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EFFECTS OF TREATMENT OF RICE HUSK ASH ON A TERNARY CONCRETE WITH CEMENT AND FLY ASH

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ABSTRACT:

In this paper, rice husk obtained from the same source with no special pretreatment was burnt in an oven within a control temperature of 500 – 600 ◦C for 30 minutes and cool in a metal container for several days. During cooling the amount of air supplied into the container was varied and this lead to different rice husk ash (RHA) products with different unburnt carbon content and appearance in color. However, the main physical and chemical properties of the RHA with lower unburnt carbon content (LRHA) and RHA with higher unburnt carbon content (HRHA) were relatively the same. LRHA and HRHA were prepared in a ternary concrete mix with cement and fly ash (FA) each with a total replacement ratio of 20%, 30% and 40% and ratio of FA:RHA maintained at 3:1through out all mixes. To understand more about the compatibility of RHA and FA, Class C and Class F FA were separately used in one similar mix design. All ternary mixes were prepared along with normal concrete, casted in cylindrical molds and then pond cured for up to 28 days. In preparing the normal concrete mix, viscosity enhancing admixture (VEA) was use to increase the cohesiveness and control the slump of the normal mix case. VEA was used to compensate the low workability of ternary mixes influenced by the addition of LRHA and HRHA. On another comparison the LRHA was reduced to smaller particle size by grinding (GRHA) and prepared in a ternary mix with cement and class F FA but this time superplasticizer was added to all mixes. These mixes were compared to normal concrete but without VEA. The objective of these comparisons were to identify the most compatible ternary mix with cement, RHA and FA and determine the effect of particle size of RHA on concrete. The particle size of RHA was analyzed using laser diffraction method and the compressive strength of different mixes were compared on 7, 14 and 28 day after pond curing. To determine the effect of VEA on concrete, two similar normal mixes with and without VEA were prepared and compressive strength compared on 7, 14 and 28 days. From the result of these experiments, LRHA was found to produce better compatibility with the ternary mix than HRHA. However, both LRHA and HRHA showed lower strength after 7, 14 and 28 days than normal concrete which can be attributed to the high particle size of LRHA and HRHA. After grinding, GRHA ternary mix produced a strength that is comparable to normal concrete. Also, it was found that when VEA of the amount 6% equivalent to total cement content was added to normal concrete the compressive strength on 7, 14 and 28 days were not significantly affected.

KEYWORDS: Rice husk ash, Supplementary cementitious material, Compressive strength, Particle size distribution

1. Introduction

In this paper, rice husk obtained from the same source with no special pretreatment was burnt in an oven within a control temperature of 500 – 600 ◦C for 30 minutes and cool in a metal container for several days. During cooling the amount of air supplied into the container was varied and this lead to different rice husk ash (RHA) products with different unburnt carbon content and appearance in color. However, the main physical and chemical properties of the RHA with lower unburnt carbon content (LRHA) and RHA with higher unburnt carbon content (HRHA) were relatively the same. LRHA and HRHA were prepared in a ternary concrete mix with cement and fly ash (FA) each with a total replacement ratio of 20%, 30% and 40% and ratio of FA:RHA maintained at 3:1through out all mixes. To understand more about the compatibility of RHA and FA, Class C and Class F FA were separately used in one similar mix design. All ternary mixes were prepared along with normal concrete, casted in cylindrical molds and then pond cured for up to 28 days. In preparing the normal concrete mix, viscosity enhancing admixture (VEA) was use to increase the cohesiveness and control the slump of the normal mix case. VEA was used to compensate the low workability of ternary mixes influenced by the addition of LRHA and HRHA. On another comparison the LRHA was reduced to smaller particle size by grinding (GRHA) and prepared in a ternary mix with cement and class F FA but this time superplasticizer was added to all mixes. These mixes were compared to normal concrete but without VEA. The objective of these comparisons were to identify the most compatible ternary mix with cement, RHA and FA and determine the effect of particle size of RHA on concrete. The particle size of RHA was analyzed using laser diffraction method and the compressive strength of different mixes were compared on 7, 14 and 28 day after pond curing. To determine the effect of VEA on concrete, two similar normal mixes with and without VEA were prepared and compressive strength compared on 7, 14 and 28 days. From the result of these experiments, LRHA was found to produce better compatibility with the ternary mix than HRHA. However, both LRHA and HRHA showed lower strength after 7, 14 and 28 days than normal concrete which can be attributed to the high particle size of LRHA and HRHA. After grinding, GRHA ternary mix produced a strength that is comparable to normal concrete. Also, it was found that when VEA of the amount 6% equivalent to total cement content was added to normal concrete the compressive strength on 7, 14 and 28 days were not significantly affected.

