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RECYCLING OF WASTE (RICE HUSK AND QUARRY DUST) FOR BUILDING MATERIALS

Kartini, K.
Assoc. Prof. Ir. Dr., Faculty of Civil Engineering, Universiti Teknologi Mara, MALAYSIA
ce_kartini2002@yahoo.com

Norhana, A.R.
MSc in Civil Engineering, Faculty of Civil Engineering, Universiti Teknologi Mara, MALAYSIA
ann_trace@yahoo.com

Abstract
In the past few years, the waste materials from large scale buildings and development activities have contributed to the problems of managing and disposing the waste materials. Such waste as cement, aggregate, timber or even demolition wastes have become the major environmental, economical and social issues as there are lacks of dumping area. Nowadays, the waste materials are commonly managed by reuse, reduce, recycling, incineration and land-filling in order to recover the increasing of the waste materials generated. On top of the options mentioned, the recycling is the best waste management disposal process. Actually, these wastes can be recycled and used as a whole or partially as building material, thus can eliminated the problems of waste management encountered. Researches into new and innovative uses of waste materials are grown continuously. In recent years, many researchers have found that the waste materials are capable to give return in terms of economy and also enhance the properties of concrete. Some of the commonly used waste materials that can be recycled as supplementary cementing materials are Rice Husk Ash (RHA), and Quarry Dust Fine Powder (QDFP). The used of these waste materials into supplementary cementitious material are identified to give enhancement in term of strength and durability performances of concrete. This paper highlighted the results of strength and durability of these mentioned materials. Studies shows that the replacement of RHA up to 30% can attained strength of 30 N/mm^2, however for QDFP concrete of 0.3, 0.4, 0.5 and 0.6 w/b ratio can replaced up to 15% except for 0.6 w/b ratio only up to 10%. In term of water permeability, replacement of OPC with RHA reduced the permeability of the concrete thus the presence of RHA resulted in lower coefficient of permeability. For superplasticized QDFP concrete, it can be considered as having low permeability especially at low w/b ratio. With the results obtained, it can be said that there are potential uses of these recyclables waste materials as building materials in construction industry.

Keywords
Waste Materials, Rice Husk Ash, Quarry Dust Fine Powder, Compressive Strength, Water Permeability

1. INTRODUCTION

Sustainable development as quoted in Brundtland Report (WCED, 1987) is define as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*", while the 1992 Earth Summit in Rio de Janeiro defined sustainable development as "*economic activity that is in harmony with the earth ecosystem*" (UNCED, 1992). Therefore with that definition, the need of sustainable material in construction of sustainable building is obvious.

Cement is the product of the silicate industry and is manufactured on the largest scale and used extensively in homes, industrial buildings and other structures. The raw materials used in making cements are naturally occurring materials. These naturally occurring materials include hydrated gypsum ($CaSO_4$ $2H_2O$), anhydride $CaSO_4$ and limestone rock (Ajiwe *et al*., 2000). With high cost of production and energy consumption to produce cement and also the major source of greenhouse gas emission, it is time to look into the use of local, sustainable and inexpensive raw materials or industrial waste materials in replacing cement to build the structures especially housing for the needy.

The utilization of the industrial waste by-products as well as the agricultural residue such saw dust ash (Kartini *et al*., 2007), rattan dust ash (Kartini *et al*., 2007), rice husk ash (Kartini, 2009), empty fruit bunch ash (Amizan and Kartini, 2009) and quarry dust fine powder (Norhana *et al.*, 2010) have been carried out in the past decades to find a suitable partial replacement for cement. These wastes material are normally thrown away without any commercial value. Studies (Kartini 2009; Gambhir, 2006; Hwang and Chandra, 1997; Mehta, 1992) showed that the outstanding technical benefit of incorporating these pozzolans as cement replacement materials, it significantly improves the durability properties of concrete to various chemical attacks due to its reduced permeability arising from a pore refining process. These properties are difficult to achieve by the use of pure Portland cement alone. This paper highlighted the results obtained from compressive strength and durability tests conducted on rice husk ash and quarry dust fine powder in determining its suitability as cement replacement material.

