SOME MECHANICAL PROPERTIES OF PUMICE LIGHTWEIGHT AGGREGATE CONCRETE INCORPORATING RISE HUSK ASH [+]

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Abstract:

At the present time, a considerable amount of works has been undertaken to investigate the mechanical properties of lightweight aggregate concrete. It is thus aimed in this work to investigate the possibility of using local pumice rocks (available in the north of Iraq) for the production of structural lightweight aggregate concrete.

In this investigation, two types of lightweight concrete (LWC) were produced using pumice stone as a coarse aggregate with natural sand and also with fine pumice aggregate, the effect of incorporating high range water reducing admixture (HRWRA) synergistically with 8% rice husk ash (RHA), as a partial replacement by weight of cement, on the mechanical properties of LWAC were investigated.

Hardened unit weight, compressive strength and splitting tensile strength were investigated for all types of lightweight aggregate concrete and at various ages of curing.

The inclusion of 8% RHA, as a partial replacement by weight of cement, with the optimum dosage of HRWRA (6% by weight of cement) showed considerable increase in mechanical properties at all ages of curing compared with the reference concrete.Key words : lightweight concrete , pumice , admixture , lightweight aggregate concrete .

المستخلص:

في الوقت الحاضر ، اجريت بحوث كثيرة للتحري عن الخواص الميكانيكية للخرسانة ذات الركام الخفيف الوزن . ان الهدف من هذا البحث هو دراسة امكانية انتاج خرسانة انشائية خفيفة الوزن بأستخدام حجر الخفاف المتوفر في شمال العراق.

تضمن هذا البحث انتاج نوعين من الخرسانة الخفيفة الوزن باستعمال حجر الخفاف كركام خشن مع الرمل الطبيعي وايضاً مع الركام الناعم الناتج من سحق حجر الخفاف واستخدامه بنفس تدرج الرمل الطبيعي، ودراسة التأثير المشترك للمضاف المقلل للماء بدرجة متفوقة مع ٨% من رماد قشور الرز كاحلال جزئي عن وزن السمنت في الخليط على الخواص الميكانيكة للخرسانة خفيفة الوزن .

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أجريت فحوص وحدة الوزن للخرسانة المتصلبة وفحوصات مقاومة الانضغاط ومقاومة شد الانفلاق خلال فترات مختلفة من معالجة الخرسانة.

وبينت النتائج ان الخرسانة الحاوية على رماد قشور الرز بنسبة ٨% من وزن السمنت مع النسبة المثلى مـــن المضاف المقلل للماء بدرجة متفوقة (٦%) من وزن السمنت ابدت زيادة في قيم النتائج لجميع الخواص الميكانيكية مقارنة مع الخلطة المرجعية .

Introduction:

Lightweight aggregate is used in construction industry for a variety of applications such as lightweight fill behind retaining walls and over utility pipelines in excavated trenches, masonry block, structural concrete , and pavement layout .Structural lightweight aggregates are produced in manufacturing plants from raw materials, including suitable shales, clays, slates, fly ashes , or blast-furnace slags. Naturally occurring lightweight aggregates are mined from volcanic deposits that include pumice and scoria[1].

The highly porous microstructure of lightweight aggregate (LWA) gives it low density and better insulation and that makes the concrete made with LWA exhibit lower thermal conductivity than that of normal weight concrete (NWC). Therefore, lightweight concrete (LWC) provides more effective fire protection than dense aggregate concrete as it is less liable to spalling and has a higher thermal insulation[2].

Pumice is a very light, porous igneous rock that is formed during volcanic eruptions. It is made up of very tiny crystals, since they cool so quickly above ground. The texture of pumice is rough and has many hollows and cavities[3].

The use of highly active pozzolanic material such as rice husk ash (RHA) in conjunction with high range water reducing admixture (HRWRA) may produce high performance concrete (HPC) with special features in both fresh and hardened states. In this study an attempt is made to investigate the using of the local pumice aggregate with mineral admixture like rice husk ash, beside a combination use of RHA with the optimum dosage of superplasticizer on mechanical properties of high performance LWAC.