2. Experimental program

2.1 Materials

Cement

Ordinary Portland cement with the same material properties was used in all mix designs. The physical and chemical properties of the cement used in this study is given in Table 1.

Rice Husk Ash

The RHA used in this study was obtained by incinerating rice husk in a 500 – 600 ◦C controlled oven for 30 minutes. The burnt rice husk was then cooled in a container for several days and the air supplied during cooling was varied leading to formation of two types of RHA. This variation affected the amount of unburnt carbon and the appearance of RHA. In this paper, the two products are referred to as LRHA for the RHA with lower unburnt carbon content and HRHA for RHA with higher unburnt carbon content. Some portion of the LRHA was grinded to finer particles and it is referred to GRHA[5][6]. See Table 1 for the physical and chemical properties of all the RHA products used in this study. Figure 1 and Figure 2 shows the particle size distribution and appearance of LRHA before and after grinding respectively.

Fly Ash

Class C and Class F fly ash were used in this study. The Class F fly ash used was a pozzolanic material in accordance with JIS A 6201-1999 standard and the class C fly ash was obtained from Thailand and satisfies ASTM C311-11b standard requirements for Class C fly ash. The physical and chemical properties of these two materials are also given in Table 1 and the physical appearance of Class C and Class F fly ash are shown in Figure 3.

Table 1 Properties of cementitious material

Properties	Cementitious Materials					
	Cement	RHA			Fly ash	
		HRHA	LRHA	GRHA	Class F	Class C
Physical properties						
SSA (cm^2/g)	3270	5260	5550	27,100	3710	2550
Density(g/cm^3)	3.16	2.13	2.14	2.14	2.36	2.66
Median particle size(μm)	-	-	92	8	-	-
Chemical properties						
SiO_2(%)	20.61	89.29	89.55	84.51	54.94	33.76
Al_2O_3 (%)	5.41	0.36	0.33	0.33	28.63	16.77
Fe_2O_3 (%)	3.08	0.06	0.06	0.55	5.90	13.62
CaO (%)	64.04	0.52	0.54	0.64	3.17	23.36
MgO (%)	1.57	0.17	0.19	0.19	1.32	3.41
L.O.I (%)	-	6.15	6.39	10.32	-	<0.01
Unburnt carbon (%)	-	4.31	3.28	-	-	-

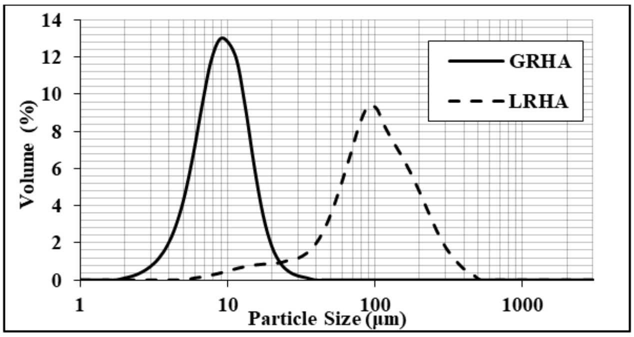

Figure 1 Particle size distribution of LRHA and GRHA

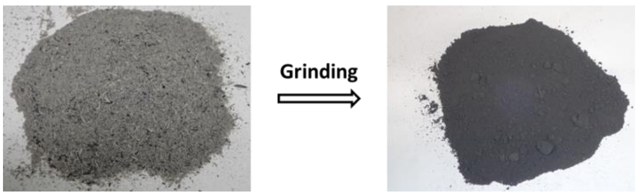

Figure 2 Image of LRHA before and after grinding

Figure 3 Image of Class C and Class F fly ash respectively

Aggregate

Locally available coarse and fine aggregates were used. The coarse aggregate was gravel stones with two different sizes of maximum size aggregate. 50 % of each size coarse aggregate was used in all the mixes. The fine aggregate used was sand after drying and sieving. The surface dry density of the coarse and fine aggregate were 2.64 g/cm^3 and 2.62 g/cm^3 respectively.