2. EXPERIMENTAL WORK

2.1 Material Used

The rice husk was burnt in a ferrocement furnace to produce rice husk ash (RHA). After burning and left for 24 hours for it to further burning, the burnt ashes were left to cool inside the furnace for another 24 hours before taken out for grinding using a Los Angeles (LA) machine. From the fineness test conducted, it was found out that the fineness of RHA as that retained on 45μm sieve was about 21.87%, which conformed to grade A of dry pulverized–fuel ash (pfa) based on ASTM C430:1992. The Blaine surface area (BET) of RHA determined using nitrogen absorption method ranged between 10.857m^2/g to 17.463 m^2/g and with specific gravity of 2.1. The average particle size of RHA is 25.83µm.

In order to produce Quarry Dust Fine Powder (QDFP), about 5 kg of quarry dust (QD) was placed in Los Angeles (LA) Machine, with 16 nos. of ball bearings in it and grinded for 5000 revolutions. After grinding, the crushed QD was sieved through 90 µm to ensure it fineness. The average passing the 90 µm sieve was 92.1%.

The other materials used in these investigations were Ordinary Portland Cement (OPC) of Type 1. Table 3 shows the chemical compositions of OPC used in this study. The mining sand as fine aggregates with maximum size of 5 mm, while the coarse aggregates are crushed granite which passing through 20 mm and retained on 10 mm. The fine aggregates and coarse aggregates that have been used were complying with the standard BS 812-103:1:1985. The fineness modulus for fine aggregate and the coarse aggregate were 4.61 and 2.43 respectively. The tap water free from contamination was used for the mixing and curing of concrete. The type of superplasticizer (Sp) used in this research is sulphonated naphthalene formaldehyde condensed polymer based admixture, commercially known as '*Rheobuild 1100*', which is a water-soluble. It satisfies the requirements of ASTM C494 Type A and Type F.

2.2 Test Methods

2.2.1 Compressive Strength

The most common measure of concrete is the compressive strength test. The test was conducted as prescribed in BS EN 12390-4:2000. The Compression Auto Test Machine with capacity of 1000 kN and the rate of load employed at 3.00 kN/m was used to break the specimens of 100mm cubes. As the strength of concrete increase with time, it is significantly to test the cubes at the various ages of curing which are 7, 28, 60, 90 and 120 days.

2.2.2 Water Permeability

Permeability is influenced by the capillary pores exist in concrete. Pores that are too small will result in a low permeability while the pores that are too large will result in a high permeability. In determining the durability of the concrete, the water permeability test based on BS 12390-8:2000 was conducted. The cylindrical specimens of 150 Ø by 150 mm height were placed in the apparatus for 3 days and pressure of 0.5 N/mm^2 was applied. Immediately after the pressure is released, the specimen was removed and split down the centre into halved. The average depths of penetration of water were then converted into the coefficient of permeability.

2.3 Samples Preparation

The mix designs for all the waste materials used were based on the British method, *i.e.* from the Department of the Environment (DOE) (1998). The concrete specimens were cast as in accordance to BS EN 12390-1:2000, and the slump test based on BS EN 12350-2:2000 was conducted to determine the workability of fresh concrete.

