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IMPROVEMENT OF THE COMPRESSIVE STRENGTH AND WATER ABSORPTION OF RECYCLED AGGREGATE CONCRETE BY USING UNCONTROLLED BURNT RICE HUSK ASH

Suraya Hani Adnan[1] and Abdulmohaimin Omar[2]
[1]Department of Civil Engineering Technology, Faculty of Engineering Technology, UTHM, Locked Bag, Parit Raja, Batu Pahat, Johor, Malaysia
[2]Faculty of Civil and Environmental Engineering, UTHM, Locked Bag, Parit Raja, Batu Pahat, Johor, Malaysia
E-Mail: suraya@uthm.edu.my

ABSTRACT

The construction industry has been using recycled aggregate to provide environmentally friendly and low cost concrete and save the natural resources. In this study, recycled aggregate (RA) has been used as replacement material for natural aggregate as a coarse aggregate in the concrete mixture. Uncontrolled Burnt Rice Husk Ash (UBRHA) has been replaced the cement in concrete mixture at different proportions for improving the properties of the recycled aggregate concrete. The performance of Recycled Aggregate Concrete (RAC) containing UBRHA, in the term of compressive strength, water absorption and ultrasonic pulse velocity has been investigated. In this study the recycled aggregate has been used in various percentages such as 0%, 50% and 100%, and UBRHA proportions from 0%, 5%, 10%, 15% and 20%. From this study, it was found that the compressive strength of RAC is decreases when RA percentage increases. However, the utilization of URBHA as cement replacement material could enhance the performance of recycled aggregate concrete. In this study, it was found that the optimum replacement for UBRHA is 5%. The compressive strength for concrete containing 5% UBRHA with 100% RA is 30.3MPa. Then, for water absorbtion, it was found that the water absorption for 5% UBRHA with 100% RA is 12.1%. Thus, it can be concluded that RAC containing URHBA could enhance the performance of RAC in term of compressive strength and water absorption. Also, from Ultrasonic Pulse Velocity testing, it could be considered that all specimens are durable concrete.

Keywords: recycled aggregate concrete, uncontrolled burnt rice husk ash, compressive strength, water absorption, ultrasonic pulse velocity.

INTRODUCTION

Concrete structure is the most common type of structure, and it keeps developing and improving day after day to meet the global and environmental requirements, this structure is basically a mixture of cement, water, sand, and coarse aggregate. However, cement considered as the most expensive and significant ingredient in concrete production. Concrete is the major structural material widely consumed in the world, after water. Most of the infrastructure and building construction in world are using concrete as construction materials. Concrete is major construction materials.

Cement is made by combining a mixture of limestone and clay in a kiln at 1450 °C. The product is an intimate mixture of compounds collectively called clinker. This clinker is finely grounded into a powder form. The raw materials used to make cement are compounds containing some of the earth's most abundant elements, such as calcium, silicon, aluminium, oxygen, and iron.

The strength of the concrete is related to the water to cement ratio and the curing conditions. A high water to cement ratio yields a low compressive strength. Sometimes other materials are incorporated into the batch of concrete to create specific characteristics. These additives are called admixtures. Admixtures are used to: alter the fluidity (plasticity) of the cement paste; increase (accelerate) or decrease (retard) the setting time; increase strength (both flexural and compression); or to extend the life of a structure. Tremendous types of admixture has been introduced till now, each one of them encounter to the concrete mix with different advantages and properties, such as air entraining ,and others, but lately a new admixtures has been introduced to the concrete industry, these admixtures called Pozzolan materials. Pozzolans are siliceous, or siliceous and aluminous materials which in itself possess little or no cementations value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementations properties (ASTM, 1595).

Pozzolanic materials are either natural or artificial such as fly ash and rice husk ash have gained acceptance as mineral admixture and or cementations replacement materials in many parts of the world. Pozzolan materials could be incorporated into the concrete mix, and it could modify its properties at different aspects. In instead, the incorporation of pozzolanic materials resulting in the reduction of bleeding it also improves workability, reduced heat of hydration, increased the resistance to aggressive chemical attack and minimizes the environment pollution. This study will address artificial pozzolan material which is rice husk ash.

