Experimental Study on the Flexural Strength of Reinforced and Re-Vibrated RHA Concrete Beam

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Abstract: This paper presents an experimental study undertaken on the flexural strength of reinforced and re-vibrated concrete beams partially replaced with Rice Husk Ash (RHA) for cement at several percentages (0%, 5%, 10% and 15%, 20%) using concrete mix ratio of 1:2:4 with water - cement ratio of 0.5. Thirty five (35) numbers of beams were re-vibrated at 10 min intervals for one hour time lag for all percentage replacement level. Flexural test of these 35 beams specimen were carried out and the results are presented. Results show that the maximum flexural strength (10.7 N/mm^2) was obtained at 5% replacement and at 20 min for re-vibration time-lag interval. It was also observed that the flexural strength of RHA concrete decreases from 30 min to 60 min for all replacements.

***Keywords*:** Flexural strength, concrete, Re-vibration, Beams, RHA, Steel, Time-lag intervals.

1. INTRODUCTION

Sustainable development of any nation can attain good success if environmental resources like agro-wastes can be harmonised with technology of Re-vibration to produce a built environment devoid of any environmental degradation. Re-vibration of concrete is the disturbance of already placed concrete after an initial setting time through vibration either internal or external after its consolidation state. Recent studies have showed that concrete properties can be altered provided the concrete is sufficiently plastic to permit the running vibrator to sink of its own weight (Krishna, 2008; Auta 2011). Insufficient vibration and defects of the concrete element leads to voids, honeycomb and bleeding of concrete which consequently resulting to structural failure and collapse.

Benefits of re-vibration include reduction in permeability, increase in bond between the reinforcing bars and the concrete as much as one third, to close plastic shrinkage and settlement cracks, to improve the wear resistance of floors and to improve the surface finish at the tops of columns and walls (Amr 2013). Re-vibration time lag and period has a major role in obtaining optimal strength of concrete as reported in the works of Krishna et al., (2008), and Auta (2011) who adopted time lag intervals of 30 min to 4 hrs period with varied range of w/c (Auta *et al*, 2015).

The major quantum of husk produced from the processing of rice is either burnt or dumped as a waste material (Agro-waste) in most of the developing nations which contributes immensely to environmental hazard, hence utilizing it as partial replacement for cement can be worthwhile (Tashima *et al.,* 2004). Rice husk is reported to possess high content of 92 to 95 per cent silica compared to other biomas fuels. Highly reactive rice husk ash (RHA) is usually obtained by burning the rice husks under a controlled temperature and atmosphere, (Tashima *et al.,* 2004). Researchers have tremendously worked on the temperature range in which RHA should be better burned to obtain a good quality and durable strength of concrete (Al-Khalaf and Yousif, 1984). RHA can be best obtained by burning the husk in temperature range of 600^{o}C to 800^{o}C for about 48 hrs in excess air (Padma *et al.*, 2014). The reinforced concrete beams produced for several percentages required proper compaction to enhance an adequate strength.

Following the report of Krishna *et al*. (2008) and Auta (2011), the utilization of re-vibration of the concrete beams being investigated in this study can help produce reinforce concrete beams void of defects such as honey combs and voids lead that could consequently lead to reduction in strength and performance.

2. MATERIALS

2.1 Materials

The materials used in this study are as follow:

Rice Husk Ash (RHA)

The rice husk was obtained from rice milling machine Chanchaga, Minna and burned at Shelter Clay Company, Pago in Niger State, Nigeria. The burning was done at a control temperature of 800°C, while investigation of elemental composition of the ash (RHA) was carried out in the Chemistry laboratory.

Coarse Aggregates

Gravel material with particle size between 19 mm to 20 mm was used as coarse aggregate for concrete work. The aggregate is clean, hard, strong particles.

Cement

The cement used was ordinary Portland Cement (OPC) as a binder with a specific gravity of 3.15 (g/cm^3). It is capable of bonding mineral fragment into a compact whole and solid in the presence of water. It conforms to the requirement of ordinary Portland cement as recommended in BS 12 (1978).