Experimental Work:

1-Materials

A-Cement

Ordinary portland cement manufactured by Adana cement factory (Turkish cement) was used in all mixes throughout this investigation. It was stored in large air-tight plastic containers to avoid exposure to atmospheric conditions and to maintain uniform quality. The percentage oxide composition and the physical properties of the cement are shown in Table(1). The results conformed to the Iraqi specification No.5/1984[4].

Table (1): Physical properties of cement*

Physical properties	**Test results**	**Limitation of Iraqi specification No. 5/1984**
Specific surface area, * (Blaine method), m^2/kg	261	≥ 230
soundness (Autoclave method)* %	0.26	≤ 0.8
Setting time, vicat's method		
Initial setting, hrs	2.05	≥ 1
Final setting, hrs	3.15	≤ 10
Compressive strength of cement		
3- days, N/mm^2	23	≥ 15
7- days, N/mm^2	29	≥23

*** Chemical and physical tests were conducted by Dijlah general company for the studies and designs of irrigation projects**

B- Fine Aggregate

Al-Kanhash river sand of 4.75mm maximum size was used throughout this work. The grading of fine aggregate is shown in Table (2) and Fig.(1). Results indicated that the fine aggregate grading was within the requirements of BS. 882 : 1992[5]

Table (2): Grading of fine aggregate and requirements

Sieve size (mm)	**acumulative % passing**	**acumulative % passing (B.S 882 : 1992)**
4.75	100	89-100
2.36	84.79	60-100
1.18	73.89	30-100
0.60	62.51	15-100
0.30	38.74	5-70
0.15	13.51	0-15
Fineness modulus = 2.27		

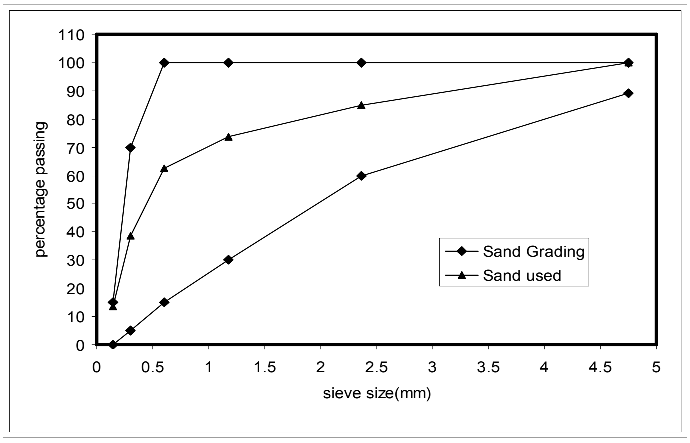

Fig. (1): Grading curve for fine aggregate according to BS limits

C- Coarse Aggregate

Natural local LWA of pumice stone was used as fine and coarse aggregate. The quarry of this stone occurs in north of Iraq in AL- Sulaymania governorate. Pumice stone has a dark color and is characterized by high permeability, low density, porous form of vitrified volcanic rock and high silicon oxide (SiO_2) concrete. The pumice stones were crushed into smaller size by using crushing and screening machine. Table (3) and Fig.(2) shows the grading of this aggregate and the limits specified by ASTM C330-87[6].

The fine material (passing sieve 4.75mm) were used as fine pumice aggregate after grading into conform with the grading of natural sand . The fine pumice aggregate was used as a total replacement by volume of the natural sand . Several physical and chemical properties of fine and coarse pumice aggregate were determined .

Table (3): Selected grading of coarse lightweight aggregate

Sieve size, mm	%passing ASTM C330	Select % passing	% Retained
12.5	100	100	0
9.5	80-100	95	5
4.75	5-40	10	85
2.36	0-20	0	10
1.18	0-10	0	--