The control OPC concrete was designed to achieve the strength of $30N/mm^2$ using the DOE method, with water to binder (OPC plus RHA) ratio (w/b) of 0.63. The amount of replacement of OPC in the mix with RHA was 10 %, 20 % and 30% with and without Sp. Table 1 summarised the mix proportions for RHA concrete mixes of Grade 30. For the Quarry Dust Fine Powder (QDFP), five (5) series of concrete mixes were prepared based on replacement of 0%, 3%, 5%, 10% and 15% of OPC with QDFP, and designated as OPC, 3QDFPSp, 5QDFPSp, 10QDFPSp and 15QDFPSp respectively. Table 2 shows the mix proportions of various percentage replacements of OPC with QDFP of Grade 30 concrete. The amount of Sp and the percentage of Sp were kept constant to ensure its consistency when OPC was replaced with RHA or QDFP. The increased in the amount of RHA or QDFP content resulted in dry mix concrete, therefore Sp was used to enhance the fluidity of the mixes. The Sp dosage in subsequent mixtures was tailored to achieve slump in the range of 100 mm to 150 mm.

Table 1: Mixture Proportion for RHA concrete of Grade 30 concrete

Designation	Grade Concrete	Mass per Unit Volume of Materials (kg/m^3)				
		Cement	RHA	Water	Aggregate	
					Fine	Coarse
OPC_{30}		325	-	205	900	940
$RHA_{30}10$		293	32	205	900	940
$RHA_{30}20$		260	65	205	900	940
$RHA_{30}30$	30	228	97	205	900	940
$OPC_{30}Sp$		325	-	205	900	940
$RHA_{30}10Sp$		293	32	205	900	940
$RHA_{30}20Sp$		260	65	205	900	940
$RHA_{30}30Sp$		228	97	205	900	940

Table 2: Mix proportion of Superplasticised QDFP concrete of Grade 30 concrete

Designation	Mass per Unit Volume of Materials (kg/m^3)						w/b
	Cement	QDFP	Water	Aggregate			
				Fine	Coarse		
					10 mm	20 mm	
OPC	342	-	205	671	398	795	
3QDFPSp	332	10	205	671	398	795	
5QDFPSp	325	17	205	671	398	795	0.6
10QDFPSp	308	34	205	671	398	795	
15QDFPSp	291	51	205	671	398	795	
OPC	410	-	205	611	395	790	
3QDFPSp	398	12	205	611	395	790	
5QDFPSp	390	20	205	611	395	790	0.5
10QDFPSp	369	41	205	611	395	790	
15QDFPSp	349	62	205	611	395	790	
OPC	513	-	205	542	384	767	
3QDFPSp	498	14	205	542	384	767	
5QDFPSp	487	26	205	542	384	767	0.4
10QDFPSp	462	51	205	542	384	767	
15QDFPSp	436	77	205	542	384	767	
OPC	684	-	205	457	355	710	
3QDFPSp	664	21	205	457	355	710	
5QDFPSp	650	35	205	457	355	710	0.3
10QDFPSp	616	68	205	457	355	710	
15QDFPSp	581	103	205	457	355	710	

3. RESULTS AND DISCUSSION

3.1Properties of Materials

A typical chemical composition of the ash obtained after burning and grinding is shown in Table 3. From the table it can be seen that SiO_2 for RHA and QDFP is 96.7% and 69.96% and LOI is 4.81% and 1.32% respectively. These show that the ashes as high content of silica and of good quality. The SiO_2 + Al_2O_3 + Fe_2O_3 of RHA were 97.8%, while for QDFP is 87.05%. From the classification of pozzolanic in ASTM C618-2003, for ashes to be classified as Class N pozzolanic, it should have minimum SiO_2 of 70% and a maximum of 6% for loss of ignition. Hwang and Chandra (1997) reported that the chemical composition of resulted RHA depend on the burning conditions of the incinerator where the husk was burnt to ashes.