Fine aggregate (sand)

Sharp sand of uniform particle size of between 2 mm to 3.35 mm obtained from a local supplier was washed, clean and used as a fine aggregate.

Steel Reinforcement

For each specimen, two numbers of steel bars of size 12 mm (Y12) were used as the tension bars and also two numbers of 12 mm steel bars as compression bars and 8 mm links was used.

Water

Portable and clean was used for all mix design. It satisfies the requirement described in BS 3148 (1980) for concrete production.

3. EXPERIMENTAL METHODS

3.1 Procedure

Preliminary tests such as sieve analysis, bulk density, specific gravity and moisture content tests on the constituents materials used like fine aggregate (sand), RHA and coarse aggregate were carried out. Test on fresh concrete such as slump and compacting factor test to point of re-vibration also conducted and results presented on Tables 1, 2 and 3. The concrete mix design of 1:2:4 and water cement ratio of 0.5 were adopted and cured for 28 days. For the re-vibrated beams, Thirty-five rectangular beams specimens were produced. The dimensions of the beams are 150 mm x 150 mm x 600 mm and were reinforced using 12mm tensile steel and a concrete cover of 25 mm for all the beams specimens. The size of the links provided were 8mm bar each at regular spacing of 125 mm c/c. The batching and casting of the beams were done in accordance to BS 1881: part 109 (1983).

The beam specimens were produced with RHA at several percentages replacements of 0%, 5%, 10%, 15%, and 20 % for cement and were re-vibrated. The re-vibration process was at 10 min interval for a period of 1 hr. Poker vibrator was used to compact the concrete mix in the 150 mm x 150 mm x 600 mm mould. The beams were de-moulded after 24hours and were followed by curing the beams at Department of Civil Engineering curing tank, F.U.T., Minna. The curing was carried out by placing the beams in the tank and filled with water and left for 28 days curing after which were tested for flexure using universal testing machine. This was done in accordance to BS 772: part 1 (2000) and results obtained are presented in Table 4 and Figure 1.

4. RESULTS AND DISCUSSIONS

4.1 Results

The results of sieve analysis, bulk density, specific gravity and moisture content tests on the constituents materials used like fine aggregate (sand), RHA and coarse aggregate, and flexural test of the beam specimens are presented on Tables 1,2,3,4 and figure 1 respectively.

TABLE 1. PROPERTIES OF FINE AGGREGATE

S.No	Test	Result	Requirement
1	Sieve Analysis:		
	a. Coefficient Of Curvature, Cc	2.41	$1 \leq Cc \leq 3$
	b. Coefficient Of Uniformity, Cu	0.6	$Cu \geq 6$
2	Specific Gravity	2.6	2.6 -3.0
3	Bulk Density (kg/m^3)		
	a. Compacted bulk density	1570	
	b. Un-compacted bulk density	1480	1500 -1700
4	Moisture content (%)	1.12	5 – 15

TABLE 2. PROPERTIES OF COARSE AGGREGATE

S.NO	Test	Result	Requirement
1	Sieve Analysis:		
	a. Coefficient Of Curvature, Cc	1.02	$1 \leq Cc \leq 3$
	b. Coefficient Of Uniformity, Cu	1.35	$Cu \geq 6$
2	Specific Gravity	2.65	2.6 -3.0
3	Bulk Density (kg/m^3)		
	c. Compacted bulk density	1570	
	d. Un-compacted bulk density	1480	1500 -1700

TABLE 3. PROPERTIES OF RHA

S.NO	Test	Result	Requirement
1	Sieve Analysis:		
	a. Fineness Modulus	1.69	2.3 – 2.1 (ASTM-C 33)
2	Specific Gravity	1.92	
3	Bulk Density (kg/m^3)		
	b. Compacted bulk density	780	
	c. Un-compacted bulk density	610	

