Influence of rice husk ash as supplementary material in cement paste and concrete

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Abstract:

This paper assesses the utility of Rice Husk Ash (RHA) as an admixture in cement paste and concrete. Specifically, it examines the effect of RHA when blended to ordinary Portland cement at 0, 10, and 20 percent by weight, along some important properties of cement paste and concrete such as the normal consistency of cement paste, setting time of cement paste, workability of fresh concrete and compressive strength of hardened concrete. The findings show that RHA could be successfully utilized as supplementary material, as hardened concrete with 10% RHA has a strength that falls under normal strength of concrete. Moreover, RHA could be classified as retarding admixture since it prolongs the hardening of cement paste under normal consistency.

Keywords: *Rice husk ash (RHA), supplementary materials, alternative construction materials*

The development and use of alternative and indigenous construction materials is a growing concern among materials engineers in developing countries. Investigations show that many additives or supplementary construction materials are available locally. Recourse to these indigenous materials can minimize construction cost, as the cost of production for these materials is lower than that of commercially available cement. Another advantage is that their manufacture can be scaled to suit the demand of small-scale production. Moreover, as these alternative construction materials may come from agricultural and industrial waste materials, their usage as building materials will help in the useful disposal of these wastes.

Considering these advantages, this study aims to investigate the viability of rice husk ash (RHA) as supplementary material in cement paste and concrete, in the hope of recommending this as mineral admixture in the production of concrete. Rice husk ash is largely considered as an agricultural waste. Its discovery and utilization as an alternative building material will not only help rice mill owners dispose these agricultural wastes but also provide additional revenue.

Specifically, the study intends to determine the effect of rice husk ash when blended with Portland cement at different dosages. The resulting mixtures will then be analyzed in terms of several significant properties of cement paste and concrete, namely, normal consistency of cement paste, setting time of cement paste, workability of fresh concrete, and compressive strength of hardened concrete.

The findings of this study shall provide baseline data for local materials engineers in their search for alternative and indigenous construction materials. More specifically, the findings can serve as basis for the committee in-charge in reviewing the codes that govern the construction industry to consider the use of rice husk ash as an admixture of ordinary Portland cement, coming up with such provisions, specifications, and standards purposely intended for this matter in the Philippine setting.

Materials and methods

Materials

Burnt rice husks from rice mills were used as the raw materials for mixture with Portland cement. Rice husk ash was processed to desired fineness through filtering in the No. 200 sieve (75 μm sieve opening), with the particles passing the sieve being considered as the partial supplementary cementing material. Moreover, tests for the fineness of the material were carried out using the Blaine Air Permeability Test and the No. 325 mesh.

For aggregates, the study made use of crushed stones and natural sand. Crushed stones, as coarse aggregates, have passed through the 3/4" sieve opening but retained in No. 4 sieve (4.75 mm sieve opening). The resulting aggregates had a maximum nominal size of approximately smaller than 19 mm and larger than 4.75 mm. Natural sand (washed sand), as fine aggregates, passed the No. 4 sieve (4.75 mm sieve opening) but retained in the No. 100 sieve (150 μm sieve opening). The resulting particles had a maximum nominal size of approximately less than 4.75 mm and larger than 150 μm.

To complete the components of proposed concrete mixture, tap water was used.

Processes

Rice husk ash was combined with Portland cement at dosages of 10 and 20 percent of the latter's weight, respectively. Portland cement with no rice husk ash (0%) was prepared and considered as the control specimen.

