A New Generation Lightweight Concrete by using Rice Husk Ash as a Light Weight Aggregate

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Abstract

Concrete made with natural aggregate originating from hard rock has a density within a narrow range because the specific gravity of most rocks varies little.

Although the volumetric content of the aggregate in the mix affects the density of the concrete, this, too, is not a major factor. Thus, in practice, the density of normal weight concrete lies within the range of 2200 to 2600 kg/m^3.

The use of sintered rice husk ash aggregate in concrete as a partial replacement of granite aggregate has been examined. The Concrete so produced is light in nature (up to 12% reduction in unit weight) and the development of such concrete with sintered aggregate minimizes the consumption of granite rock, resulting in protection of the natural environment due to using a large amount of rice husk ash.

It is observed from the present investigation that, with partial (20%, 30% and 40% by weight) replacement of natural granite aggregate by sintered rice husk ash aggregate; the important physical properties of concrete such as compressive strength and dynamic modulus of elasticity are retained. On other hand the water absorption values within the permissible value for durability considerations.

الخلاصة

خرسانة الركام الخفيف الوزن الذي يتم الحصول عليه من الصخور الصلبة تكون كثافاتها متقاربة وذلك لان الوزن النوعي لاغلب الصخور لايختلف كثيرا عن بعضها البعض .

بالرغم من ان المحتوى الحجمي من الركام في الخلطة يؤثر على كثافة الخرسانه ولكن هذا ليس العامل الرئيسي لانه عمليا كثافة الخرسانة الاعتيادية الوزن تقع بين 2200 Kg/m^3 – 2600 Kg/m^3 .

ان استخدام منصهر رماد قشور الرز كركام خفيف الوزن كاستبدال جزئي من الركام المستحصل من صخور الكرانايت تم دراسته ,وبذلك تم تقديم خرسانة خفيفة الوزن (تقليل وحدة الوزن بحدود 12%) ,وان هذا النوع المطور من الخرسانة الخفيفة الوزن تقلل من الاعتماد على استحدام صخور الكرانايت .وبذلك يمكن حماية البيئه والمحيط نتيجة لاستخدام كميات كبيره من رماد قشور الرز.

من خلال هذه الدراسة الجديده تبين ان استبدال جزئي (20%, 30%, 40%) من الركام الاعتيادي بركام منصهر قشور الرز ادى الى تحسين الخواص الفيزياويه المهمه للخرسانة المصنوعة من هذا النوع من الركام مثل مقاومة الانضغاط ومعامل المرونه الديناميكي .ومن ناحيه اخرى فان قيم امتصاص الخرسانة للماء تقع ضمن حدود الديمومه المسموح بها.

Introduction

Rice husk ash is the shells produced by dehusking process of paddy rice. Each ton of paddy rice produces about 200kg of husks, which on combustion yield approximately 40 kg of ash (Yousif, 19788). Rice husk ash was prepared by burning the rice husk in a controlled temperature furnace in order to get a pozzolanic material with high content of amorphous silica and minimum amount of unburned carbon. Generally the optimum burning condition were 500°C for 2 hours(Al-Kalaf & Yousif, 1984).

Below this temperature, the ignition was not fully completed and the considerable amount of the unburnt carbon was expected to have an adverse effect upon the pozzolanic activity of the resulting ash.

So as granite aggregate is a vital element as a light weight aggregate in concrete and its extensive use results in destruction of hills causing geological and environmental imbalance(Sharipov *et al.,* 1982). The environmental impacts of crushed stone aggregate extraction are a source of increasing concern in many parts of the world. The impacts include loss of forests, noise, dust, blasting vibrations and pollution hazards. Unplanned exploitation of rocks may lead to landslides of weak and steep hill slopes. The concern about the depletion of natural sources and the effect on environment, has particularly focused attention on possibility of use of synthetically produced (from waste materials) aggregates as an alternative to naturally occurring materials. Rice husk ash was used for the preparation of sintered aggregates to be used in concrete. These aggregate were prepared by sintering((Sharipov *et al.*, 1982; Juhasz & Vamos, 1981). the mixture of rice husk ash and semi plastic clay at definite proportion at a sintering temperature of 1200 C to 1300 C.

The aggregates so prepared were rice husk ash based light weight aggregates. The mix design of concrete was done according to British Standard guidelines. The quantities of rice husk ash aggregate for 20%, 30% and 40% replacement by weight were estimated; and four mixes, so prepared were examined for their suitability in structural use. The rice husk ash aggregate was light in nature and its use in concrete reduced the self weight of the structure, besides attaining better thermal insulation performance and met within the requirements durability specification.