Viscosity Enhancing Agent

A water insoluble admixture “asuka clean” is an industrial product which was used in the study as viscosity enhancing agent as correction for normal concrete mix to avoid segregation of aggregate. This product is derived from cellulose and have the effect of increasing the viscosity of concrete and suppressing material segregation.

Superplasticizer

The superplasticizer used in the study is MasterGlenium SKY 8808 known as SP8HU in Japan. This is a liquid high range water reducing admixture.

2.2 Mix Designs

Three different mix designs of the same water-binder (W/B) ratio of 0.45 were prepared in this study. The first mix design was used to compare the compatibility of the different types of RHA without any special treatment and fly ash used in this study, the second one was used to determine the effect of VEA[4] on a normal concrete mix and the third was used to study the effects of special treatment by grinding of RHA on the ternary mix of RHA, FA and cement. The characteristics of all the mix designs used are shown in Tables 2-4.

Table 2 Mix design 1

No.	Mix ID.	W/B	RHA (%)	FA (%)	Unit weight					
					Cement	RHA	FA	Sand	Gravel	Water
1	N	0.45	0	0	617	0	0	513	769	277
2	FLR1		5	15	493	31	92	538	808	277
3	FLR2		7.5	22.5	432	46	139	551	827	277
4	FLR3		10	30	370	62	185	564	847	277
5	FHR1		5	15	493	31	92	538	808	277
6	FHR2		7.5	22.5	432	46	139	551	827	277
7	FHR3		10	30	370	62	185	564	847	277
8	CLR		7.5	22.5	432	46	139	551	827	277

In Mix Design 1, eight study cases were prepare of which only the normal concrete had extra admixture. VEA was used as an additive of the normal concrete to reduce the slump and avoid segregation of aggregates in the mix. This was necessary because RHA was used in its original state in all other mixes and this significantly affected the workability of concrete so to control the slump for comparison either superplasticizer was necessary for all RHA incorporated mixes or adding VEA to the normal mix. The latter was chosen in this study because the author wanted to know the effect of combined RHA and fly ash in concrete with no additive.

Table 3 Mix design 2

No.	Mix ID.	W/B	VEA (%)	Unit weight (kg/m^3)			
				Cement	Sand	Gravel	Water
1	NV0	0.45	0	577	545	817	260
2	NV1		6	577	545	817	260

In Mix Design 2, the effect of the VEA on normal concrete was studied. The VEA was added to the mix by 6% of amount of cement used and compared to the same mix without the VEA.

In Mix Design 3, the grinded RHA, GRHA was prepared in a ternary mix with fly ash and cement at 20 % and 30 % (FA plus GRHA) replacement of FA: GRHA ratio at 3:1. In this design the superplasticizer was used in all the case studies.

Table 4 Mix design 3

No.	Mix ID.	W/B	RHA (%)	Fly ash (%)	SP (%)	Unit weight (kg/m^3)					
						Cement	RHA	Fly ash	Sand	Gravel	Water
1	NC	0.45	0	0	0.1	399	0	0	636	953	180
2	RFC1		5	15	0.05	343	21	64	682	1024	193
3	RFC2		7.5	22.5	0.2	303	32	97	688	1033	195

2.3Method

After mixing and measuring the fresh properties of concrete in accordance with JSCE test procedures on all test cases, specimens were casted into 200 mm by 100 mm diameter cylindrical molds for one day to set. After one day of setting, specimens were demolded and then placed into a water tank for curing. Specimens were cured until their test date of 7, 14 and 28 days. Compressive strengths of all specimens were measured on 7, 14 and 28 day after casting except for specimen that included the use of Class C fly ash in Mix Design 1. The compressive strength of this case study was only measure on 7 and 28 days due to limited availability of material.