Basically, rice husk is a dry thin layer covering the rice seeds, and it wasn't utilized in concrete production before. But recently, it became one of the best pozzolan, and has gained acceptance usage as mineral admixture. Rice milling generates a by-product known as husk. This surrounds the paddy grain. During milling of paddy about 78 % of weight is received as rice, broken rice and bran, the rest of 22 % of the weight of paddy is received as husk. This husk is used as fuel in the rice mills to generate steam for the parboiling process. This husk contains about 75 % organic volatile matter and the balance 25 % of the weight of this husk is converted into ash during the firing process, is known as rice husk ash (RHA). This RHA in turn contains around 85 % - 90 % amorphous silica.

Recycled aggregate concrete is a viable source of aggregate and cement adequately in a granular soil sub-cases, and the new concrete. Units to be operated in such a way and to reduce isolation and withdrawal and to avoid any contamination occur. The cumulative effect of the fresh concrete and hard conditions, affects the properties of concrete. Mixture proportions thus, the choice of units is an important process. Despite some differences in the amount of characteristics is likely to characteristics that are taken into account in the selection of the roughness of the thickness of the particle classification of shape and surface of the abrasion resistance and killed, cavities and includes the specific gravity, and absorption and surface moisture.

EXPERIMENTAL WORK

A. Materials

Ordinary Portland Cement (OPC)

The cement used for this study is an ordinary Portland cement with a brand name of PHOENIX. The cement is stored in airtight steel drum in the Material Laboratory of Universiti Tun Hussein Onn Malaysia (UTHM).

Aggregates

Fine aggregate and coarse aggregate was used for producing concrete specimens for this study. For fine aggregate, the mining sand with maximum size of 5 mm was used. The sand was sieved prior to casting concrete.

For this study, two types of coarse aggregate were used namely the Natural Aggregate (NA) and Recycled Aggregate (RA). For NA, the crushed granite with maximum size of 20 mm was used. For RA, it was prepared by crushing the waste cubes dumped at the outside of Material Laboratory of Universiti Tun Hussein Onn Malaysia (UTHM). The waste cubes were randomly collected without considering the age of the cubes. It was broken into smaller pieces by using hammer and then crushed in jaw crusher for the size between 5 mm to 20 mm. The specific gravity for NA and RA are tabulated in Table-1.

Table-1. The specific gravity for natural aggregate and recycled aggregate.

Specific gravity	NA	RA
SSD	2.58	2.19
Oven Dried	2.48	2.11
Apparent	2.77	2.3

Uncontrolled burnt rice husk ash

Rice husk is one of the main agricultural residues obtained from the outer covering of rice grains during the milling process; it constitutes 20% of the 500 million tons of paddy produced in the world. The rice husk ash (RHA) had no useful application and had usually been dumped into water streams and caused pollution and contamination of springs until it was known to be a useful mineral admixture for concrete. In this experimental work uncontrolled burnt rice husk ash was used. Figure-1 shows the uncontrolled burnt RHA and Table-2 tabulates the chemical composition of uncontrolled burnt RHA.

Figure-1. Uncontrolled burnt RHA.

Table-2. Chemical Composition of UBRHA.

Chemical composition	Percentage (%)
Orig-g	8
Added-g	2
SiO_2	75.20%
K_2O	2.71%
P_2O_5	1.53%
C	1.00%
CaO	0.64%
MgO	0.60%

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B. Concrete mixtures

Fifteen (15) concrete mixtures were prepared and Table 3 illustrates the mix proportions for each series of concrete mix. Target strength of the concrete at 28 days is 30 MPa, its water-cement ratio is 0.5 and its slump value is designed for 60 mm-180 mm. The proportion of uncontrolled burnt RHA replacement is 0 %, 5 %, 10 %, 15 % and 20% by weight of cement. For each replacement level of uncontrolled burnt RHA, different percentages replacement of RA as coarse aggregate to NA was employed. The replacement percentages are 0 %, 50 % and 100 %. For each concrete mix, three cubes were prepared where an average reading was taken as data for interpretation. The concrete cubes had been cured in water until testing time.