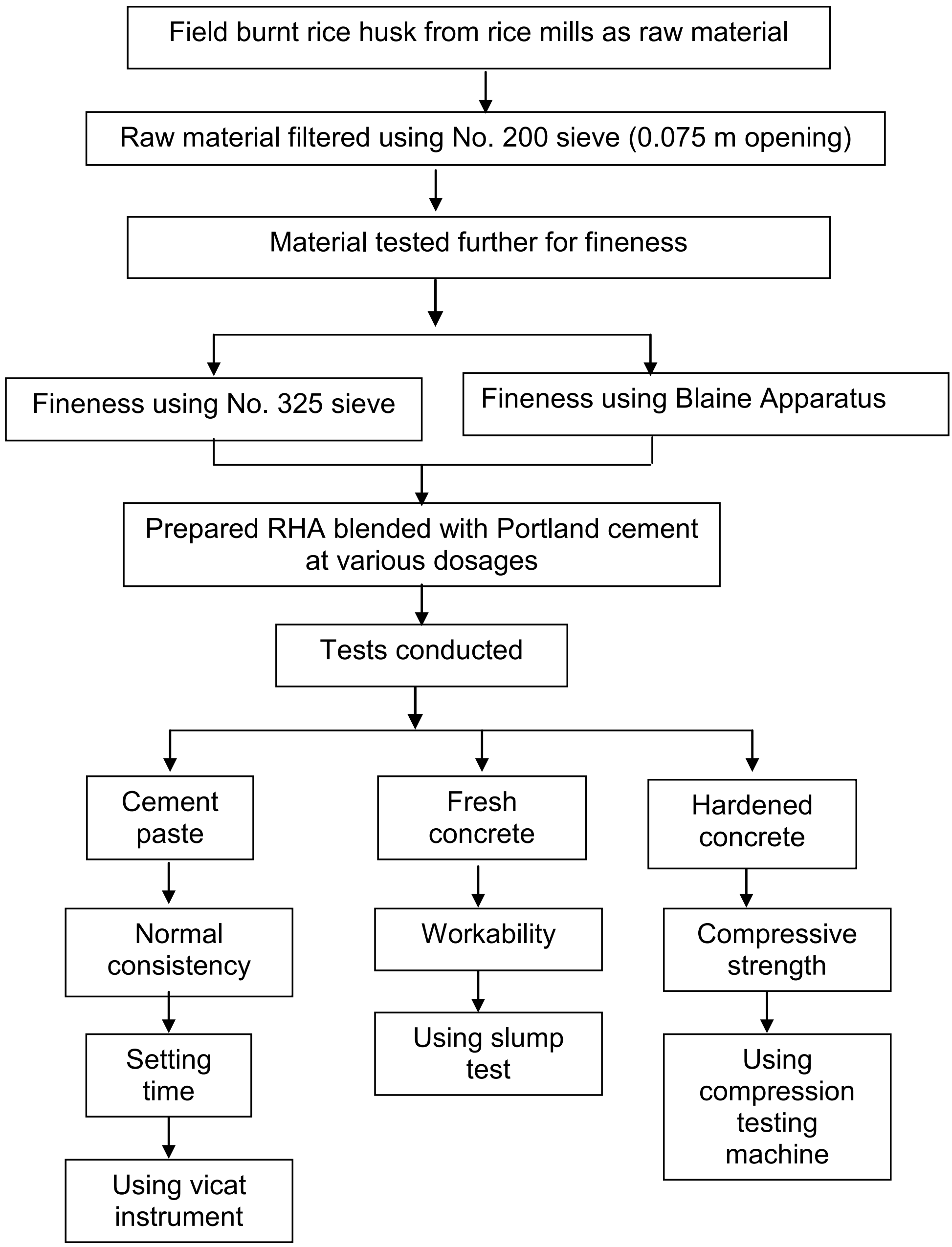
The various mixtures were subjected to tests for setting time, slump, and (after hardening) compressive strength. (Prior to these processes, a test was done on the RHA to determine its chemical constituents as supplementary cementing material using an x-ray fluorescence machine.) The setting time determination was carried in accordance with ASTM C191, following the American Society for Testing and Materials (ASTM) guidelines. For the slump test, the ASTM C143 procedures were followed. The test on the compressive strength of the concrete sample was done on 28-day old specimen, using compression testing machine.

Figure 1 illustrates how the study was carried out, including the various tests conducted and the instruments used.

Data treatment

Statistical treatments used were the average or mean of the data gathered in the laboratory, linear correlation analysis, linear regression analysis and Chi-square test.

Figure 1. Research design flowchart



Results and discussion

Table 1 presents the average values of normal consistency of cement paste at 0%, 10%, and 20% RHA partial replacement of ordinary Portland cement. The presence of rice husk ash in the cement paste greatly influenced the normal consistency of the cement paste mixture. Rice husk ash has caused the cement paste to absorb large amounts of water. Rice husk ash, thus, is a mineral admixture that requires more water to attain its normal consistency.

