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A Review on the Effect of Pozzolanic Properties of Rice Husk Ash in Concrete

AdetoyeOlubunmi A.[1], AfolayanTaiye J.[2], Sani Aliyu[3]

[1, 2] Student M.E (Structural Engineering), Department Civil Engineering, Faculty of Engineering, Abubakar Tafawa Balewa University, Bauchi.
[3]Assistant Professor, Department Civil Engineering, Faculty of Engineering, Abubakar Tafawa Balewa University, Bauchi.

ABSTRACT

This Paper reviews the utilisation of rice husk ash as partially replacing cement in concrete.Concrete is a blend of cement, sand, coarse aggregate and water. The key factor that adds value to concrete is that it can be designed to withstand harshest environments significant role. The recent developments in concrete technology has shown the use of alternate additives having cementitious properties in cement asPozzolanas are important ingredients in the production of an alternative cementing material to ordinary Portland cement (OPC). The cost of cement used in concrete works is on the increase and unaffordable, yet the need for housing and other constructions requiring this material keeps growing with increasing population, thus the need to find alternative binding materials that can be used solely or in partial replacement of cement and also the production of the cement has greatly increased which results lots of problems in environment as it involves the emission of CO_2 gas. Recycling of agricultural wastes such as rice husk ash as pozzolan is being increasingly encouraged, particularly in developing countries. Rice Husk Ash (RHA) is an agro-waste material found locally in abundance in Nigeria and many other parts of the world obtained from calcination of Rice Husk. It has been shown from several studies that rice husks when burnt in controlled conditions between 500^0C to 700^0C to form rice husk ash.

KEYWORDS - Pozzolanic Materials, Ordinary Portland Cement, Rice Husk Ash, Mechanical Properties, Compressive Strength, and Durability.

1 INTRODUCTION

Cement is the most widely used construction material throughout the world. This leads to an enormous production of cement to meet the increasing demand for housing and infrastructure. Cement production is however harmful on the environment due to carbon dioxide emission. Reducing cement production while maintaining sustainable development has been an important issue in the development of construction materials. Many countries of the world are faced with inadequate provision of physical infrastructure; shelter and related amenities, which are typical factors of under development that need to be addressed through provision of alternative, cheap and affordable materials. In these areas, development requires the use of cement and other related materials such as coarse aggregate.The cost of cement used in concrete works is on the increase and unaffordable, yet the need for housing and other constructions requiring this material keeps growing with increasing population, thus the need to find alternative binding materials that can be used solely or in partial replacement of cement. Most of the researchers in construction industry are doing their best to minimize cost of construction materials by the use of available local materials in the area (Joshua et al, 2014). Replacing Portland cement with percentages of pozzolan has been reported as a good alternative. Currently, research efforts have been geared towards the use of local alternative construction materials including agricultural wastes and residues as construction materials. Materials such as Rice husk ash, Cow Dung Ash (CDA), Fly Ash, Slag, and Silica Fume, can be used as partial replacement for cement (Ojedokun et al., 2014).

Pozzolan is defined as a siliceous or alumino-siliceous material that, in finely divided form and in the presence of moisture, chemically reacts at ordinary room temperature with calcium hydroxide, released by the hydration of Portland cement, to form compounds possessing cementitious properties (Canadian Standard Association, 2000).

According to Ghassan et al (2013), researchers have shown that replacement of rice husk, blast furnace slag, egg shell etc. in concrete can improve concrete workability and durability. Most concrete structures are constructed using Ordinary Portland Cement as the main type of cement. The high cost of cement has made building construction very expensive. The cement industry has one of the highest carbon footprints which make traditional concrete unsustainable in the future.

2. LITERATURE REVIEW

Nigeria is currently the highest rice producer in West Africa, producing an average of 3.2 million tons of paddy rice or 2.0 million tons of milled rice. It is also the largest consuming nation in the region, with the growing demand amounting to 4.1 million tons of rice in 2002 (Domke and Mude, 2015). Rice husk is one of the most widely available agricultural wastes in many rice producing countries around the world. Globally, approximately 600 million tons of paddy rice is produced annually. Averagely 20% of the rice paddy is husk, giving an annual total production of 120 million tons (Sreenivasulu and Reddy,2014). Burning of rice husk in ambient atmosphere produces a residue called rice husk ash (RHA). For every 1000kg of rice paddy milled, about 220kg (22%) of husk is produced, and when this husk is burnt in the boilers, about 55kg (25%) of rice husk ash (RHA) is generated (Sreenivasulu and Reddy,2014).

