Coventry University and
The University of Wisconsin Milwaukee Centre for By-products Utilization,
Second International Conference on Sustainable Construction Materials and Technologies
June 28 - June 30, 2010, Università Politecnica delle Marche, Ancona, Italy.
Main Proceedings ed. J Zachar, P Claisse, T R Naik, E Ganjian. ISBN 978-1-4507-1490-7
http://www.claisse.info/Proceedings.htm

Investigation of Use of Rice Husk Ash-Calcined Clay Blend as a Pozzollana

Kwasi Osafo Ampadu[1], Belinda Osafo-Ampadu[2], Henry Adjei[3], Nkansah Bawuah[4]

[1]Principal Engineer (Development), Department of Feeder Roads, Ministry of Road Transport, PMB, Accra, Ghana. Email: <ohbroke@netscape.net>
[2]Civil Engineering Student, Coventry University, U.K. Email: <candybel86@yahoo.co.uk>
[3]Final Year Student, Department of Civil Engineering, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. E-mail: <sharkflair2g@yahoo.com>
[4]Project Manager, Bespa Services, P.O Box 3093, Kumasi, Ghana. E-mail: <wacasyom@yahoo.com >

ABSTRACT

This study aims to investigate the pozzollanic behaviour of a blend of Rice husk Ash and Calcined Clay (RHACC) pozzolana. Rice husk was used to fire clay pellets and the resulting ash inter grinded with the calcined clay pellets. The two materials were chosen to exploit the heat energy of rice husk and its high silica content to enrich calcined clay to produce a Rice husk Ash-Calcined Clay (RHACC) blend pozzolana. Various proportions of Rice Husk Ash and Calcined Clay were blended to produce the RHACC pozzolana which was then used in replacing Ordinary Portland Cement (OPC) at a ratio of 30:70 by weight to cast concrete cubes. 100% OPC was also used as binder to cast concrete cubes to serve as a control specimen. The results of the concrete cube strength tests indicate an optimum Rice Husk Ash : Calcined clay blend of 50:50

INTRODUCTION

This study aims to investigate the pozzollanic behaviour of a blend of Rice husk Ash and ground calcined clay (RHACC) for economic reasons. Rice husk Ash is a material with very low bulk density but of high silica content between 87% - 97% [C. S. Prasad et al , 2000] while ground calcined clay is a material with a much higher bulk density compared to that of rice husk but of medium silica content . In particular, the Mfensi Clay used in this study has a silica content of 61% [J. K. Nsiah, 2007]. A blend of the two materials is expected to have a synergy effect as the higher silica content of the rice husk is expected to enrich that of the resulting material above that of calcined clay, whilst the higher bulk density of the calcined clay is also expected to increase that of the resulting material above that of rice husk ash. More importantly, the heat energy to be derived from the rice husk could be exploited as a source of fuel to provide heat energy to calcine the clay as an economic advantage. The calorific value of rice husk varies with rice variety, moisture and bran content but a typical value for husks with 8-10% moisture content and essentially zero bran is 15 MJ/kg [DTI, 2003]. This study also aims to determine the optimum blend ratio of rice husk ash and calcined clay powder to obtain a material with excellent pozzollanic properties with medium bulk density.

Heat Energy to be derived from Rice Husk

It is estimated that every tonne of paddy produces about 0.20 t of husk and every tonne of husk produces about 0.18 t to 0.20 t of ash, depending on the variety, climatic conditions, and geographical location [N Bouzoubaa et al , 2001]. Table 1 summarizes the weight of rice husk to be inter-mixed with clay pellets to obtain the required ratio of rice husk ash (RHA) and Calcined Clay to produce a particular blend of RHACC pozzollana. **Table 1** also indicates the respective amount of thermal energy to be derived from the rice husk to fire the clay to produce the various RHACC blends. When these values are compared to the energy consumption of 0.72 – 0.95 MJ/kg of brick in a vertical shaft brick kiln (VSBK), a Chinese technology for firing bricks [http://www.vsbkindia.org/factfile.htm], then it is seen that the heat energy available in the rice husk is more than enough to fire the clay. It is reasonable to assume that, firing clay to produce calcined clay is similar to firing green bricks to produce burnt bricks, in terms of energy consumption.