Table 1. Summary of the Average Values of Normal Consistency

RHA Partial Replacement (%)	Total Mass of Cement (gm)	Mass of RHA (gm)	Water Content at Normal Consistency (%)
0	650	0	25.69
10	650	65	34.20
20	650	130	43.54
Correlation Coefficient, r = +0.999			
Linear Regression Line, y = 0.8925x + 25.552			

Neville (1997) found that the water content of the cement paste at normal consistency is within the range of 26 and 33 percent. The consistency of the cement paste varies with the amount of water mixed in the combined materials. In short, water is the main controlling factor for the normal consistency of the cement paste. With this, RHA passes as an admixture that could be used in concrete mixtures.

Table 2 shows the result of the test conducted to determine the chemical constituents of the Rice Husk Ash as supplementary cementing material. The data show that RHA contains Silica as the major and primary element, which makes the material classified as Pozzolanic. Neville (1997) stated that rice husks are natural waste products having high silica content. Silica is a chemical component of rice husk ash and this is extremely fine-grained material producing silicon or silicon alloys. It possesses cementitious and pozzolanic properties and fills spaces between cement particles resulting in denser mixes with fewer air and water voids. Further, Metha (1993) stated that the presence of pozzolan in a hydrating cement paste can lead to the processes of pore-size and grain-size refinement, which have the effect of reducing both the size and volume of voids, microcracks, and calcium hydroxide crystals, thus causing a substantial improvement in strength and impermeability. The use of rice husk ash also helps reduce the bleeding in fresh concrete mixtures and serve as a highly active pozzolan.

Table 2. X-Ray Chemical Test Result of Rice Husk Ash (RHA)

Constituent	**Element**	**Percentage Content**
CaO	Lime	0.67
SiO2	Silica	85.77
Al2O3	Alumina	-0.24
Fe2O3	Iron	0.32
MgO	Magnesium	-0.17
K2O	Potassium	0.81
Na2O	Sodium	0.09

Table 3 indicates the range of setting times of the cement paste at different dosages of Rice Husk Ash that is mixed with Ordinary Portland Cement. The setting time of the cement paste mixture was affected by the presence of rice husk ash as partial replacement of ordinary Portland cement. Initial setting time and the final setting time of the cement paste containing rice husk ash is *longer* compared to the control specimen. As such, rice husk ash *prolongs or lengthens* the setting time of the cement paste and, therefore, it is considered as a *retarder*.

Table 3. Summary of the Average Values of Initial and Final Setting Time

Partial Replacement of Rice Husk Ash (%)	**Setting Time of Cement Paste (Min.)**	
	Initial Setting Time (Min.)	**Final Setting Time (Min.)**
0	97	210
10	108	212
20	196	385
Coefficient "r"	+0.912	+0.871
Regression Line	y = 4.95x + 84.167	y = 8.75x + 181.50

Table 4 shows the result of the slump test of fresh concrete using the designed replacement of Rice Husk Ash into the Ordinary Portland Cement. It can be seen in the table that RHA reduces the slump of the fresh concrete, making it less workable. This means that the presence of RHA in the fresh concrete mixture lessens the consistency and fluidity of the fresh concrete, confirming Singh's (1995) claim that generally rice husk ash leads to a less workable mix and reduces slump of the fresh concrete.

Table 4. Summary Average Values of Slump of Fresh Concrete

% RHA Replacement	**Workability of Fresh Concrete as Measured by Slump Test**			**Coeff. "r"**
	Water Cementitious Ratio, w/cm			
0.55	0.60	0.65		
0	5 mm	50 mm	161 mm	+0.971
10	0 mm	0 mm	39 mm	+0.866
20	0 mm	0 mm	0 mm	0
Coefficient "r"	-0.866	-0.866	-0.958	
Computed Chi-Square "X2"	12.661			
Tabulated Chi-Square "X2"	11.14 @ 5% L.S.			

Table 5 shows the result of the test conducted to evaluate the compressive strength of the hardened concrete containing various dosages of supplementary rice husk material at water cementitious materials ratios (w/cm) of 0.55, 0.60, and 0.65. Data indicate that RHA reduces the compressive strength of hardened concrete at 28 days period. However, at 10% RHA replacement there is slight variation of compressive strength between w/cm of 0.60 and 0.65. And at 20% rice husk ash, the compressive strength of hardened concrete increases as w/cm increases from 0.55 to 0.65.