Rice husks are procedure from paddy rice. Typically, 40kg of ash can be obtained from 1000 kg of paddy rice. However, open field calcination is not encouraged because of pollution problems and it also produces poor quality rice husk ash. Rice husk ash is a waste material which is obtained from rice mills a, it is a suitable substitute for cement at very low cost (Madhu, 2016). According to Seyed and Ahmadi (2017), Rice husk is by- product taken from rice mill process, with approximately the ratio of 200 kg per one ton of rice, even in high temperature it reduces to 40 kg. It has been shown from several studies that rice husks when burnt in controlled conditions between 500^0C to 700^0C and ground to particle sizes of less than 10 µm, results in a highly reactive RHA in the form of non-crystalline or amorphous silica (Chindaprasirt&Sirivivatnanon, 2008; Deepa, 2008). Uncontrolled combustion of rice husks results in poor quality of RHA. At temperatures lower than 500^0C, the ashes contain high carbon content and loss on ignition above 10 percent (Deepa,2008). Above 700^0C, crystalline silica ash is formed ((Deepa, 2008). It has been found out that the RHA produced from open burning has relatively high carbon content (above 4%) which adversely affect concrete performance and also results in a structure of highly crystalline form that is of low reactivity (Hwang and Chandra, 2016).

An investigation by Coutinho (2003) replaced 10, 15 and 20 percent of the Portland cement content with Portuguese rice husk ash. Apart from being a cheap alternative, it also improved the durability of concrete. The RHA in the amorphous form of silica, which has the potential to be used for structural concrete, is produced through controlled incineration conditions (temperature and duration). Until the early seventies, researchers utilized rice husks ash derived from uncontrolled combustion in their investigations. Some research established that a highly reactive rice husk ash can be produced by maintaining temperature below 500^0C under oxidizing conditions for relatively prolonged period (Mehta, 1979). Prolonged heating above this temperature may cause the material to convert, in part, to crystalline silica, first to cristobalite and then to tridymite. Further work has showed that for incineration temperatures of up to 700^0C, the silica is predominantly in amorphous form and that the crystals present in the ashes grew with the time of burning (Chopra, et al., 1981). Other work showed that the ash prepared at temperature of about 500^0C to 600^0C consists of amorphous silica, with cristobalite crystals being detected at 800^0C. At 1150^0C, both cristobalite and tridymite crystals become predominant (Hamad &Khattab, 1981).

Kapur (1981) has reported that a twelve hours incineration of rice husks at 800^0C produces a large proportion of the amorphous silica while Yeohet al (1979) observed that incinerating RH for less than one hour at about 900^0C produces amorphous silica.

2.1 Physical Properties of Rice Husk Ash.

Some physical properties of Rice Husk Ash that are of structural relevance are the specific gravity, mean particle size, and its Blaine fineness. Marthong (2012), and Karim et al. (2013) showed that the specific gravity of RHA varies between 2.05 – 2.53. These values are relatively lower than the specific gravity of the ordinary Portland cement which is between 3.10 and 3.14 (Ganesanet al., 2008) that it is meant to partially replace. In order for RHA to be used as a binder, majority of research studies conducted concluded that the material has to be ground into a very high specific surface area of up to 100 m2/g before use (Ganesanet al., 2008 and Nguyen et al., 2011). Antiohoset al. (2014) revealed that highest pozzolanic activities were achieved when the more reactive RHA was ground to7000 cm^2/g. Also, for RHA to be pozzolanic, its particle size should be between 5.6 – 8 mm (Nguyen et al, 2011).

2.2 Pozzolanic Properties of Rice Husk Ash

The oxides composition of Rice Husk Ash (RHA) as obtained by various researchers (Joel 2010; Oyekan and Kamiyo 2011) showed a very high silica content – above 70%. This is an indication of how reactive RHA is, since silica is the compound that has been found to be responsible for the strength in concrete (Nair et al., 2008). This is particularly good, for the high silica in RHA enables it to contribute to the strength development process if used in concrete production. Also, the sum of SiO2+Al2O3 + Fe2O3 exceeds 70% for all the RHA specimens used.