Materials

Cement:

Ordinary Portland cement was used in this work, its 28 days compressive strength was found to be 46.5 N/mm^2. It was stored in air tight plastic containers to avoid exposure to atmospheric conditions. Test results indicated that the adopted cement conformed to the Iraqi specification No.5/1984.

Fine Aggregate:

Natural sand of 4.75mm maximum size was used as fine aggregate. The grading of fine aggregate is shown in Table 1 .Results indicate that the fine aggregate grading is within the requirements of the B.S. 882/1992 specification. Table 2 shows the specific gravity, sulfate content and absorption of fine aggregate, which are within the requirements of the Iraqi specification No.45/1984(B.S. 882/1992)

Rice Husk Ash (RHA):

Rice Husk Ash (RHA) was prepared by burning the rice husk in a controlled temperature furnace in order to get a pozzolanic material with high content of amorphous silica and minimum amount of unburned carbon. Generally the optimum burning condition were 500°C for 2 hours.

Below this temperature, the ignition was not fully completed and the considerable amount of the unburnt carbon was expected to have an adverse effect upon the pozzolanic activity of the resulting ash.

The x-ray diffraction analysis fig.(1) indicated that the ash contains mainly amorphous silica with very small amount of unburnt carbon. This amorphous silica, when converted into very fine particles by grinding makes the ash as a highly active pozzolan(Cook & Suwanitaya, 1983). The grinding of ash was effected by a grinding mill for a period of 20 hours for each 0.5 kg of the ash. The fineness was determined by Blaine air permeability method in accordance with ASTM C204-84(ASTM, 1989).

A specific surface area of 28000 cm^2/gm was attained. The RHA used in this work conforms to the chemical and physical requirements of ASTM C 618(1989) class N pozzolan, Tables 3 and 4 respectively.

Coarse Aggregate

Natural aggregate:

Crushed aggregate of 10mm maximum size was used. Table 5 shows the grading of the coarse aggregate which conforms to the Iraqi specification No. 45/1984. The specific gravity, sulfate content and absorption of coarse aggregate are illustrated in Table, 2.

Sintered rice husk ash aggregate:

In the present investigation concrete was prepared with the combined coarse aggregates (natural granite aggregate) and sintered rice husk ash aggregates, produced by sintering the mixture of 75%-82% rice husk ash and 8%-20% clay at 1200 to 1300 C.

During the sintering process the ash particles have interacted in the pellet (figure 2) to form ceramic bonding resulting in hard mass. Most of the quartz particles have transformed pellet also contains iron in metallic form to crystobolite form and alumino-silicate in form of mullite. The chemical composition of the sintered rice husk ash aggregate is shown in Table 6. The proportions of these aggregates are, normal aggregate: sintered aggregate: 80:20, 70:30 and 60:40.

Concrete Mix

Proportioning of Ingredients:

Proportioning of ingredients of concrete has been done according to British Standard guidelines. The quantities of materials for the mixes with partial replacement of natural aggregate by 20%, 30%,40% by weight of sintered rice husk ash aggregate was done with special attention to the water absorption values of sintered aggregates. Four mixes were prepared:

Mix 1: concrete with natural granite aggregate, without sintered rice husk aggregate.

Mix 2: concrete with 80% natural granite aggregate and 20% sintered rice husk ash aggregate.

Mix 3: concrete with 70% natural granite aggregates and 30% sintered rice husk ash aggregate.

Mix 4: concrete with 60% natural granite aggregate and 40% sintered rice husk ash aggregate.

These quantities are shown in Table 7.

Casting, Curing and Test of Specimens:

For each mix, cited in Table 7, good number of 150 mm side cube and 100 mm×100 mm x400mm prisms test specimens were cast. Immediately after casting, these specimens were covered with wet burlap at the casting site for 24 h. Following this the test specimens were transferred to the curing tank. The specimens were tested for 7-days and 28-days strengths. The compressive strength test was determined according to B.S-1881; part 116(1989). 100mm cubes were tested, using 2000 KN capacity hydraulic universal testing machine (ELE-Digital Elect 2000), at a loading rate of 15 MPa per minute.

The average of three cubes was adopted at each testing age 7 and 28 days.