Table 1. Heat energy to be derived from Rice husk to produce various blends of RHACC.

RHA:Calcined Clay Blend Ratio. (x:y)	30:70	40:60	50:50	60:40
Weight of dry clay pellets to produce 100 kg of RHACC, Wc= y (Kg)	70	60	50	40
Weight of Rice Husk to obtain the required RHA Wr= (x/0.2) (Kg)	150	200	250	300
Available Heat Energy from the rice husk to fire the clay E= Wr.TE / Wc (MJ/Kg)	32	50	75	113

TE = Thermal Energy of rice husk = 15 MJ/Kg) [DTI, 2003].

METHODOLOGY

Preparation of the RHCC pozzolana.

The production of the rice husk ash-calcined clay (RHACC) pozzolana is described below.

Moulding of the clay balls

Clay mined from a pit at Mfensi was soaked for 24 hours to improve upon its workability. The clay was then moulded into pellets of average size 20 mm. These pellets were dried in the sun for about forty-eight hours.

The kiln

A 3mm steel plate was rolled into a cylindrical shape of diameter 750mm and welded. A conical shape was also formed with the same material and welded unto one end to provide a tapering end. The tip of the cone was cut to obtain an opening of about 300 mm. The inner surface of the kiln was lined with a paste made with a mixture of lime, rice husk ash and hot water to a thickness of about 150mm to provide insulation against heat losses during the firing process in order to retain enough heat in the kiln to calcine the clay. A perforated metal pipe of 100 mm diameter was placed concentrically inside the kiln and the lower end joined to a similar pipe by an elbow joint. The vertical end of the pipe was closed while the horizontal section was connected to a blower to blow air through the kiln to ensure enough oxygen supply into the kiln during the firing. The top part of the kiln is open to facilitate loading of the clay pellets and rice husk but was closed with a lid through which a 1200 mm length of 100mm diameter pipe had been inserted to act as a chimney through which flue gases are discharged during firing. **Fig 1** shows a sketch of the kiln. **Fig 2** also shows a sample of the rice husk.