3. Results and Discussion

The recorded fresh properties of concrete used in all mix designs are given in Table 5. From the results of Mix Design 1, it shows that FLR series produced a better workability than FHR series in all three different cases of 20 %, 30% and 40% net replacement of FA and RHA. CLR when compared to FLR2 showed no significant difference in slump or air content between these cases.

In Mix Design 2, the objective was to determine the effect of VEA on the compressive strength of concrete. For this reason, the fresh properties of concrete was not recorded in these cases. However, these properties were recorded in Mix Design 3 and the results are also shown in Table 5. The results show that grinding of RHA significantly contributes to improving workability when compared to not grinded RHA in the ternary mix. At 20% net replacement in the ternary mix (RFC1) showed better workability than normal concrete.

The compressive strength comparison of Mix Design 1, 2 and 3 are given in Figure 4, 5 and 6 respectively. In Figure 4, the comparison results showed that the normal case (N) had a relatively larger strength than all ternary mix cases. Also, a decreasing strength trend was observed as the cement replacement percentage by RHA and fly ash increased.

This result was expected because the particle size of the RHA used was relatively high and this significantly affected the pozzolanic activity and the specific surface area of RHA which are key parameters for performance of RHA. Comparing the performance of LRHA and HRHA, it was observed that in all cases and age of concrete, FLR series had a better strength than FHR series. From this, it can be said the LRHA have a superior performance and its preparation method is more effective. The case including Class C fly ash showed similar strength performance to that of similar mix proportioned concrete using Class F fly ash.

Table 5 Fresh properties of concrete

No.	ID.	RHA (%)	FA (%)	VEA (%)	SP (%)	Air (%)	Slump (mm)
Mix Design 1							
1	N	0	0	6	0	-	-
2	FLR1	5	15	0	0	0.5	18.5
3	FLR2	7.5	22.5	0	0	0.5	14.6
4	FLR3	10	30	0	0	1.2	9.5
5	FHR1	5	15	0	0	0.1	-
6	FHR2	7.5	22.5	0	0	0.6	17
7	FHR3	10	30	0	0	1.5	11
8	CLR	7.5	22.5	0	0	0.7	15
Mix Design 2							
1	NV0	0	0	0	0	-	-
2	NV1	0	0	6	0	-	-
Mix Design 3							
1	NC	0	0	0	0.1	1.48	17.2
2	RFC1	5	15	0	0.1	0.5	19.6
3	RFC2	7.5	22.5	0	0.2	0.7	14

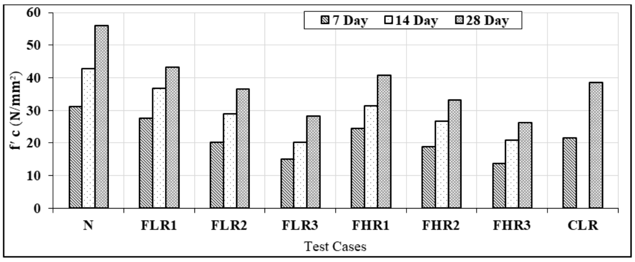

Figure 4 Compressive Strength of Mix Design 1

This was also observed in the fresh properties of the two cases. Therefore, it can be said that both types of fly ash are similarly compatible to RHA. Figure 5 shows the compressive strength of Mix Design 2 which studied the effect of VEA as an agent to avoid segregation of concrete. From the graph it can be seen that the addition of VEA did not significantly change the strength of concrete at 7, 14 or 28 days. From these results, it can be validated that this VEA can be used to control workability of concrete in situation where comparison is to be done for concretes that varies largely in workability.

Figure 6 shows the compressive strength performance of ternary mix including RHA after grinding compared to normal concrete. From the results, it can be seen that at all ages the strength of the ternary mix was significantly improved and comparable with the normal case. It can be argued that due to the short burning time of RHA which resulted in a high unburnt carbon residue in the material could have contributed to reducing the strength performance of the ternary mixes. Also, considering the strength development of pozzolanic materials, it is expected that the ternary mixes will develop in strength more rapidly than the normal case after the 28 day.