TABLE 4. FLEXURAL STRENGTH OF BEAM SPECIMEN FOR 28 DAYS CURING

Percentage of RHA	Specimens	Re-vibration time interval (minutes)	Weight (kg)	Flexural strength (bar)	Flexural strength (N/mm^2)
	A_0	0	33.50	90	9
	A_1	10	35.65	100	10
	A_2	20	35.80	105	10.5
0	A_3	30	33.50	90	9
	A_4	40	33.65	88	8.8
	A_5	50	33.10	85	8.5
	A_6	60	33.90	81	8.1
	Bo	0	35.65	92	9.2
	B_1	10	33.05	104	10.4
	B_2	20	33.29	107	10.7
5	B_3	30	33.00	103	10.3
	B_4	40	34.50	96	9.6
	B_5	50	35.05	90	9.0
	B_6	60	34.50	88	8.8
	C_0	0	33.80	70	7.0
	C_1	10	34.54	70.3	7.03
	C_2	20	33.50	70.5	7.05
10	C_3	30	34.54	70	7.0
	C_4	40	33.05	70	7.0
	C_5	50	33.15	70	7.0
	C_6	60	35.05	70	7.0
	D_0	0	33.20	68	6.80
	D_1	10	33.50	68.3	6.83
	D_2	20	33.60	68.9	6.89
15	D_3	30	32.54	70.0	7.0
	D_4	40	34.05	68	6.80
	D_5	50	33.70	68	6.80
	D_6	60	33.80	68	6.80
	E_0	0	34.00	50	5.0
	E_1	10	33.00	62	6.2
	E_2	20	32.80	61	6.1
20	E_3	30	32.35	58	5.8
	E_4	40	33.00	51	5.1
	E_5	50	33.00	50	5.0
	E_6	60	33.05	51	5.1

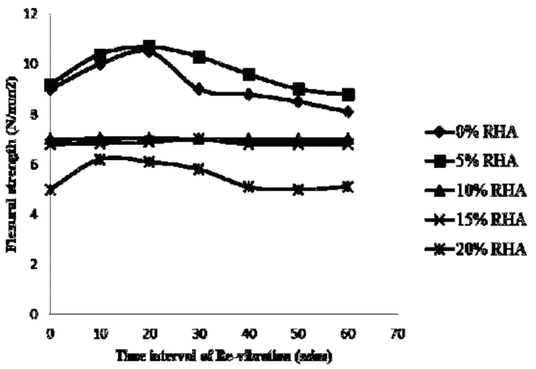

Figure 5: Effect of re-vibration on the flexural strength with time for all percentage replacements of RHA for cement

4.2 Discussions

The major focus of this study is on the effect of re-vibration on the flexural strength of reinforced RHA concrete beam. This is clearly depicted by the results in Table 4 and figure 1.

From Table 4, it is visible that the flexural strength increases at the initial stage of re-vibration of the concrete beam at 10 min and 20 min intervals giving 10N/mm^2 to 10.5 N/mm^2 respectively for 0% replacement level (A_0). The early increase in strength of the control can be attributed to the contribution of the tricalcium silicate (C_3S) in the OPC, but later there is a decline of flexural strength from 30 min re-vibration due to debonding of chemical compound C_3S which leads to decrease in strength from 30 min to the lap hour with the corresponding decrease in strength from 9 N/mm^2 of beam marked $A_{3,}$ A_4 (8.8 N/mm^2), A_5 (8.5 N/mm^2) and to 60 min intervals (8.1 N/mm^2) respectively.

On Table 4 and in figure 1, flexural strength of beam B specimen with 5% RHA replacement for cement is presented. The increase in strength is due to the initial re-vibration which causing densification and volumetric compaction of the concrete beam attaining a maximum flexural strength of 10.7 N/mm^2 at 20 min and then gradually decreasing in strength from 30 min (10.3 N/mm^2) to 60 min (8.8 N/mm^2) the next successful re-vibration.