Table 3: Chemical composition (%) of OPC, RHA and QDFP

Chemical composition	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	MgO	CaO	Na_2O	K_2O	P_2O_5	MnO	SO_3	LOI
OPC	15.05	2.56	4.00	0.12	1.27	72.17	0.08	0.41	0.06	0.06	2.90	1.33
RHA	96.7	1.01	0.05	0.16	0.19	0.49	0.26	0.91	-	-	-	4.81
QDFP	69.96	12.81	4.28	0.22	0.44	1.84	0.51	8.12	0.20	0.10	0.20	1.32

2.2 Compressive Strength

The results of the compressive strength for the RHA concrete taken up to 120 days are presented graphically in Figure 1. It shows that the compressive strength of RHA concrete is well above the targeted strength of 30 N/mm^2. It can be seen that with the increase of RHA in the mixes, the compressive strength reduced however, they still achieved the target strength of the specified grade. Therefore, the optimum amount of OPC that can be replaced with RHA is about 30% for Grade 30. However, it is expected that the optimum can go more than 30% replacement. The table also showed that prolong curing of these concretes resulted in increased in strength.

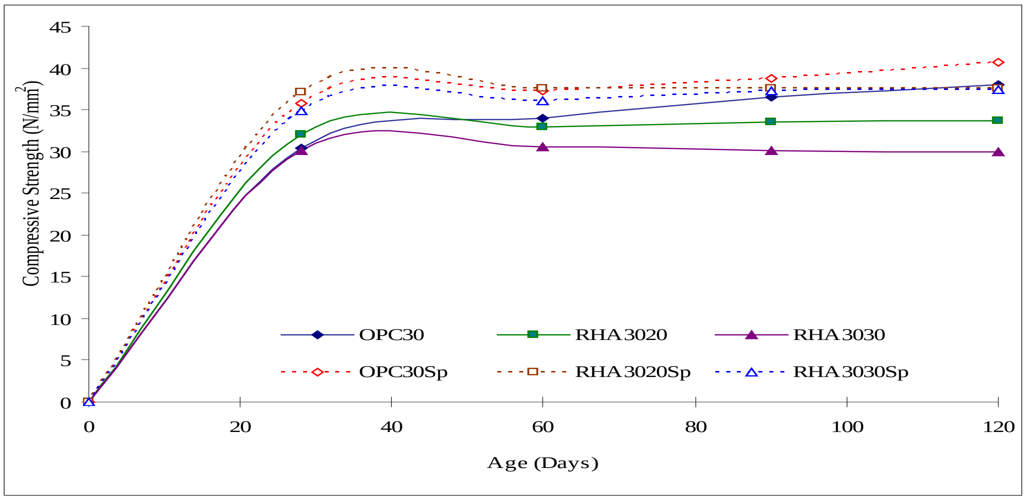

Figure 1: Compressive strength of RHA concrete of Grade 30

When the amount of cement replacement with RHA in a concrete increases, the mix becomes very dry or unworkable if the amount of water in the mix is to remain constant. This is because of the adsorptive character and large surface area of the cellular RHA. For that reason, a proper dosage of Sp was added into the mix. From Figure 1, it can be seen that for Grade 30 concrete, replacement of 20% and 30% and with Sp, there is an increased in strength, in fact, the results showed a higher values compared to OPC control concrete.

Figure 2 shows the results of compressive strength of superplasticised QDFP concrete versus age for Grade 30 concrete at w/b ratio of 0.6 taken at 7, 28, 60, 90 and 120, while for w/b ratio 0.3, 0.4 and 0.4, the results were tabulated in Table 4. From Figure 2, it can be seen that the compressive strength of all the superplasticised QDFP concrete reduces as the percentages of QDFP replacement increases from 3% to 15%, however achieved the targeted strength of Grade 30, except for at 15% replacement, and this is also true for other w/b ratio as tabulated in Table 4, *i.e.* the compressive strength decreases as the percentages of replacement and w/b ratio increases. The compressive strength of the concretes increased as the period of curing prolonged. The superplasticised QDFP taken at 28 days recorded values ranges from 64 N/mm^2 to

37N/mm², 42 N/mm² to 30 N/mm², 42 N/mm² to 30 N/mm² and 35 N/mm² to 24 N/mm² for replacement from 3% to 15% at 0.3, 0.4, 0.5 and 0.6 w/b ratio respectively. The results show that, the trend seems to be similar for all replacements and at various w/b ratio hence, it is definitely true that as the strength decreases with increased in moisture content.