Dynamic modulus of elasticity test was performed according to B.S.1881; part 5(B.S.1881, Part 5, 1989). The specimens were clamped at its midpoint with an electromagnetic exciter unit placed against one end face of the specimen and a pick up placed against the other. Petroleum jelly was used to provide a slight adhesion between the system and the specimen.

The test results are the average of three specimens. The dynamic modulus of elasticity is computed from the formula:

$$\mathbf{Ed = 4n^2 \ell^2 \rho \times 10^{-12}}$$

Where:

Ed = dynamic modulus of elasticity, (N/mm^2)

n=fundamental longitudinal frequency, (Hz)

ℓ =length of specimen, (mm)

ρ=density of specimen, (kg/m^3)

Prisms with 100x100x400mm were used.

To know the surface ingress of moisture, water absorption test was conducted . The water absorption values as recorded in Table 9 were well within the permissible values for durability considerations.

Results and Discussion

The compressive strength result of concrete with sintered rice husk ash aggregate is slightly less than that of normal concrete with granite aggregate. The difference is less than 1%. These values are, however, well above the target strength of the grades of concrete.. Sofar as the value of modulus of elasticity is similar to that with natural granite aggregate. The results conform to the specified values as per BIS 456-2000. The use of sintered rice husk ash aggregate in concrete reduces the self weight of the structures, test results are shown in Table 9. The water absorption values as recorded in Table 8 were well within the permissible values for durability considerations.

Conclusion

In addition to the lightweight characteristics, sintered rice husk ash aggregate concrete possesses strength and modulus of elasticity similar to concrete with natural granite aggregate. The values of water absorption are in the range of durability requirements. Hence, this investigation is of valued industrial application.

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Table 1 Grading of fine aggregate compared with the requirement of B.S. 882: 1992

Sieve size (mm)	Cumulative Passing%	Limits of B.S 882/1992 specification overall grading
4.75	100	89-100
2.36	92.1	60-100
1.18	82.0	30-100
0.600	64.8	15-100
0.300	21.0	5-70
0.150	7.15	0-15
Fineness modulus= 2.32		

Table 2 Physical properties of aggregates.

Physical properties	Granite agg.	Sintered rice husk ash agg.	Fine agg.
Bulk unit weight Kg/m	1580	730	1610
Specific gravity	2.63		2.60
Water absorption,%	0.63	18.00	0.75
Agg. Crushing value,%	16.8	36.8	--
Sulfate content	0.06		0.08

Max. Size 10 mm

Figure 2 Photograph showing different size fractions and smooth surface of sintered pellets made from rice husk ash