Table 5. Average Values of Compressive Strength of Hardened Concrete

RHA Replacement (%)	**Compressive Strength, MPa Water-Cementitious Materials Ratio**			**Coeff. "r"**
	0.55	**0.60**	**0.65**	
0	22.92 MPa	30.58 MPa	29.58 MPa	+0.800
10	22.64 MPa	22.64 MPa	21.82 MPa	-0.866
20	9.86 Mpa	15.80 MPa	16.35 MPa	+0.902
Coefficient "r"	-0.875	-0.999	-0.995	
Computed "X2"	1.47			
Tabulated "X2"	11.14 @ 5% L.S.			

It can be seen that 10% partial replacement of RHA by weight is within the limits of an ordinary strength of concrete. The strength of the concrete at various dosages of RHA is considered as within the range of strengths of Ordinary Portland Cement Concrete. Concrete with compressive strength that is less than 20 Mpa (3000 psi) is called low strength concrete, 20 MPa to 40 MPa (3000 psi to 6000 psi) is considered as moderate strength concrete, and concrete with more than 40 MPa (6000 psi) is known as high strength concrete (Metha, 1993). Therefore, this means that hardened concrete with up to 10% RHA partial replacement of Ordinary Portland Cement can be considered as structural concrete or moderate strength concrete, while concrete with 20% rice husk ash partial replacement will be considered as low strength concrete.

Conclusion and recommendations

The study has demonstrated that RHA can be appropriately used as a supplementary material in cement paste and concrete preparation, subject to the following considerations:

1. Hardened concretes with up to 10% rice husk ash as partial replacement are considered moderate strength concrete or structural concrete and can be used for structural work. Concrete at 20% rice husk ash partial replacement is considered low strength concrete and can be utilized for nonstructural concrete works (Wang and Salmon, 1998).

2. The use of rice husk ash as mineral admixture in cement paste requires a *larger amount of water* to attain its normal consistency. If it is required to reduce the amount of water in the cement paste (but increase the plasticity to meet the desired normal consistency like that of the ordinary Portland cement paste), then it is recommended that a certain amount of *plasticizers* be used.

3. Rice husk ash *prolongs or lengthens* the setting time of the cement paste and therefore it is a *retarder*. There are advantages of prolonging the setting time of cement paste most especially for massive concrete constructions like concrete dams, concrete spur dikes, concrete floodwalls, and other similar structures that contain large volume of concrete. Rice husk ash as a *retarder* reduces cracks in the concrete and prevents the abrupt evaporation of heat in massive concrete structures. It also prolongs the workability of fresh concrete and provides better blending of concrete especially for successive pours. These are some of the substantial contributions of mineral admixtures in massive concrete structures. However, it is recommended that small amounts of *chemical admixtures* are to be added if it is desired to accelerate the setting time of the cement paste.

4. Rice husk ash is an additive that reduces the slump of the fresh concrete causing the concrete mixture to be less workable. However, this condition can be remedied by modifying the concrete mixture using chemical admixtures (while maintaining the same amount of water) without deleterious effect on the strength of the concrete.

5. Concrete is noted to be very strong in compression but weak in other properties like tensile strength and flexural strength or strength at

rupture. These properties are important especially in the analysis and design of concrete structures. As these properties were not included in this study, it is recommended that a further study be taken to investigate these properties in concrete containing rice husk ash as mineral admixture and with the addition of small amount of chemical admixtures.

6. Rice husk ash used in this study was taken from field burnt rice husk and was prepared through sieving or filtering using the No. 200 sieve (that is, without further benefit of crushing). It would be interesting if another study could be done on RHA that has been burnt in a controlled temperature as well as on RHA that has been made finer by grinding.

References

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Neville, M.A. (1997). Properties of Concrete. Addison Wesley Longman Limited. England