Table-3. Mix proportions for concrete mix.

Concrete series	**RA** (%)	**UBRHA** (%)	**Cement** (kg/m^3)	**Water** (kg/m^3)	**CA** (kg/m^3)		**FA** (kg/m^3)
					NA (kg/m^3)	**RA** (kg/m^3)	
Control concrete	0	0	410	225	1040	0	694
RA50	50	0	410	225	520	520	694
RA100	100	0	410	225	0	1040	694
UBRHA 5	0	5	389.5	225	1040	0	694
UBRHA 5-RA50	50	5	389.5	225	520	520	694
UBRHA 5-RA100	100	5	389.5	225	0	1040	694
UBRHA 10	0	10	369	225	1040	0	694
UBRHA 10-RA50	50	10	369	225	520	520	694
UBRHA 10-RA100	100	10	369	225	0	1040	694
UBRHA 15	0	15	348.5	225	1040	0	694
UBRHA 15-RA50	50	15	348.5	225	520	520	694
UBRHA 15-RA100	100	15	348.5	225	0	1040	694
UBRHA 20	0	20	328	225	1040	0	694
UBRHA 20-RA50	50	20	328	225	520	520	694
UBRHA 20-RA100	100	20	328	225	0	1040	694

C. Testing

There are three types of testing that has been conducted which are as followed:

(i) Compressive strength

The compressive strength of the concrete cubes was determined according to BS EN 12390-3 (2002). Cube sized 100 mm x 100 mm x 100 mm was used as specimen testing. The cube specimens were tested at 7 and 28 days.

(ii) Water absorption

Water absorption test is a method of determining the rate of absorption of water by concrete cube by measuring the increase in the mass of the specimen resulting from absorption of water. The test procedure has been done by weighing the specimen and record the weight. Then the sample was immersed it in water for 7 and 28 days, and weighing it again. The increase in weight as a percentage of the original weight is expressed as its absorption (in percent). The average absorption of the test samples shall not be greater than 5% (BS 1881: Part 122).

(iii) Ultrasonic pulse velocity

Ultrasonic testing is one of the more common non-destructive testing methods performed on cubes. This testing utilises high frequency mechanical energy ie sound waves, to conduct examinations and measurements on a test area. Typically the UT inspection system consists of a transducer, pulser/receiver, and display unit. A pulser/receiver is an electronic device that can produce high voltage electrical pulses to the transducer. When driven by the pulser, the transducer generates high frequency ultrasonic sound energy into the cube in the form of sound waves. When there are discontinuities such as inclusions, porosity, cracks, etc. in the sound path, part

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of the mechanical energy will be reflected from the discontinuities surface. The reflected sound waves signal received by the transducer is then transformed back into an electrical signal and its intensity is shown on the display unit.

The sound waves travel time can be directly related to the distance that the signal has travelled. From the signal, information about reflector location, size, orientation and other features can be determined.

This test has been done after 7 and 28 days from casting to determine the speed of ultrasound for the hardened concrete, thus to determine the quality of concrete cube (ASTM C597-9).

RESULTS AND DISCUSSIONS

A. Compressive strength result

The results of compressive strength of concrete cubes are presented in Table-4. From these results it can be shown that UBRHA 5 obtained the highest compressive strength compared to other series of concrete at 28 days. This result also indicated that concrete containing 5% of UBRHA obtained higher in compressive strength than that of 10%, 15% and 20% replacement of UBRHA in cement. Thus, it can be stated that 5% of UBRHA is the optimum cement replacement percentage.

