Effect of Re-vibration on the Compressive Strength of 56-aged RHA - Cement Concrete

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Abstract:
This paper investigates the effect of re-vibration on the compressive strength of 56 days RHA-cement concrete. Eighty-four cubes (84) were cast using twelve (12) cubes each for 0%, 5%, 10%, 15%, 20%, 25% and 30% replacements of OPC with RHA respectively, to obtain the optimal value of RHA percentage replacement in the mix ratio 1:2:4 concrete mix with 0.5 water/cement ratio. The optimal compressive strength at 56 days curing was found to be 19.11N/mm^{2}at 10% RHA. Another set of sixty six (66) concrete cubes were cast, forty two (42) of which were produced using the optimum percentage (10%) of RHA replacement while the remaining twenty four (24) cubes were produced without RHA (0%). All the cubes were re-vibrated,excluding the control cube specimen, for two (2) minutes each at an interval of ten (10) minutes after the initial vibration of mixing/placement of the concrete up to one hour duration of successive re-vibration using table vibrator and cured for 7, 28 and 56 days. These were tested for compressive strength. The results show that the maximum compressive strength (33.33 N/mm^2) of revibrated 56 days(10% RHA-90% cement) concrete was higher than 23.22N/mm^{2}of the normal 28 days non-revibrated concrete (control 0% RHA). This result suggests that re-vibration has enhanced the compressive strength of RHA concrete 28 days curing of the concrete and even better at 56 days curing.

Keywords: Concrete, Compressive Strength, 56 Days Curing, Re-vibration, RHA-cement, Vibration.

Introduction

Vibration of concrete has been reported to play a major role on the strength and quality concrete (Dunham, Rush and Hanson, 2007). It is also established that initial vibration can provide improved concrete-steel bond when compared with hand tapping with rod (Mindess, Young, and Darwin, 2003). However, less is reported about the importance of re-vibration, the process in which a vibrator is reapplied to monolithic concrete at some time after initial vibration. Initial vibration of concrete may not totally eliminate defects, such as honey comb and voids leading to reduction in strength and performance. But re-vibration eliminates defects (honey comb and voids) and thereby increasing the compressive strength of the concrete, improved concrete quality, increased bond, better impermeability, reduction in shrinkage and creep, reduction in surface and other voids as well as cracks in fresh concrete and so on (Krishna, Rathish and Bala, 2008).

Re-vibration can be done usually at any time as long as the running internal vibrator can sink by its own weight into the concrete but not after the final setting time of the concrete (Krishna *at el*., 2008; Auta, 2011; Amr, 2013).Re-vibration time lag is one of the major factors that can affect the compressive strength of concrete. Krishna *et al.* (2008) recommended the optimal time lag interval of re-vibration for different w/c ratio when a minimum re-vibration time lag interval of 30 minutes to 4 hours was adopted while Auta (2011) reported that the effect of re-vibration on the strength of concrete was dynamic.

The setting period for concrete is divided into initial setting and the final setting. Initial set corresponds to the time when concrete is no longer workable and has relatively no slump; while final set indicates the time at which the concrete begins to harden, but has not developed measurable strength (Mindess, Young, and Darwin, 2003;Dunham, Rush and Hanson, 2006).

When burnt under controlled conditions, the RHA is highly pozzolanic, but when in an uncontrolled manner (Ogunbode, Hassan and Isa,2011), the ash which is essentially silica is converted to crystalline forms and become less reactive. However, when blended with cement to produce concrete, it is observed to be highly pozzolanic (Ogunbode, *atel*., 2011).

This study therefore, introduces re-vibration into the blending mix (RHA-cement) and investigates its effect on the compressive strength of concrete with RHA as partial replacement for cement at 56 days curing other than the normal 28 days curing specifiedby standards(Reynolds and Steedman, 1988; BS EN 12390, 2002).

To achieve the aim of this study therefore, the following objectives were carried out:

I. Chemical analysis of the RHA;

ii. Casting a total of 154 number of revibrated and non-revibrated concrete cubes specimen with various percentage replacement of RHA for cement;

iii. Determination of compressive strength by crushing of the cube specimen using universal testing machine.

Methodology

Materials

The materials used in this study include:

Sand: The sand used was clean, sharp river sand that was free of clay, loam, dirt, Organic and found passing through 5mm standard sieves specified inBS EN 12620 (2008).

Water: The water used was fresh, colourless, odourless, tasteless and drinkable potable water that was free from organic matter of any kind. This complies with the specification in BS EN 1008 (2002).

Cement: Dangote brand of Ordinary Portland cement procured from Gidan Mangoro, in Minna Niger State, was used as the main binder. It conforms to type 1 cement as specified by BS EN 197-1: (2000).

Gravel: The gravel used was brought from Kpakungu Minna, also found clean and the sizes were mainly percentage passing through 20.00mm B.S sieve specified by specified by BS EN 12620 (2008).