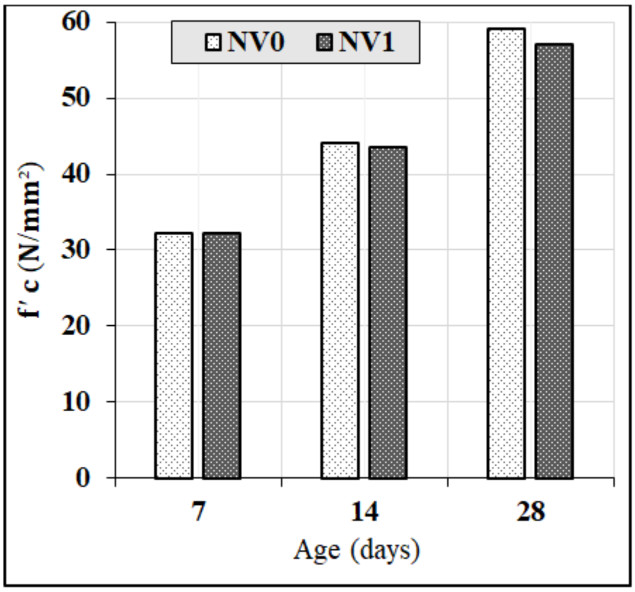

Figure 5 Compressive Strength of Mix Design 2

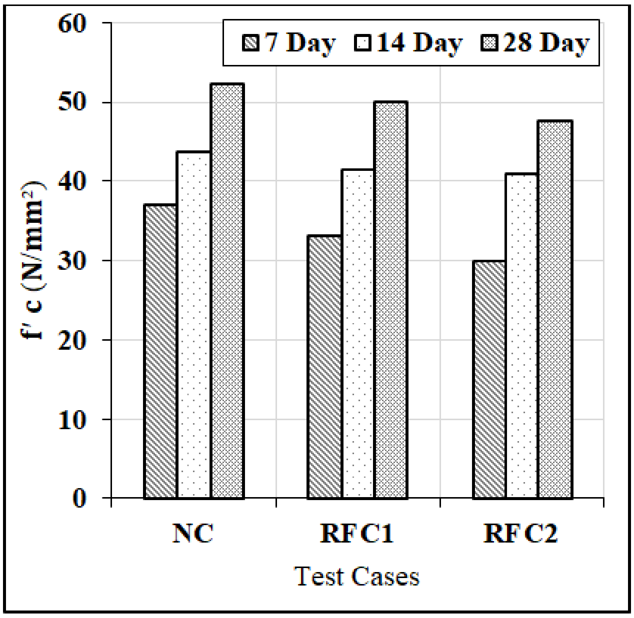

Figure 6 Compressive Strength of Mix Design 3

4. Conclusions

From the results the following conclusions can be drawn:

1. Burning time and temperature have been highlighted in many researches as key to optimizing the performance of RHA in concrete. This study shows that rice husk burnt for just 30 minutes can produce desirable RHA product and by varying the cooling system after burning RHA product can vary significantly. By this method, the energy required to burn RHA can be significantly reduced and therefore further reducing the already low overall cost of processing RHA.

2. Class F and Class C fly ash showed similar compatibility result both in fresh and hardened states when mixed in a ternary concrete with RHA and cement.

3. The unburnt carbon residue in RHA significantly affected the performance of RHA as highlighted in the comparison of FLR series and FHR series in Mix Design 1. FLR series containing RHA with lower unburnt carbon content of 3.28 % produced superior performance in both fresh and harden states of concrete than FHR series with 4.31% unburnt carbon content.

4. It has been report in many studies that due to the large specific surface area and high silica content of RHA the pozzolanic reactivity is enhanced and this study further proves this. From results of Mix Design 3, the SSA of RHA was increased by 338% by grinding RHA and this coincided with improving harden properties of RHA as well as contributing to improving the workability of ternary mixes.

5. RHA in its original state after burning showed very poor workability properties therefore extra measures should be taken to improve this property. Grinding of RHA to smaller particle size significantly improves the workability of RHA.

6. VEA used in this study can improve the cohesive properties of concrete with high slump and risk of segregation can be mitigated. Adding 6% VEA of total cement content to concrete did not significantly affect the strength properties of concrete for up to 28 days.

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