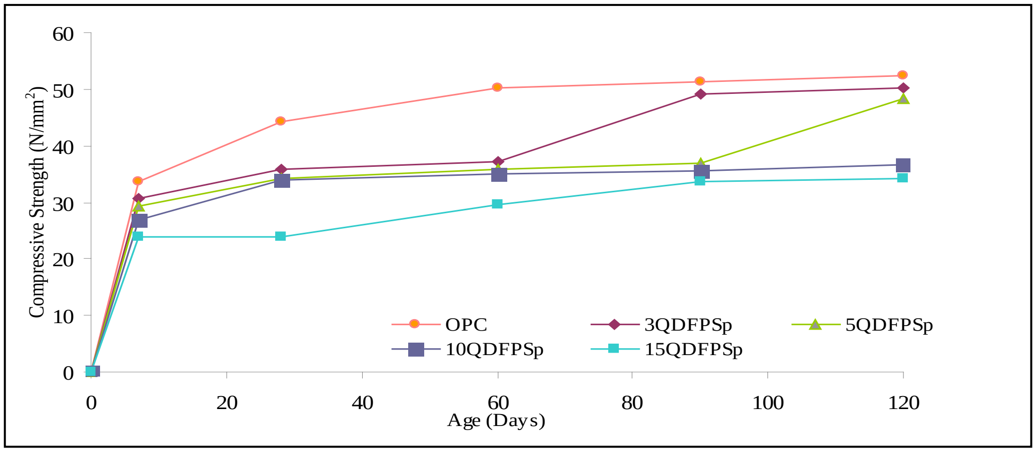

Figure 2: Compressive strength of superplasticised QDFP concrete of Grade 30

Table 4: Compressive strength of superplasticised QDFP concrete of Grade 30

Designation	w/b ratio	Compressive strength (N/mm²)				
		7 days	28 days	60 days	90 days	120 days
OPC	0.3	60	66	69	70	72
3QDFPSp		54	64	65	68	71
5QDFPSp		48	58	63	65	67
10QDFPSp		40	53	60	61	63
15QDFPSp		29	37	40	57	61
OPC	0.4	37	46	54	56	58
3QDFPSp		33	42	54	55	56
5QDFPSp		33	41	52	53	55
10QDFPSp		32	39	45	52	51
15QDFPSp		28	30	36	42	48
OPC	0.5	35	45	51	51	52
3QDFPSp		33	42	48	50	50
5QDFPSp		30	40	46	48	49
10QDFPSp		28	39	44	46	47
15QDFPSp		28	30	35	39	43

2.2 Water Permeability

Table 5 shows the coefficient of permeability of the concrete mixes taken at 28 days with and without Sp. From Table 5, it can be seen that replacement of OPC with RHA reduced the permeability of the concrete, thus resulted in reduction in the porosity and subsequently the pores of the concrete. Thus, suggested that the presence of RHA resulted in lower coefficient of permeability, thus improves the durability of concrete. This is due to pore refinement attributed to RHA fineness, or RHA occupy the empty space in the pore structure and substantially reduces the permeability of the concrete, or a transformation of large permeable pores to a small impermeable pore. Another possible reason is that with lower grade (Grade 30) and with high (0.6) w/b ratio in the mix resulted in more voids as this water occupies the space in concrete and as it evaporates it leaves voids hence, increase the absorption value. The effect is more pronounced with the addition of Sp. It is also obvious that Sp played an important role in enhancing the fluidity of RHA concrete mixes, thus produces high impermeable RHA concrete. Speare *et al.* (1999) also show that the presence of RHA resulted in lower coefficient of permeability.