RHA and Chemical Test

Rice husk ash (RHA): RHA used was bought from a threshing site at Gidan Mangoro, Minna, Niger state. The RHA was obtained by incineration of the dry Rice husk at a temperature of about 580°C. After that, the incinerated husk was pounded with mortar and pestle then made to pass through 75microns B.S sieve.

Chemical Test RHA: A sample of the RHA was taken to laboratory where the Oxides compositions were determined.The X-RAY Diffraction (XRD) test of the RHA was also carried out. This is atechnique used to disclose without destruction or distortion the in-depth information on the chemical composition and crystallographic makeup of natural and manufactured materials. It is the scattering of X-Rays by the different atoms within a crystal. This test was done to determine the silica phase of the RHA powder. The result is presented in Table 1.

Productions of Concrete Cubes

The designmix ratio of aggregates was 1:2:4 proportion selected from optimize proportions of cement, water and aggregates to produce concrete that satisfies the requirements of strength, workability, durability and economy, while the slump and the compacting factor were determined in accordance with standards (BS EN 12350-2, 2000; BS 1881: Part 103, 1983).

The first set of cubes cast were 84 cubes specimen using 12cubes each for0%, 5%, 10%, 15%, 20%, 25% and 30% replacements by weight of RHA for OPC and were cured for 7, 28 and 56 days in accordance with BS 1881: Part 116 (1983) to obtain the optimal percentage replacement.

The second set of sixty six (66) concrete cubes specimen were cast, forty two (42) of which were produced using the optimum percentage (10%) of RHA replacement for cement, while the remaining twenty four (24) cubes were produced without RHA (0%) and cured for 7, 28 and 56 days. This set of cubes were re-vibrated for two (2) minutes each at an interval of ten (10) minutes after the initial vibration of mixing up to one hour duration of successive re-vibration using table vibrator. The cubes were de-moulded after 24hrs of their placement in the curing tank with water, cured and tested for their compressive strength at 7, 28 and 56 days respectively, in accordance with BS EN 12390 (2002) using crushing machine. The results are presented in figure 3.

Results and Discussions

Chemical Composition of the RHA

The chemical properties of RHA used in this study are shown on table 1. It is seen that the RHA proportion of silicon dioxide (SiO_2), aluminium oxide (Al_2O_3) and iron oxide (Fe_2O_3) when combined together was 65.70%, which is slightly below the 70% specified by ASTM C 618 (1991) for pozzolana. The lower value obtained here compared to is dependent on material source, specie, method of burning the Rice husk (open, closed or controlled temperature incineration) and other environmental factorsthat affect the quality of RHA (Muthadhi and Kothandaraman, 2010;Xinyu, Xiaodong, Liu, Hongzhuo, Yumei and Zichen, 2015).

Table 1. Composition of Elemental oxides of the rice husk ash

Elements	*RHA % by weight*	*OPC % by weight*
Specific Gravity	*1.90*	*3.15*
SiO_2	*63.28*	*20.70*
Al_2O_3	*1.88*	*5.75*
Fe_2O_3	*0.54*	*2.5*
CaO	*0.37*	*64.0*
MgO	*3.59*	*1.00*
MnO	*0.13*	*0.05*
Na_2O	*3.78*	*0.20*
K_2O	*3.14*	*0.60*
P_2O_5	*0.16*	*0.15*
Total $SiO_2 + Fe_2O_3 + Al_2O_3$	*65.70*	*28.95*

The sand used is an uniformlywell graded sand of zone 4 (BS EN 12620, 2008) and a well graded gravel(Arora, 2010) in the classifications of aggregates adequate for a workable concrete.The specific gravity test of fine aggregate was 2.62, while 2.67 was determined for coarse aggregate. That of RHA was 1.90. These values are in agreement with the BS EN 12620 (2008) requirement of 2.6 to 3.0 for fine aggregate and 2.4 to 2.8 for coarse aggregate.Fineness Modulus of the RHA(FM) was calculated as =1.57less than Fineness Modulus of 2.3 – 3.1 specified by standards, but similar to the Fineness Modulus result of 1.40 submitted by Ettu, Osadebeand Mbajiorgu(2013).

Effect of re-vibration on the compressive strength of 56 days aged concrete

The effect of re-vibration on the 56 days age RHA-C concrete were investigated for 7, 28 and 56 days curing. The summary of the results are presented graphicallyfor different replacement percentages of RHA and re-vibration time lag.

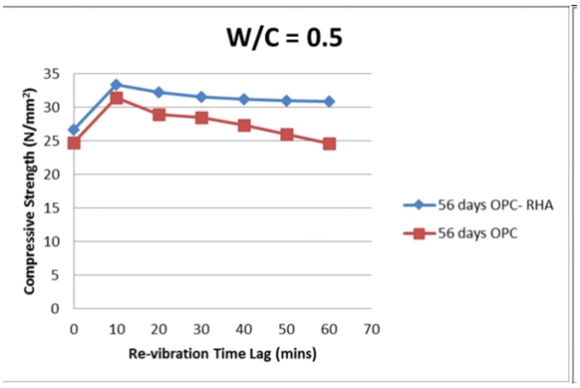

Figure 1: Variation of Compressive Strength with Re-vibration Time Lag at 28 days.