From this table also, it can be seen that concrete containing RA obtained lower in compressive strength compared to concrete without RA. The strength is decreased as the proportion of replacement for RA is increases. However, when 5% of UBRHA is used as cement replacement material in concrete containing RA, the result of compressive strength is higher compared to concrete containing RA without UBRHA.

UBRHA contributes into pozzolanic reaction with calcium hydroxide, $Ca(OH)_2$ from the primary cement hydration process and forms additional calcium silicate hydrate, C-S-H gel. This reaction form the dense calcium silicate hydrate, C-S-H gel which has an ability to improve the Interfacial Transition Zone (ITZ) and densifying the pore structure inside the concrete that lead into enhancement of compressive strength in concrete (Toutanji et al., 2004). These results are also is parallel to Gastaldini *et al.* (2014), as his experimental results obtained that with the addition of RHA 5% the compressive strength increases, however with the addition of RHA more than 5% the strength start to decrease. This behavior can be explained by the availability of less water for cement hydration because the rice hull ash absorbs some water during mixing (Gastaldini *et al.*, 2014).

Table-4. Compressive strength results for 7 and 28 days.

Concrete series	7 days	28 days
Control concrete	23.2	32.3
RA50	23	30.8
RA100	21	30
UBRHA 5	24.2	37
UBRHA 5-RA50	23.7	34.5
UBRHA 5-RA100	21.2	30.3
UBRHA 10	22.7	35.7
UBRHA 10-RA50	22.6	30.1
UBRHA 10-RA100	18	27.6
UBRHA 15	19.4	29.7
UBRHA 15-RA50	17.9	27.6
UBRHA 15-RA100	16	28
UBRHA 20	17.4	27.2
UBRHA 20-RA50	16.7	28.5
UBRHA 20-RA100	15.3	27.3

B. Water absorption result

The results for water absorption for various concrete series were illustrated as in Figure-2. It can be seen that concrete UBRHA 20-RA 100 at 28 days obtained highest in water absorption percentage compared to other concrete series. As the RA content is increases, the water absorption also increases. These results are due to the attached mortar to aggregate (Topcu, 1997 and Xiao *et al.* 2005).

Also, as UBRHA content is increases, the water absorption also increases. Thus, it can be indicated that the replacement of UBRHA in concrete does not lower the water absorption in concrete.

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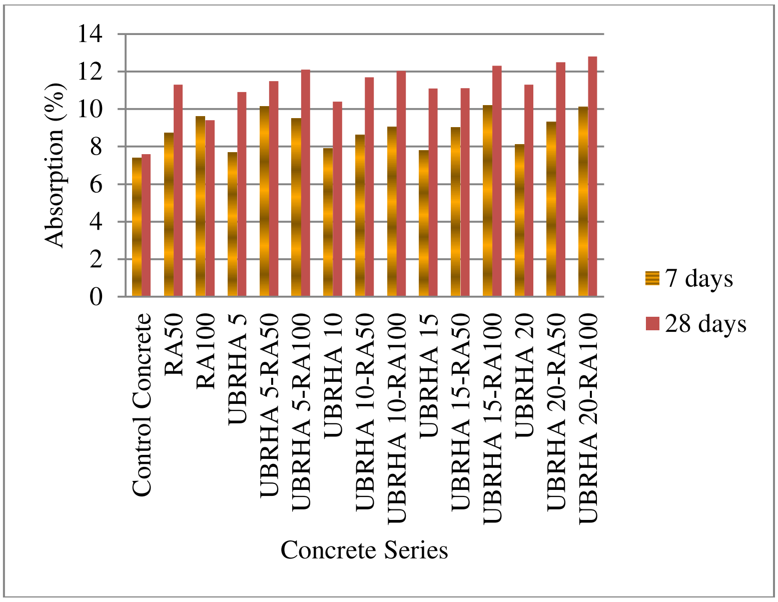

Figure-2. Water absorption results for 7 and 28 days.