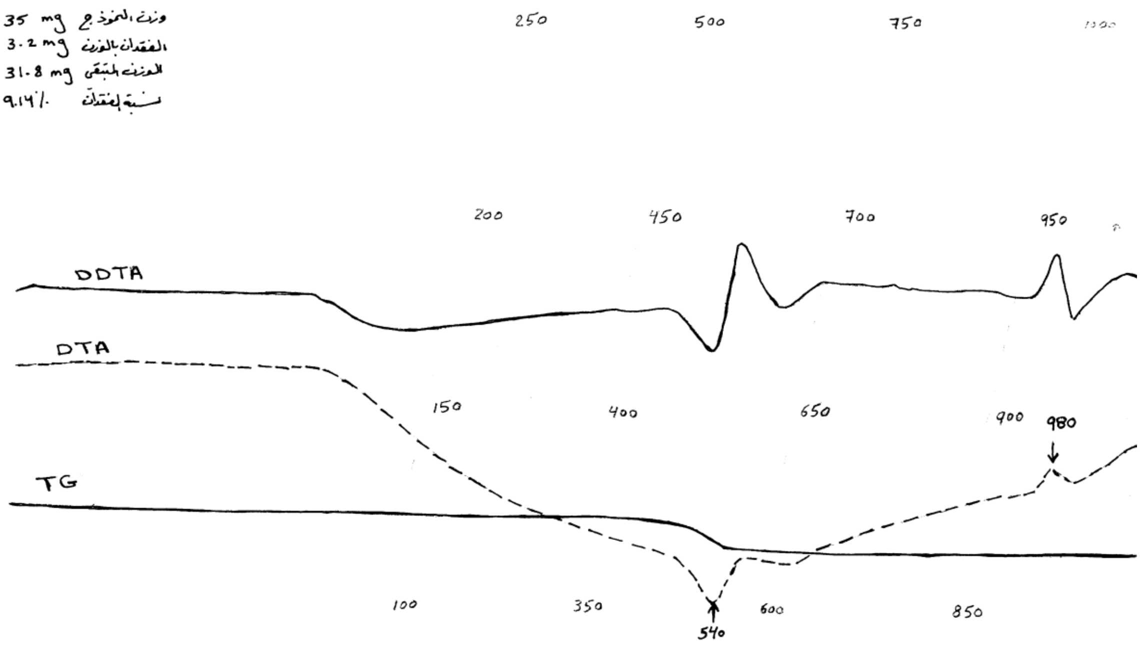

Fig. 1 DTA curve for Rice Husk Ash

Table 3 Chemical requirement of pozzolan ASTM C_{618}

Oxide composition	Pozzolan class N	RHA
SiO_2 + Al_2O_3+Fe_2O_3, min. percent	70	86.02
SO_3, max. percent	4	0.1
Loss on ignition	10	2.51

Table 4 physical requirements of pozzolan ASTM 618

Physical properties	Pozzolan Class N	RHA
Surface area (Blaine method) min. cm^2/gm	-	28000
Pozzolanic activity index with portland cement at 28 days, min. percent of control	75	142.0
Flow table, max. percent	115	110
Specific gravity	-	2.14

Table 5 Grading of coarse aggregate

Sieve Size (mm)	Cumulative Passing%	Limits of Iraqi specification No.451984
14	100	100
10	90	85-100
5	15	0-25
2.36	2.2	0-5

Table 6 Chemical composition of rice husk ash and rice husk ash_aggregate, % weight

Oxide composition	Rice husk ash	Sintered rice husk ash
SiO_2	85.61	87.28
Al_2O_3	0.10	1.4
Fe_2O_3	0.31	0.19
CaO	1.31	1.35
MgO	1.70	1.6
SO_3	0.10	-
Na_2O	1.50	0.87
K_2O	3.77	1.46
L.O.I.	2.51	1.68

Table 7 Composition of one meter cube of concrete

Set of concrete	Mix No.	Quantity of cement	w/c ratio	Quantity Of sand	Granite Agg. Kg	Rice husk ash agg.Kg
Set one	Mix 1	385	205.00	558	510.8	-
	Mix 2	385	225.55	558	408.6	47.9
	Mix 3	385	235.14	558	357.5	71.9
	Mix 4	385	244.75	558	306.4	95.5
Set two	Mix1	421	205.00	548	502.0	-
	Mix 2	421	224.21	548	401.6	47.1
	Mix 3	421	233.64	548	351.4	70.2
	Mix 4	421	243.09	548	301.2	94.3

Table 8 Mix proportions by weight (cement : sand : coarse aggregate)

Set of Concrete	Mix No.	Mix proportions by weight			Unite weight Kg/m^3
		Cement	Sand	Coarse agg.	
Set one	Mix 1	1	1.449	3.317	2317
	Mix 2	1	1.449	2.965	2174
	Mix 3	1	1.449	2.789	2105
	Mix 4	1	1.449	2.613	2040
Set two	Mix1	1	1.307	2.981	2326
	Mix 2	1	1.307	2.66664	2187
	Mix 3	1	1.307	2.505	2115
	Mix 4	1	1.307	2.348	2052

Table (9) surface absorption ((ml/m^2/sec)*10^{-2}) for concrete durability

Concrete set	Mix	Initial surface absorption(10 min) ml/m^2/s	limits	Finial surface absorption(2 h) ml/m^2/s	limits
Set one	Mix 1	0.235	0.5	0.052	0.15
	Mix 2	0.238		0.059	
	Mix 3	0.247		0.066	
	Mix 4	0.256		0.73	
Set two	Mix 1	0.215		0.049	
	Mix 2	0.219		0.053	
	Mix 3	0.226		0.060	
	Mix 4	0.237		0.064	

Table (10) Compressive strength and young's modulus of elasticity of concrete mixes

Set of concrete	Mix	7-days compressive strength, N/mm^2	28-days compressive strength ,N/mm^2	young's modulus(secant modulus)of elasticity, N/mm^2
Set 1	Mix 1	21.55	30.44	29.60
	Mix 2	21.03	30.07	29.55
	Mix 3	21.11	29.85	28.80
	Mix 4	20.18	29.70	28.68
Set 2	Mix1	24.3	35.4	32.52
	Mix 2	24.15	35.18	31.64
	Mix 3	24.08	35.18	31.45
	Mix 4	23.93	35.03	31.20