Figures 1 and 2 show the results of the compressive strength test of re-vibrated OPC-RHA and OPC concrete cubes.

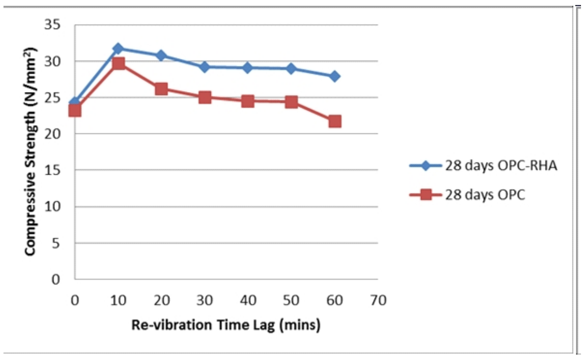

Figure 2: Variation of Compressive Strength with Re-vibration Time Lag at 56 days.

At 28 days, the OPC-RHA concrete that was re-vibrated 10 minutes after the initial vibration during mixing/placing showed an increase in strength from 24.33N/mm² for control (non-revibrated) to 31.78N/mm² (re-vibrated). Also, the non-revibrated OPC concrete attained strength of 23.22N/mm^2, the concrete that was re-vibrated 10 minutes after the initial vibration during mixing/placing showed an increase in strength up to 29.67N/mm^2. The result reveals that as the re-vibration time lag was increased at

10 minutes interval, there was a corresponding decrease in the compressive strength of 30.78N/mm^2, 29.11N/mm^2 and 27.89N/mm² at 20, 30 and 60 minutes respectively for the OPC-RHA concrete, while OPC concrete strength reduced to 26.22N/mm^2, 25.11N/mm^2 and 21.82N/mm^2 at 20, 30 and 60 minutes respectively.

Furthermore, a similar trend was observed at 56 days, there was an increase in strength of the OPC-RHA with curing age and re-vibration. The control concrete (non-revibrated) produced compressive strength of 26.67N/mm^2 which increased to 33.33N/mm^2 after re-vibration was introduced 10 minutes after the initial vibration during mixing and placement. However, a decrease in strength was observed as the re-vibration time lag was increased to 20, 30, 40, 50 and 60 minutes having strength of 32.22N/mm^2, 31.56N/mm^2, 31.56N/mm^2, 31.00N/mm^2 and 30.89N/mm^2 respectively.

The OPC control concrete (without re-vibration) produced compressive strength of 24.75N/mm^2 which increased to 31.44N/mm^2 after re-vibration was introduced 10 minutes after the initial vibration during mixing/placing. However, a decrease in strength was observed as the re-vibration time lag was increased to 20, 30, 40, 50 and 60 minutes having strength of 28.89N/mm^2, 28.44N/mm^2, 27.33N/mm^2, 26.00N/mm^2 and 24.67N/mm^2 respectively. All the strength values obtained are higher than 21N/mm^2 specified by Reynolds and Steedman (1988) as minimum compressive strength (20N/mm^2) of normal concrete at 28days age.

Therefore, the result shows that re-vibration enhances workability and consequently, the compressive strength of OPC and OPC-RHA concrete which is in terms with the findings of Krishna *et al., (*2008). The result also revealed that re-vibration of OPC-RHA concrete within the first 60 minutes produced a higher strength than the non-revibrated OPC-RHA concrete generally and was better at 56 days age OPC-RHA concrete.

Greater strength gained at 56 days curing is due to the pozallanic reaction that becomes stronger at older age of curing. RHA reacts with calcium hydroxide released during hydration. This reaction is slower at early age curing (factor responsible for lower strength gain), but becomes more prominent at older ages such as 56 and 90 days (Balendran and Martin-Buades, 2000; Hossain, 2005; Adesanya and Raheem, 2009a; Raheem and Olasunkanmi 2012;Waswa-Sabuni,Syagga, Duloand Kamau,2002; Hague and Kayali, 1998; Ettu,et. al.,2013) compared to the normal concrete (control) strength at 28 days curing.

Conclusions and Recommendation

The effect of re-vibration on the compressive strength of 56 days aged RHA-cement concrete has been investigated and presented. Re-vibrationis seen to increase the compressive strength of OPC and OPC-RHA concrete by completely eliminating void, provided it is carried out within the setting time of concrete (Krishna *et al.*, 2008; Auta, et al., 2015 and Tuthill, 1977).

The compressive strength of the re-vibrated OPC-RHA at 56 days was generally observed to be higher than the re-vibrated and non-revibrated OPC concrete at 28 days curing. It is thus recommended to re-vibrate the concrete up to 20mins and with reasonable replacement of up to 10% RHA for cement.

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