Rasheed Abdulwahab (2021) investigated the influence of co-addition ofMetakaolin (MK) and treated Rice Husk Ash (RHA) in the production of concrete. The kaolin was calcined at a temperature of 650^0C for 2 hours and thereafter characterized. Rice husk ash was roasted to temperature of 700^0C and thereafter treated with H2SO4. MK was replaced in varying percentages of 0%, 5%, and 10%. Thereafter, RHA was added by weight of the cement in varying percentages of 1%, 2%, and 3% to the optimum MK replacement (5%). From the results, it was found that concrete with 5% MK and 2% RHA had enhanced compressive strength as against the control. Hence, it can be inferred that 5% MK and 2% RHA concrete could be used in the construction industry. The increase in the strength properties of the concrete could be as a result of additional binding tendency exhibited by MK and RHA.

Osama et.al (2021) reported that Rice Husk Ash (RHA) used in concrete in the presence and absence of steel fibers and concrete performance was examined. A total of nine mixes were designed: one was a control, four were without steel fibers containing only RHA, and the last four mixed RHA with steel fibers from 0.5 to 2%. Tests with 5, 10, 15, and 20% percentages of RHA replacing the concrete were targeted. Results were compared with the reference samples and the reasonability of adding Rice Husk Ash to concrete was studied. From the results, it was noted that about 10% of cement might be replaced with Rice Husk Ash mixed in with steel fibers with almost equal compressive strength. Replacing more than 15% of cement with RHA will produce concrete with a low performance in terms of strength and durability.

Mohamed & Bassam (2019) investigated the efficiency of RHA and FA replacement ratios on fresh and hardened properties of concrete mixtures. The experimental program consisted of 21 concrete mixtures, which were divided into three groups. The cementitious material contents were 350, 450 and 550 kg m^{-3} for groups one, two and three, respectively. The replacement ratios from the cement content was 10, 20 and 30% respectively, for each recycle material (RHA and FA). The slump and air contents of fresh concrete were measured. The compressive strength, splitting tensile strength, flexural strength, modulus of elasticity and bond strength of hardened concrete as mechanical properties were also analyzed. The compressive strength was monitored at different ages: 3, 7, 28, 60 and 90 days. The water permeability test of hardened concrete as physical properties was conducted. Test results showed that the RHA and FA enhanced the mechanical and physical properties compared with the control mixture. The cementitious content of 450 kg m−3 exhibited better results than other utilized contents. In particular, the replacement ratios of 10 and 30% of RHA presented higher mechanical properties than those of FA for each group. The water permeability decreased as the cementitious content increased due to the decrease in air content for all mixtures. The water permeability loss ratios increased as the cementitious content decreased.

Watee (2018) reported the influence of RHA on the mixture properties. Special attention was paid to its efficiency for increasing the strength by partial cement replacement to obtain high-strength soil cement, and it was compared with fly ash. Test results showed that up to 35% of RHA could be advantageously added up to enhance the strength if the cement content in the mixture is larger than 10%. The RHA enhances the strength of cement-admixed clay by larger than 100% at 28 days. For curing time of 14 and 28 days, the RHA exhibits higher efficiency on Portland cement replacement when the cement and overall cementitious contents are not less than 20 and 35%, respectively. The optimum condition for high-strength mixture is achieved when RHA is added to the 20% cement content mixture. When compared with fly ash of similar grain size, the efficiency of RHA is higher when the content to be added is greater than 15%. This indicates the suitability of RHA for use in high-strength soil-cement.

Seyed and Ahmadi (2017) evaluated the benefits resulted from various ratios of rice husk ash (RHA) on concrete indicators through 5 mixture plans with proportions of 5, 10, 15, 20 and 25% RHA by weight of cement in addition to 10% micro- silica (MS) to be compared with a reference mixture with 100% Portland cement. Tests results indicated the positive relationship between 15% replacement of RHA with increase in compressive strengths by about 20%. The optimum level of strength anddurability properties generally gain with addition up to 20%, beyond that is associated with slight decrease in strength parameters by about 4.5%. The same results obtained for water absorption ratios likely to be unfavorable. Chloride ions penetration increased with increase in cement replacement by about 25% relative to the initial values (about less than one fifth).