Table 6 shows the coefficient of permeability of the superplasticised QDFP concrete mixes taken at 28 days. It shows that the coefficient of permeability of concrete containing QDFP increases as the percentage of replacement increases from 3% to 15%, thus adding large amount of QDFP in the mix increases the permeability of the concrete. From the table, it can be seen that the coefficient of permeability for all the superplasticized QDFP concrete are higher than the control OPC concrete for all w/b ratio. It can also be seen that the coefficient of permeability reduces as the days of curing increases. For Grade 30 concrete and with the high w/b ratio of 0.6, it recorded the highest coefficient of permeability compared to w/b ratio of 0.5, 0.4 and 0.3 respectively. This might be due to the large amount of water in the mixes, thus resulted in excess of pores after water dries up. However, as pozzolanic material the QDFP concrete can be considered as having low permeability. This is true as Neville (2002) stated that for coefficient of concrete with 10^{-11} or 10^{-12} m/sec, they are considered as having a very low permeability.

Table 5: Coefficient of permeability of RHA concrete mixes

Mixes	w/b ratio	Depth of Penetration, (mm)	Coef. of permeability (m/sec)
OPC_{30}		102.82	4.073×10^{-10}
$RHA_{30}20$	0.6	60.84	1.426×10^{-10}
$OPC_{30}Sp$		100.10	3.860×10^{-10}
$RHA_{30}30Sp$		38.03	0.572×10^{-10}

Table 6: Coefficient of permeability of superplasticised QDFP concrete mixes

Mixes	w/b ratio	Depth of Penetration (mm)	Coef. Of Permeability (m/sec)
OPC		9.76	0.0374×10^{-10}
3QDFPSp		46.21	0.7860×10^{-10}
5QDFPSp	0.6	81.55	2.5673×10^{-10}
10QDFPSp		101.56	4.0121×10^{-10}
15QDFPSp		130.76	6.5881×10^{-10}
OPC		7.51	0.0219×10^{-10}
3QDFPSp		21.02	0.1717×10^{-10}
5QDFPSp	0.5	45.83	0.8113×10^{-10}
10QDFPSp		54.14	1.1347×10^{-10}
15QDFPSp		62.34	1.5075×10^{-10}
OPC		7.34	0.0209×10^{-10}
3QDFPSp		20.07	0.1576×10^{-10}
5QDFPSp	0.4	33.28	0.4307×10^{-10}
10QDFPSp		41.53	0.6647×10^{-10}
15QDFPSp		54.48	1.1478×10^{-10}
OPC		5.91	0.0135×10^{-10}
3QDFPSp		15.74	0.0982×10^{-10}
5QDFPSp	0.3	27.05	0.2835×10^{-10}
10QDFPSp		36.09	0.5051×10^{-10}
15QDFPSp		48.84	0.9232×10^{-10}

4. CONCLUSIONS

i. When the amount of RHA and QDFP in the mix increased, it would produce dry and unworkable mixtures unless Sp is added. The inclusion of Sp in RHA and QDFP concretes while maintaining the w/b ratio increased the slump and improved the cohesiveness of the concrete.
ii. Concrete containing up to 30% RHA can attain strength of 30 N/mm^2, in fact with Sp inclusion the strength improved better compared to OPC control concrete. However, for superplasticised QDFP concrete with 0.3, 0.4, 0.5 and 0.6 w/b ratio can replaced up to 15% except for 0.6 w/b ratio only up to 10%.
iii. Replacement of OPC with RHA reduced the permeability of the concrete, thus resulted in reduction in the porosity of the concrete and subsequently the pores. Thus, suggested that the presence of RHA resulted in lower coefficient of permeability. For superplasticised QDFP concrete with high proportion of replacement and with high w/b ratio, the permeability of concrete increases compared to OPC concrete, however as a pozzolanic material the QDFP concrete can be considered as having low permeability especially at low w/b ratio.
iv. The RHA and QDFP as recyclable waste materials can be utilized as supplementary cementitious material in making concrete, thus reducing or eliminating the problem encountered in waste management.

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