.80
425 μm	12.32	25.20	74.80
300 μm	20.47	60.72	39.28
150 μm	31.37	92.09	7.91
75 μm	6.50	98.59	1.41
Pan	1.22	100.00	0.00
Total	100	—	—

Table 2

Sieve analysis for coarse aggregate

Sieve size (mm)	Percentage retained (%)	Cumulative percentage retained (%)	Cumulative percentage passing (%)
28	0.00	0.00	100.00
20	67.48	67.48	32.52
14	27.21	94.69	5.31
10	3.68	98.37	1.63
6.3	1.16	99.53	0.47
5.00	0.05	99.58	0.42
3.35	0.09	99.69	0.31
Pan	0.33	100.00	0.00
Total	100	659.34	—

Table 3

Characteristics of fine aggregate

S.No.	Test	Result	BS requirement
1	Specific gravity	2.61	2.6–3.0
2	Bulk density (kg/m^3)	1530	1500–1700
3	Moisture content (%)	5	5–15
4	Fineness modulus (FM) from standard sieves only	2.85	2.0–3.3

Table 4

Characteristics of coarse aggregate

S.No.	Test	Result	BS requirement
1	Specific gravity	2.71	2.4–2.8
2	Bulk density (kg/m^3)	1500.17	1300–1800
3	Moisture content (%)	1.5	1–5.0
4	Water absorption (%)	0.84	0.5–5.0

Table 5

Characteristics of rice husk ash (RHA)

S.No.	Test	Result	BS requirement
1	Specific gravity	2.28	2.6–3.0
2	Bulk density (kg/m^3)	568.343	1500–1700
3	Moisture content (%)	5	5–15

Specific gravity of the aggregates was found to be 2.28 for rice husk ash, 2.61 for fine aggregate and 2.71 for coarse aggregate. The bulk densities of the materials were found to be 568.343 kg/m^3 for compacted rice husk ash, while that of compacted coarse aggregate was found to be 1500.285 kg/m^3. Characteristics of fine aggregate; coarse aggregate and RHA consisting of their specific gravities, bulk densities and moisture content are presented in Tab. 3, 4 and 5 and are within the range of BS requirements. Characteristics of the concrete with 20 % cement replacement for RHA are presented in Tab. 6 consisting of water cement ratio (w/c), mix proportion, slum test result, maximum and minimum compressive strength. Again, the result shows a compromise to the BS requirements.

Table 6

Characteristics of concrete with 20% rice husk ash partial replacement

S. No.	Test	Non revibrated concrete with 20 % RHA	Revibrated concrete with 20 % RHA	Control with 0 % RHA
1	Water to cement ratio (w/c)	0.65	0.65	0.65
2	Mix Proportion, Cement/RHA: fine aggregate: coarse aggregate	1:2:4	1:2:4	1:2:4
3	Slum in (mm)	30	30	30
4	Number of cubes cast	3	36	3
5	Maximum compressive strength after 7 days curing (N/mm^2)	5.63	17.87	13.78
5	Maximum compressive strength after 14 days curing (N/mm^2)	8.55	19.95	14.93
6	Maximum compressive strength after 28 days curing (N/mm^2)	10.81	21.18	18.26

The maximum compressive strength of non-revibrated normal concrete (one without cement replacement) and concrete with 20 % replacement of cement with RHA is shown in Fig. 1. The graph indicates a decrease in the compressive strength of

Table 7

The compressive strength of concrete after 7 day curing period

S/No	Ash (%)	Vibration mode	Interval period of vibration (minutes)	Compressive Strength (N/mm²)
1	0	non revibrated (control)	0	13.78
2	20	non revibrated	0	5.63
3	20	revibrated	10	9.33
4	20	revibrated	20	10.36
5	20	revibrated	30	11.56
6	20	revibrated	40	12.62
7	20	revibrated	50	13.42
8	20	revibrated	60	13.78
9	20	revibrated	70	13.96
10	20	revibrated	80	14.62
11	20	revibrated	90	14.84
12	20	revibrated	100	15.64
13	20	revibrated	110	16.44
14	20	revibrated	120	17.87

Table 8

Compressive strength of concrete after 14 day curing period

S/No	Ash (%)	Vibration mode	Interval period of vibration (minutes)	Compressive strength (N/mm²)
1	0	non revibrated (control)	0	14.93
2	20	non revibrated	0	8.55
3	20	revibrated	10	10.22
4	20	revibrated	20	12.00
5	20	revibrated	30	12.89
6	20	revibrated	40	13.33
7	20	revibrated	50	14.00
8	20	revibrated	60	14.62
9	20	revibrated	70	15.29
10	20	revibrated	80	16.13
11	20	revibrated	90	16.80
12	20	revibrated	100	18.22
13	20	revibrated	110	19.20
14	20	revibrated	120	19.95

Table 9

Compressive strength of concrete after 28 day curing period

S/no	Ash (%)	Vibration mode	Interval period of vibration (minutes)	Compressive strength (N/mm²)
1	0	non revibrated (control)	0	18.26
2	20	non revibrated	0	10.81
3	20	revibrated	10	11.87
4	20	revibrated	20	13.29
5	20	revibrated	30	13.83
6	20	revibrated	40	14.22
7	20	revibrated	50	15.33
8	20	revibrated	60	16.04
9	20	revibrated	70	16.62
10	20	revibrated	80	17.64
11	20	revibrated	90	18.22
12	20	revibrated	100	19.07
13	20	revibrated	110	20.31
14	20	revibrated	120	21.47

concrete with 20 % RHA as a replacement for cement at all ages of curing. Fig. 2 depicts the compressive strength of revibrated concrete with 20 % RHA replacing cement at successive intervals of 10 minutes for a total time of 120 minutes. The results presented show a gradual increase in compressive strength of the specimens at each successive interval of revibration time lag.