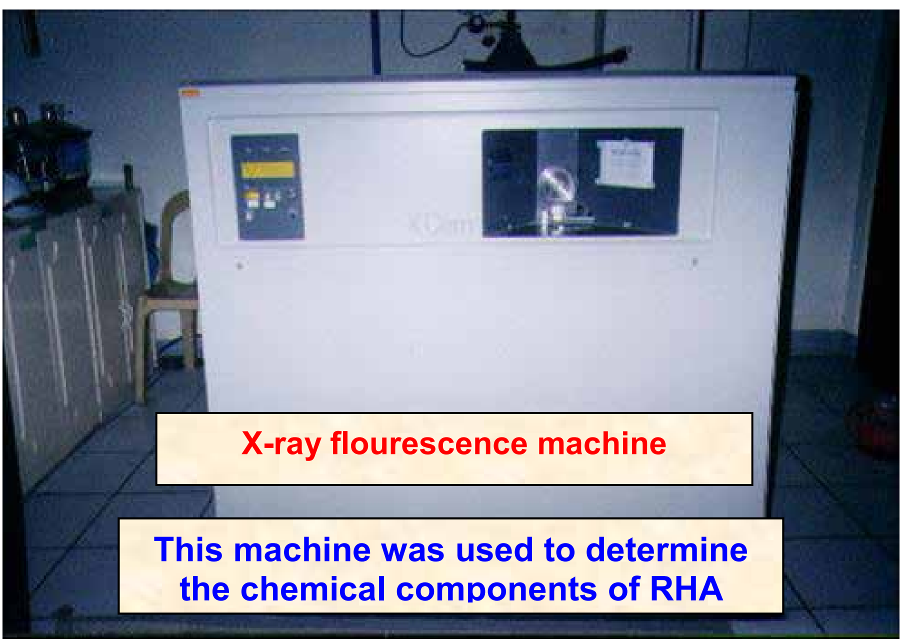
Singh S. B. (1995). Rheological properties of cement paste, mortar, and concrete containing combinations of pozzolanas. AIT Thesis No. ST 95-32. Asian Institute of Technology. Bangkok, Thailand.

Wang, C. K. & Salmon, C. G. (1998). Reinforced Concrete Design. Addison Wesley Educational Publishers, Inc. England.

Annexes. *Materials and equipment utilized*


Slump cone

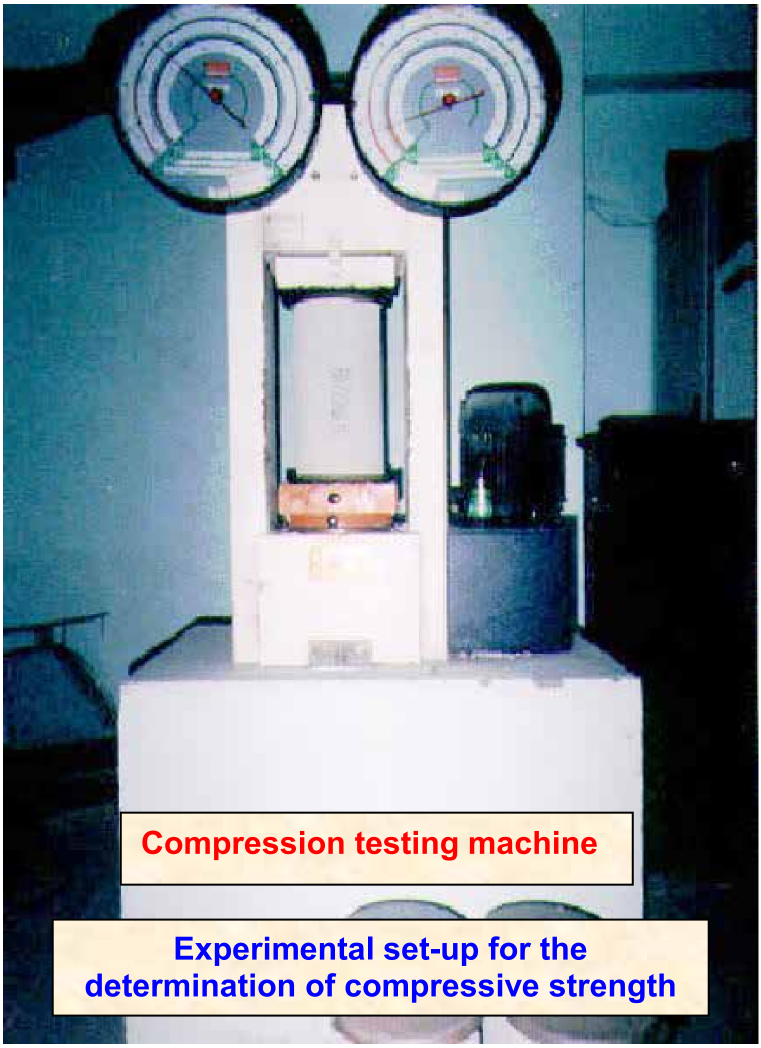

Blaine apparatus


X-ray flourescence machine

This machine was used to determine the chemical components of RHA

Vicat instrument

Set-up for slump measurement



Experimental set-up for the determination of compressive strength