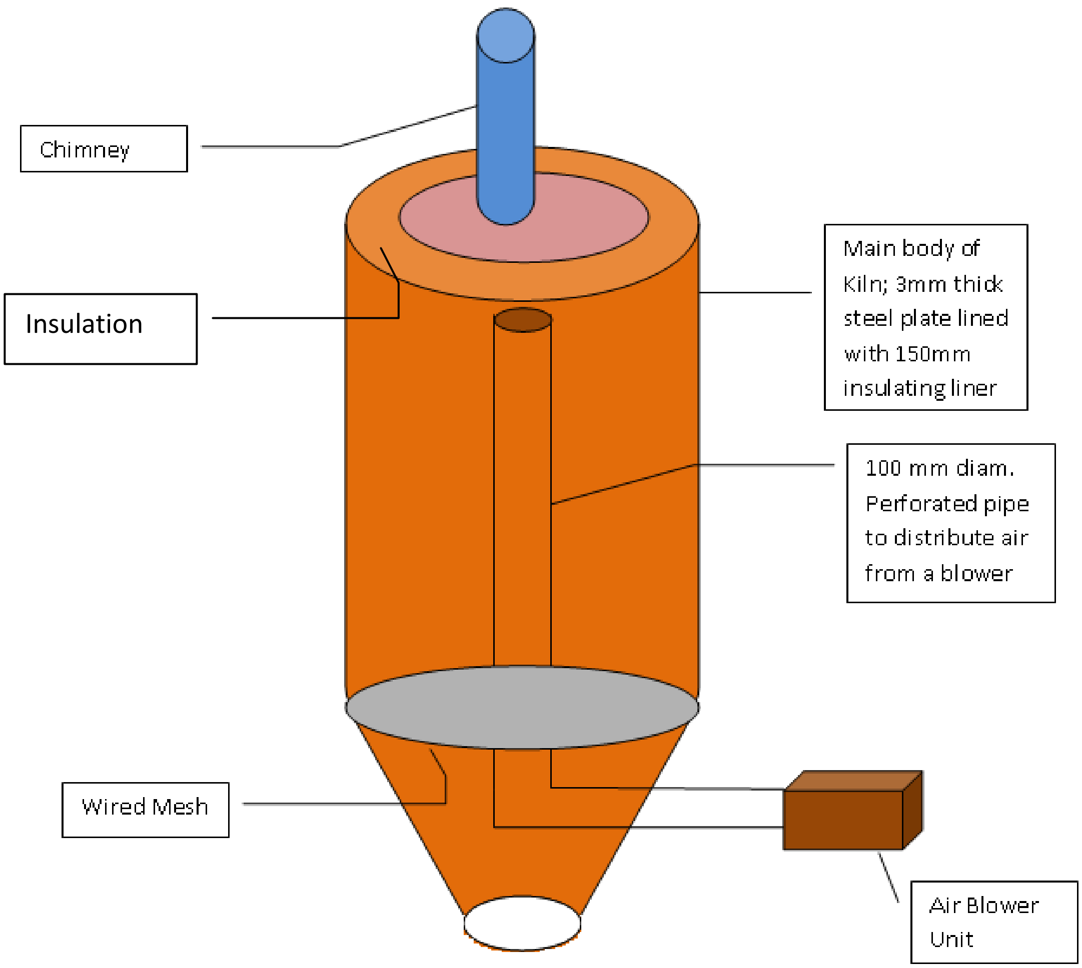

Fig. 1. Sketch of Kiln used to fire the clay with rice husk

Firing of clay pellets and rice husk

The kiln was loaded with the clay pellets intermixed with enough quantity of rice husk to act as the source of fuel for the firing. A gas torch was used to provide the initial spark and after some time, the blower was started to blow enough air through the clay pellets/rice husk mixture in the kiln. A thermocouple was used to monitor the temperature to ensure that it does not exceed 700^oC. The blower was cut off when the temperature gets to 650^oC and restarted when it falls below 600^oC. The upper and lower temperature limits were chosen to ensure that the rice husk ash that will result after the firing of the clay becomes amorphous silica as opposed to crystalline silica [N Maeda, 2001]. **Fig. 3** shows a sample of the calcined clay pellets. The blackish pellets are over-burnt whilst the yellowish pellets indicates the properly calcined clay pellets. The over-burnt pellets were removed and thrown away.

Milling of the Calcined Clay into powder

The sorted pellets were crushed by a pestle in a mortar and prepared for grinding. This was then grounded in a plate mill. The calcined clay and the rice husk ash were milled separately and sieved to obtain a fine powder passing 50 µm sieve size.

Fig. 2 Rice husk for the firing of the clay pellets.

Fig. 3. Typical clay pellets resulting from the firing process.

(*brownish* -*'properly burnt' and blackish* - *'over-burnt'. Over burnt clay pellets were removed and thrown away)*

Blending of RHA and Calcined Clay Powder to form RHACC pozzolana.

The RHA and Calcined clay powders were blended at four different ratios; 30:70, 40:60, 50:50 and 60:40 to produce various types of RHACC pozzolana. The entire calcium hydroxide produced in cement system is utilised by Rice husk ash to form secondary hydration products when cement is admixed with 30% of RHA [P K Mehta, 1997]. Due to depletion of calcium hydroxide, permeability of concrete is highly reduced, whereby resistance of concrete to acids, is highly improved [P K Mehta, 1997]. Preliminary tests conducted on RHACC by the author (unpublished) also revealed that a binder made by replacing 30% of Ordinary Portland Cement (OPC) with RHACC pozzollana gave the optimum result with respect to compressive strength. Each blend of RHACC pozzolana was used to replace 30% OPC to form a binder to cast concrete cubes for testing in order to determine the optimum ratio of RHA and Calcined Clay to produce RHACC pozzolana.

Mixture Proportions

Based on our preliminary study above, each blend of RHA and Calcined Clay powder was used to replace 30% OPC to form a binder for the casting of concrete cubes. 100% OPC was also used to cast some of the cubes to serve as the control specimen. The ACI method of mix design was used to obtain the mix proportions of the various constituents based on a characteristic strength of $30N/mm^2$. **Table 2** shows the proportion of the constituents in kg/m^3 for the various concrete specimens that were cast. The batching was done by weight. The weight composition of coarse aggregate and fine aggregate as well as the water-binder ratio were the same for each specimen.