C. Ultrasonic pulse velocity result

This test is conducted for assess the uniformity and relative quality of concrete and to identify the presence of voids and cracks. Normally, the high pulse velocity reading in concrete is to indicate the good quality of concrete (Chao-Lung *et al.*, 2011). Malhotra (1976) has proposed that concrete has good durability when its velocity pulse value is in the range of 3660-4575 m/s.

Table-5 tabulated the results for ultrasonic pulse velocity for concrete series at 7 and 28 days age of curing. From this table it was recognized that an increase in UBRHA tends to increase the velocity until at 15% of UBRHA.

Also, from this table, it can be identified that concrete with RA obtained lower in velocity compared to concrete without RA. Thus, it can be stated that concrete with RA was less durable compared to concrete with NA. However, at 28 days, UPV of all specimens is higher than that of 3660 m/s, therefore the specimens could be considered as durable concrete (Malhotra, 1976).

Table-5. Ultrasonic pulse velocity results for 7 and 28 days.

Concrete series	7 days	28 days
Control concrete	3678	4205
RA50	4033.6	4313.3
RA100	3668.3	3993.3
UBRHA 5	3995	4305
UBRHA 5-RA50	3838.3	4170
UBRHA 5-RA100	3753	3915
UBRHA 10	3863.3	4323.3
UBRHA 10-RA50	3915	4113.3
UBRHA 10-RA100	3821.6	3871.7
UBRHA 15	3863.3	4495
UBRHA 15-RA50	3681.6	3920
UBRHA 15-RA100	3825	3870
UBRHA 20	3925	4281.6
UBRHA 20-RA50	3496.6	4013.3
UBRHA 20-RA100	3813.3	3768.3

CONCLUSIONS

This study illustrates the performance of Recycled Aggregate Concrete (RAC) containing Uncontrolled Burning Rice Husk Ash (UBRHA).

It can be concluded that with the presence of 5 % UBRHA as a partial cement replacement in the concrete containing RA, the result of compressive strength is higher compared to concrete containing RA without UBRHA.

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Concrete containing RA obtained higher in water absorption compared to concrete without RA due to adhered mortar. From ultrasonic pulse velocity it can be concluded that concrete containing UBRHA performed as more durable concrete than that of concrete without UBRHA.

It can be recommended that the further study can be conducted by adding other pozzolans materials such as fly ash, silica fume and controlled burning RHA in RAC.

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REFERENCES

Gastaldini, A.L.G, da Silva, M.P.., Zamberlan, F.B., Neto Mostardeiro. 2014. Total shrinkage, chloride penetration, and compressive strength of concretes that contain clear-colored rice husk ash. Construction and Building Materials. 54, pp. 369-377.

Chao-Lung, H., Anh-Tuan, B.L. and Chun-Tsun, C. 2011. Effect of rice husk ash on the strength and durability characteristics of concrete. Construction and Building Materials. 25, pp. 3768-3772.

Malhotra V.M. 1976. Testing hardened concrete: nondestructive methods. American Concrete Institute Monograph Series.

Toutanji, H., Delatte, N., Aggoun, S., Duval, R. and Danson, A. 2004. Effect of Supplementary Cementitious Materials on the Compressive Strength and Durability of Short-Term Cured Concrete. Cement and Concrete Research. 34(2), pp. 311-319.

Topcu, I.B. 1997. Physical and Mechanical Properties of Concrete Produced With Waste Concrete. Cement and Concrete Research. 27(12), pp. 1817-1823.

Xiao, J., Li,J. and Zhang, Ch. 2005. Mechanical Properties of Recycled Aggregate Concrete under Uniaxial Loading. Cement and Concrete Research. 35(6), pp. 1187-1194.

ASTM C597-9. Standard test method for pulse velocity through concrete. ASTM standards for American Society for Testing and Materials; 1997.

British Standard Institution. 1983. Method for determination of water absorption BS 1881: Part 122.

BS EN 12390-3. 2002. Testing hardened concrete. Compressive strength of test specimens. British Standards Institution, London, U.K.