Taku (2016) investigated the effect of the calcination temperature of rice husk on the pozzolanic properties of the resulting rice husk ash (RHA). Rice husk was collected from a rice milling plant and washed to remove sand and other impurities, beneficiated using the water beneficiation method and calcined at temperatures of 400, 500, 600, 700and 800℃, respectively for three hours. Samples were taken for XRF analysis, setting time determination and specific gravity test. The result of XRF analysis revealed that RHA calcined at temperatures between 400℃ and 800℃ contains more than 70% silica as stipulated by ASTM C618 for pozzolanas. The silica content though varies slightly with different calcination temperature of the rice husk ash. Also, calcination removed impurities present in the rice husk. Besides that, the specific gravity of RHA decreases with increasing calcination temperature from 2.00 at 400℃ to 1.05 at 800℃. Setting times of RHA mortars at 15% replacement of OPC with RHA shows no definite pattern with increasing temperature. However, the initial and final setting times of OPC-RHA mortars at all calcination temperatures were higher than that of OPC mortar. As a whole, calcination improves the silica content of rice husk ash for use as a pozzolana as well as removes mineral impurities that may affect the pozzolanic properties of the rice husk ash.

An investigation by Obam et.al (2011) confirmed RHA as a pozzolan and a potential cementitious material. The material was mixed with 45 per cent slaked lime. The resultant product 'cement' has a specific gravity of 2.1. The initial and final setting times were found to be 4 ½ and 76 hours respectively. The pozzolanic Activity Index of the ash was determined. It was found to be highly pozzolanic. The average compressive strength was found to be 3.2 N/mm^2 (32.6 kg/cm^2). The relationship between the compressive strength of its concrete and water-cement ratio was also studied. The optimum water-cement ratio was found to be 0.86.

Dabai (2009) conducted a compressive strength tests on six mortar cubes with cement replaced by rice husk ash (RHA) at five levels (0, 10, 20, 30, 40 and 50%). After the curing age of 3, 7, 14 and 28 days. The compressive strengths of the cubes at 10% replacement were 12.60, 14.20, 22.10, 28.50 and 36.30 N/mm^2 respectively and increased with age of curing but decreased with increase in RHA content for all mixes. The chemical analysis of the rice husk ash revealed high amount of silica (68.12%), alumina (1.01%) and oxides such as calcium oxide (1.01%) and iron oxide (0.78%) responsible for strength, soundness and setting of the concrete. It also contained high amount of magnesia (1.31%) which is responsible for the unsoundness. The final result, therefore, indicated that RHA can be used as cement substitute at 10% and 20% replacement and 14 and 28 days curing age.

Waswa-Sabuni (2003) conducted a survey to assess the quantities of rice husks at the rice milling plants in Kenya. Samples of rice husks from Mwea Rice Mills were used to confirm the pozzolanic properties of rice husk ash (RHA). Chemical analysis of the ash showed high silica (SiO2) content (more than 50%) which is a requirement for a good pozzolanic material. The engineering properties of the cement resulting from a mixture of OPC plus RHA and lime plus RHA were satisfactory with addition of up to 50% RHA. The RHA improved greatly the compressive strength of lime. The cost of producing RHA was considered in pricing the resulting binder and it showed that the use of RHA to supplement OPC and lime reduced the overall cost of the binder.

Yamamichiet al. (2003) studied RHA as a supplementary cementing material. Compressive strength of up to 91 days was determined as well as capillary absorption and chloride resistance being carried out to evaluate the durability of concrete made with RHA. The rice husks were incinerated in an oven heated up to 650°C, and maintained at that temperature for eight hours, then cooled down to room temperature and finely ground. The compressive strength of up to thirty percent were found to be suitable in RHA partial replacement in concrete when compared with a control mix (not added RHA).

3. CONCLUSION

The use of Rice Husk Ash as a supplementary cementitious material is recommended because of its properties and availability. From the review, several percentages of replacement are done to investigate the mechanical properties of modified concrete with control mix and the following conclusions can be drawn:

(1) The utilization of supplementary cementitious material like rice husk ash in concrete can help to reduce the environmental, technical and economic issues caused by cement production.

(2) RHA is more reactive as indicated in the combined SiO_2, $Al_2O_3$and Fe_2O_3content exceed 80%, demonstrated that the RHA are in the same category with the Class F fly ash (ASTM C618-05, 2005) with high pozzolanic characteristics.

(3) The chemical analysis done on rice husk ash indicated high amount of silica for rice husk ash (0ver 60%) which is a very good value for workability.

(4) Use of 10-20% RHA in replacement of cement increases strengths of all basic properties viz. compressive strengths, flexure strengths, split strengths, tensile strengths etc. and durability improvement. The compressive strength of concrete with replacement of cement results in increased strength compared to the normal.

(5) 2% Rice Husk Ash and 5% Metakaolin gave better compressive strength at shorter age of curing than 5% Mk only with prolonged period of curing with a percentage strength increment of 5.94%. However, the results of compressive strength of both test experiments (5% Mk +2% TRHA) gave strength increment of 34.38% and 30.22% respectively.