Experimental Test Procedure

The various proportions of the constituents were batched by weight and mixed together manually using a mixing bowl and hand trowel until a homogeneous concrete mixture was obtained. The concrete was placed in 150 mm x 150 mm x 150 mm moulds and well compacted by rodding. The cubes were later labelled according to the RHA to Calcined Clay ratio. Nine (9) test cubes were prepared for each specimen. The cubes were removed from the moulds after 24 hours air curing and then cured in water bath maintained at room temperature of 25^{o}C. Compressive strength tests were performed on the cubes after seven (7) days, fourteen (14) days and twenty-eight (28) days of curing.

Table 2. Mixture Proportions of Concrete specimens

Specimen RHA:Calcined Clay Blend	Cement (Kg/m^3)	RHACC Pozzollana (Kg/m^3)	Coarse aggregate (10 mm size) (Kg/m^3)	Fine aggregate (Kg/m^3)	Water (Kg/m^3)
Control	396.0	-	1,091.0	679.1	191.4
30:70	118.8	277.2	1,091.0	679.1	191.4
40:60	158.4	237.6	1,091.0	679.1	191.4
50:50	198.0	198.0	1,091.0	679.1	191.4
60:40	237.6	158.4	1,091.0	679.1	191.4

RESULTS AND DISCUSSIONS

Table 3. shows the test results of the compressive strength test of the concrete specimens at various curing periods. It is seen that the early strength (7-day) development of the 40:60 specimen is higher than that of all the specimens including the control specimen whilst the 28-day compressive strength of the 50:50 specimen was the highest among that of all the specimens incorporating RHACC pozzolana. Also, the 28-day compressive strength of all the specimens were above 20 N/mm^2 and quite close to each other but were less than that of the control specimen of 32 N/mm^2 and also the designed strength of 30 N/mm^2.

CONCLUSION

The results indicate that the rice husk ash calcined clay pozzollana (RHACC) is feasible and has the prospect of economy with respect to energy requirement in its production since no external source of energy is required in its production. The 28-day compressive strength of 23 N/mm^2 obtained for the optimum blend of 50:50, even though lower than the designed strength, is suitable for the construction of the structural members of low-rise housing units in a developing country like Ghana with huge deficit in housing units.

Table 3. Compressive Strength of Concrete cubes

Specimen	7-day strength N/mm^2	14-day strength N/mm^2	28-day strength N/mm^2
Control	12.44	27.56	32.00
30:70	10.28	17.90	21.19
40:60	19.17	19.70	22.52
50:50	13.36	20.41	23.08
60:40	17.00	20.33	22.93

Designed strength of concrete 30 N/mm^2

FUTURE WORK ON RHACC POZZOLLANA

This paper is limited in scope to the production process and compressive strength test. The research is however, on-going and as such additional tests are being done and the results will be published in due course.

REFERENCES

Bouzoubaa N. and Fournier B. 2001, 'Concrete Incorporating Rice Husk Ash: Compressive Strength and Chloride Ion Penetrability'. Materials Technology Laboratory, CANMET, Department of Natural Resources, Canada, July 2001 p 1.

DTI, 2003, 'Rice Husk Ash Market Study'. Confidential Report, http://www.dti.gov.UK/renewables/Publication/pdfs/exp129.pdf

Maeda N, Wada I, Kawakami M, Ueda T and Pushpalal G K D, 2001. 'Development of a New Furnace for the Production of Rice Husk Ash'.The Seventh CANMET / ACI International Conference on Flyash, Silica Fume, Slag and Natural Pozzolans in Concrete, vol 2, Chennai, July 22–27, 2001, p 835.

Mehta P K., Paulo Monteiro J M, 1997. 'Concrete-Microstructure, Properties and Materials'. Indian Concrete Institute, Chennai, pp 281.

Prasad C S, Maiti K N and Venugopal R, 2000. 'Effect of RHA in White Ware Composition'. Ceramics International, vol 27, p 629.

NSIAH J. K., 2007, The Study of Mfensi Clay in the Ashanti Region of Ghana, Department of Industrial Art, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. Ghana J. Sci. 47 pp 123-129