Revibration can be seen to increase the compressive strength of the concrete specimens compared to the control concrete specimens in all ages of 7 days, 14 days and 28 days of curing periods.

4. Conclusion and recommendations

The effect of revibration on the compressive strength of concrete with 20 % rice husk ash (RHA) as partial replacement for cement and with a water cement ratio (w/c) of 0.65 has been investigated and presented. The result shows that the maximum compressive strength of the non-revibrated concrete with 20 % RHA as cement replacement at each age of curing is less than that of the control specimens of their corresponding ages of curing. However, as revibration time

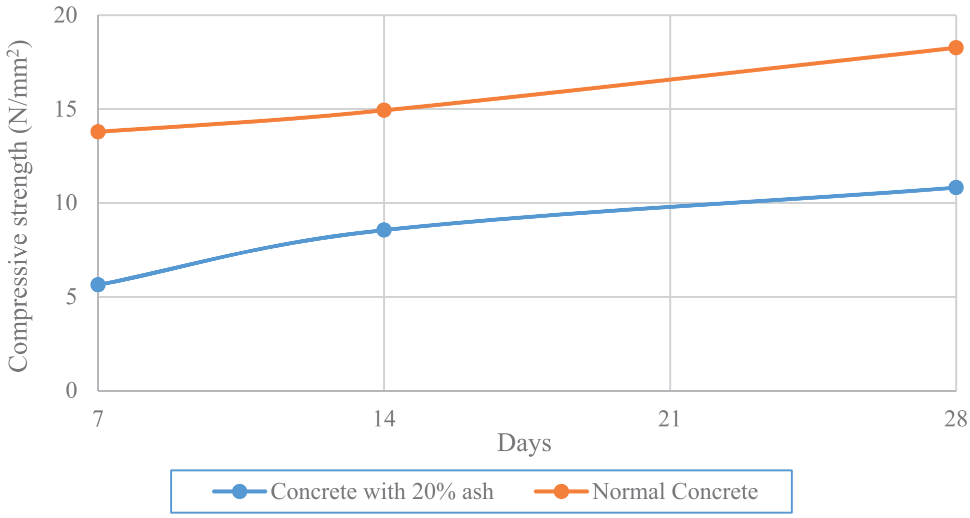

Fig. 1. Compressive strength of normal concrete (without cement replacement) and concrete with 20 % RHA as cement replacement at 7 days, 14 days and 28 days curing

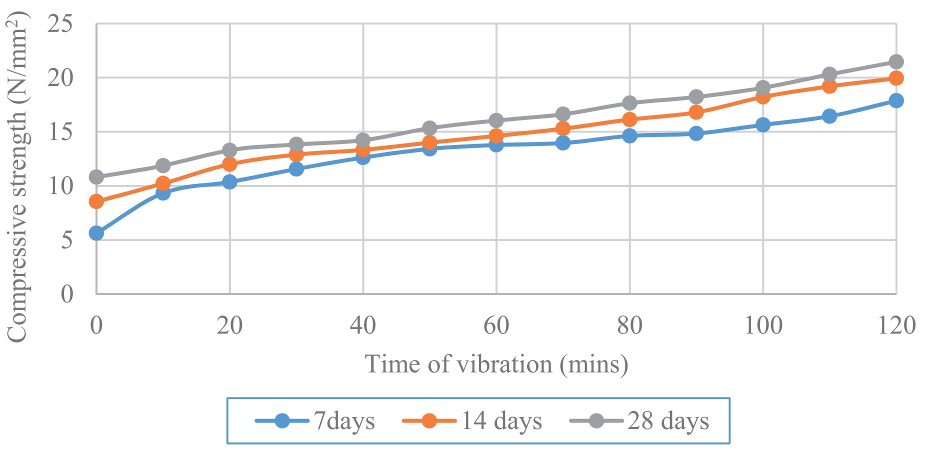

Fig. 2. Variation of compressive strength with time of revibration of concrete with 20 % RHA as cement replacement at 7 days, 14 days and 28 days curing

increases, the compressive strength increases and eventually matches and even surpasses the compressive strength of the control specimens. In this study, for revibration lasting 120 minutes, the compressive strength of concrete with 20 % RHA as cement replacement increased by about 23 % for specimen cured for 7 days specimen, while the increase of 22 and 15 % was obtained for the 14 and 28 days of curing respectively. This is an indication of positive effect of revibration on the compressive strength of the concrete.

This study shows that to attain an equivalent or higher compressive strength of non-revibrated concrete with 0 % cement replacement, concrete with 20 % RHA as cement replacement, requires revibration during 70 minutes at 7 and 14 days of curing, and during 90 minutes at 28 days of curing.

Rice husk as an agricultural by-product can be harnessed into a useful building material especially in areas where it is in abundance. However, the use of RHA as a partial replacement for cement in concrete should be economically advantageous taking into the consideration the revibration cost. The use of RHA as a partial replacement for cement in concrete is not recommended when revibration is not envisaged as it results in concrete having very low compressive strength at all ages of curing. An average duration of 90 minutes is recommended for re-vibration of concrete with 20 % RHA as cement replacement for optimal or higher compressive strength.

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