(6) Above all, Rice Husk Ash – Cements should be encouraged and produced by cements factories closest to the arears where rice is grown. the best way to harness rice husk ash is to making factories closest to them, harness them into pozzolanic blended cement.

REFERENCES

[1] Antiohos, S. K.; V. G. Papadakis and S. Tsimas (2014). Rice Husk Ash (RSA) Effectiveness in Cement and Concrete as a Function of Reactive Silica and Fineness. Cement and Concrete Research, 61(62): 20 – 27.

[2] Canadian Standards Association, CAN/CSA A3000-98,‘Cementitious Materials Compendium‖, 2000, 193. Compos. 32 (2); 212-127.

[3] Chindaprasirt, P., Rukzon, S., &Sirivivatnanon, V. (2008). Resistance to Chloride Penetration of Blended Portland Cement Mortar Containing Palm Oil Fuel Ash, Rice Husk Ash and Fly Ash. Construction and Building Materials, 22, 932-938.

[4] Chopra, S. K., Ahluwalia, S. C., ,&Laxmi, S. (1981). Technology and Manufacture of Rice Husks Ash Masonry (RHAM) Cement. Paper presented at the Procedings ESCAP/RCTT Third Workshop on Rice Husk ASh Cement New Delhi.

[5] Coutinho, S. J. (2003). The Combined Benefits of CPF and RHA in Improving the Durability of Concrete Structures Cement and Concrete Research 25, 51-59.

[6] DabaiM.U , Muhammad C., Bagudo B.U, and Musa A. (2009): Studies on the Effect of Rice Husk Ash as Cement Admixture. Nigerian Journal of Basic and Applied Science (2009), 17(2)252-256. http://www.ajol.info/browse-journals ISSN 0794-5698

[7] Deepa, G. N. (2008). A Structural Investigation Relating to the Pozzolanic Activity of Rice Husk Ashes. Cement and Concrete Research, 38, 861-869.

[8] Domke, P.V. and Mude, V.D (2015). “Natural Fiber Reinforced Building Materials”, IOSR Journal of Mechanical and Civil Engineering (IOSR – JMCE). Volume 12, Issue 3 Ver. II, May – June. 2015, pp 104-107.

[9] Ganesan, K.; K. Rajagopal and K. Thangavel (2008). Rice Husk Ash Blended Cement: Assessment of Optimal Level of Replacement for Strength and Permeability Properties of Concrete. Construction and Building Materials, 22(8): 1675-1683.

[10] Ghassan K. A, Mouin A and Panagiotis G. A (2013): Natural Pozzolana as a Partial Substitute for Cement in Concrete. The Open Construction and Building Technology Journal, 2013, 7, 33-42

[11] Grane, P. O., (1980), ―Non-cement-base hydraulic binders‖, Appropriate Industrial Technology for Construction & Building Materials, United Nation Industrial Development Organization, UN, N.Y., 218p, pp 48-57.

[12] Hwang, C. L. and Chandra, S. (2016). The Use of Rice Husk Ash in Concrete. Available on line at: https://3cl1105uvd.files.wordpress.com/2013/06/book-bysatish-chandra-220504.pdf. Assessed December 21, 2020.

[13] Joel, M. (2010). A Review of Partial Replacement of Cement with Some Agro Wastes. Nigerian Journal of Technology, 29(2): 12 – 20.

[14] Joshua, O., Olusola, K. O., Ayegba, C., & Yusuf, A. I. (2013). Assessment of the quality steel reinforcement bars

[15] Karim, M. R.; M. F. M. Zain, M. Jamil and F. C. Lai (2013). Fabrication of a non-cement composite binder by using slag, palm oil fuel ash and rice husk ash with sodium hydroxide as an activator. Construction and Building Materials, 49: 894-902.

[16] MadhuK, BhavanaT.D and Adil S.E (2016): Study on partial replacement of cement with rice husk ash and metakaolin. International Journal of Advanced Research, IJAR. www.journalijar.com. December, 2016.

[17] Marthong, C. (2012). Effect of Rice Husk Ash (RHA) as Partial Replacement of Cement on Concrete Properties. International Journal of Engineering Research & Technology, 1(6): 1 –8.

[18] Matawal, D. S. and Duna, S. (2002). Properties of Mortar Produced Using Rice Husk Ash as Partial Replacement of Cement. Journal of Civil Engineering Publications. 5(4): 35-43.