On Table 4 where cement is replaced partially with 10%, 15%nand 20% RHA respectively, the trend and pattern of flexural strength variation with time interval of re-vibration is the same with 0% and 5% RHA, but in decreasing order. Thus the maximum flexural strength attained is 7.03N/mm^2 at 20 min (C_3); 7N/mm^2 at 20 and 30 min (D_3 and D_4), 6.2N/mm^2 at 10min.

From the above discussion, it can be shown that early re-vibration of concrete enhanced the flexural strength of concrete and thereafter causes the material to debond thereby lowering the flexural strength. It is also supported by Krishna *et al.*, (2008), and Auta (2011) Krishna that re-vibration will always increase concrete strength once done within plastic range of the concrete at specified w/c ratio (Auta *et al.*, 2015) and mix proportion of aggregates (Tuthill 1977). Hence when revibration is exceeding these limits the strength begin to decrease.

5. CONCLUSIONS

Based on the findings of this study the following conclusions are made:

Optimum flexural strength is observed at 5% RHA replacement corresponding to the re-vibrated time interval of 20 min and decreases from 30 min to 60 min of re-vibration intervals.

The addition of RHA is therefore seen to improve the flexural strength of the beam up to 5% RHA replacement and the inclusion of reinforcement has fundamentally improves the strength of beams. Hence, it can be recommended that replacement of RHA for cement should not be done beyond 5% for w/c ratio of 0.5.

To explore such agro-waste (green) and employ technology (re-vibration) in concrete production is to be in the path of sustainable green engineering development.

REFERENCES

BS 812: part 2 (1995) Methods for determination of bulk density of aggregate, BSI, London, UK

BS 812: part 103 (1985), Methods for determination of particle size distribution- sieve test, BSI, London, UK

BSI – British Standard Institution (1983): BS 1881: Part 109: Methods of batching and casting of concrete beams.

BSI – British Standard Institution (1980): BS 3148: Methods of test for water for making concrete. British Standard Institution, London

BSI – British Standard Institution (1983): BS 882: specification for aggregate from Natural Sources for Concrete. British Standard Institution, London

BSI – British Standard Institution (1980): BS 3148: Methods of test for water for making concrete. British Standard Institution, London

Arora, K.R (2010). Soil Mechanics and Foundation Engineering, 7th Ed. Delhi: Lomus, Offset press, A.K. Jain Standard Publishers Distributors.

Auta, S.M. (2011)."Dynamic Effect of Re-vibration on Compressive strength of concrete.'' Department of Civil Engineering, Federal University of Technology, Minna, Niger state. *Nigeria Journal of Technological Research* 13-17.

Auta, S.M., Mamud, A. &Abdulazzez, Y. (2015). Effect of water cement ratio on the compressive Strength of Re-vibrated concrete. *Environmental technology and Science Journal 6 (2),* 14-21.

Amr, M.I. (2013). Vibration and Re-vibration. Benha Higher Institute of Technology 3rd Civil Engineering DEP, 1-31

Krishna Rao M.V, P. Rathish Kumar and NV.R.C BalaBhaskar. (2008).Effect of re-vibration on compressive strength of concrete. *Asian journal of Civil Engineering (Building and Housing)*, *9(3)* 291-301.

Padma Rao, Pradhan Kumar A., &Bhaskar Singh B. (2014). A Study on Use of Rice Husk Ash in Concrete. Dept. of Civil Engineering, Vignan University, Vadlamudi, Guntur, AP, *India.International Journal of Education and applied research, 4,* 75-81

Tashima, M. M., Silva, C.A.R., Akasaki, J.L., & Barbosa, M.B. (2004). The Possibility of Adding the Rice Husk Ash (RHA) to the Concrete. In the *Proceedings of the International RILEM Conference on the Use of Recycled Materials in Building and Structures*. 778 – 786.

Tutihill, L. H., (1977) Re-vibration re-examined, *Concrete Construction*, 22(10), pp. 537-539.