[19] Mehta, P. K. (1979). The Chemistry and Technology of Cements Made from Rice Husk Ash. Paper presented at the UNIDO/ESCAP/RCTT Workshop on Rice Husk Ash Cement, Peshawar.

[20] Mohamed Amin & Bassam AbdelsalamAbdelsalam (2019); Efficiency of rice husk ash and fly ash as reactivity materials in sustainable concrete Sustainable Environment Research volume29

[21] Nair, D. G.; A. Fraaij, A. A. K. Klaassen and A. P. M. Kentgens (2008). A Structural Investigation Relating to the Pozzolanic Activity of Rice Husk Ashes. Cement and Concrete Research, 38: 861–869.

[22] Nguyen, V. T.; G. Ye, K. van Breugel, A. I. A. Fraaij and D. D. Bui (2011). The study of using rice husk ash to produce ultra-high performance concrete, Construction and Building Materials 25(4): 2030-2035.

[23] Ojedokun, O. Y., Adeniran, A. A., Raheem, S. B. and Aderinto, S. J. (2014) Cow Dung Ash (CDA) as Partial Replacement of Cementing Material in the Production of Concrete British Journal of Applied Science & Technology, 4(24): 3445-3454

[24] Osama Zaid, Jawad Ahmad, Muhammad Shahid Siddique and Fahid Aslam (2021). Effect of Incorporation of Rice Husk Ash Instead of Cement on the Performance of Steel Fibers Reinforced Concrete. Front. Mater., 30 June 2021 | https://doi.org/10.3389/fmats.2021.665625

[25] Oyekan, G. L. and Kamiyo, O. M. (2011). A study on the engineering properties of sandcrete blocks produced with rice husk ash blended cement. Journal of Engineering and Technology Research, 3(3), 88-98.

[26] Rasheed Abdulwahab, Samson OlalekanOdeyemi, HabeebTemitopeAlao, ToyyibAdeyinkaSalaudeen (2021); Effects of metakaolin and treated rice husk ash on the compressive strength of concrete. Online Publication Date: 25 Jan 2021 Res. Eng. Struct. Mater URL:http://www.jresm.org/archive/resm2020.223ma1014.html

[27] SeyedAlireza and Mojtaba Ahmadi (2017); Rice husk ash as a partial replacement of cement in high strength concrete containing micro silica: Evaluating durability and mechanical properties. j.cscm.2017.05.00. Construction Materials Volume 7, Pages 73-81

[28] Sreenivasulu, S. and Reddy, A.C (2014). "Mechanical Properties Evaluation of Bamboo Fiber Reinforced Composite Materials", International Journal of Engineering Research (IJER), Volume No. 3 Issue No Special 1, March, 2014, pp 187-194.

[29] Taku, J. K, Amartey, Y. D, Kassar T (2016). Comparative Elemental Analysis of Rice Husk Ash Calcined at Different Temperatures Using X-ray Flourescence (XRF) Technique. American Journal of Civil Engineering and Architecture, 2016, Vol. 4, No. 1, 28-31 Available online at http://pubs.sciepub.com/ajcea/4/1/4 © Science and Education Publishing DOI:10.12691/ajcea-4-1-4

[30] Waswa-Sabuni, B., Syagga P.M, Dulo S.O, Kamau G.N (2003); Rice Husk Ash Cement – An alternative pozzolana cement for Kenyan building Industry DOI: 10.4314/jce.v8i1.18992. Journal of Civil Engineering, JKUAT:Vol. 8 (2003).

[31] WateeHomtragoon, RaksiriSukkarak, WaratKongkitkul, and PitthayaJamsawangPublished (2018). Efficiency of Rice Husk Ash as Cementitious Material in High-Strength Cement-Admixed Clay. Advances in Civil Engineering , vol. 2018, Article ID 8346319, 11 pages, 2018. https://doi.org/10.1155/2018/8346319

[32] Yamamichi, H., Qingge, F., ,& Sugita, S. (2003). Some Properties of Concrete with Highly Active Rice Husk Ash Paper presented at the Proceedings of the 6TH CANMET/ACI: International Conference on Durability of Concrete SP - 212.

[33] Yeoh, A. K., Bidin, R. R., Chong, C. N. ,& Tay, C. Y. (1979). The Relationship Between Temperature and Duration of Burning of Rice Husk in the Developmnet of Amorphous Rice Husk Ash Silica. Paper presented at the UNIDO/ESCAP/RCTT Follow - up Meeting on Rice Husk Cement, Setar.