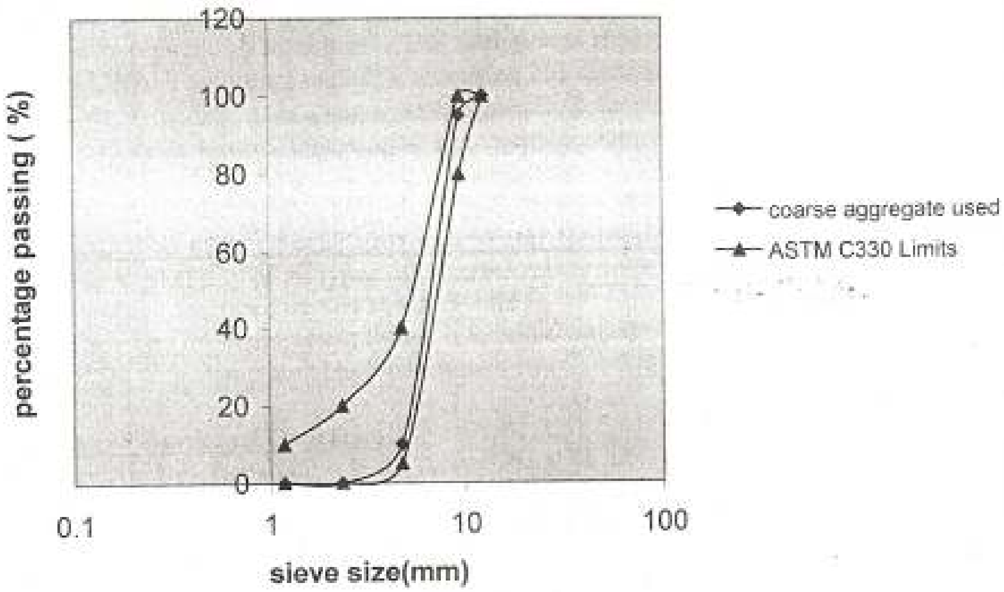

Fig. (2): Grading curve for coarse pumice aggregate

D- Water

Ordinary tap water was used in this research for mixing and curing all concrete specimens.

E- Superplasticizer : High Range Water Reducing Admixture (HRWRA)

A superplasticizer type sulphonated melamine formaldehyde condensate, which is known commercially as Melment L10, was used throughout this study as a high range water-reducing admixture. Supperplasticizer was used to produce high strength concrete by reducing the w/c ratio while maintaining equal workability, 50 ±5mm slump, to reference mix.

F- Rice husk ash (RHA)

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 was 500 C^o for 2 hours[7]. A grinding mill effected the grinding of ash for a period of 15 hours for each 0.5 kg of the ash.

The fineness was determined by Blaine air permeability method in accordance with ASTM C204-84[8].

2. Pozzolanic Activity Index of Rice Husk Ash (RHA):

The pozzolanic activity index (P.A.I) with Portland cement was determined according to ASTM C311-87a [9], as follows :

P.A.I = (A/B)×100 ……….(1)

Where :
A = Average compressive strength of test mix cubes.
B = Average compressive strength of reference mix cubes.

3. Concrete Mixes:

The reference concrete mixture was designed to give a 28-day characteristic compressive strength of 28 N/mm^2 . The design was made to conform to the requirement of structural LWAC, according to AC1 Committee 213 classification[10].

Four types of mixes were investigated. Reference concrete, 8% RHA-HRWRA concrete for both sanded–lightweight aggregate concrete and ALL-Lightweight aggregate concrete.

4. Determination of the Workability and Water Reduction of the Concrete:

The workability of all types of concrete mixes were measured by slump test according to the procedure described in ASTM C143-89[11].

The w/c or water/cementitious materials ratios were adjusted to maintain equal workabilities with slump equal to 50 ±5mm.

5. Testing of Hardened Concrete:

1) 28-Day Air Dry Density

The test was performed in accordance with ASTM C567-85[12] using 100×200mm cylindrical specimens. The specimens were left for 1 day in moulds inside the moisture cabinet, and then they were stripped from the moulds and wrapped securely with a polythene bag for 6 days. After that, they were removed from the bag and immersed in water for 1 day. On the second day saturated surface dry and suspended-immersed weight were taken. The specimens were left in the laboratory for 21 days, then the dried specimens were weighted and the 28-day air dry density was calculated by using the following equation:-

$$\textbf{28-day air dry density } (kg/m^3) = (A \times 997)/(B-C) \quad \ldots\ldots(2)$$

where :
A = 28-day weight of concrete cylinder, as dried (kg).
B = saturated surface-dry weight of cylinder (kg).
C = suspended-immersed weight of cylinder (kg).

2) Compressive Strength Test

The compressive test was carried out on 100 mm cubes using a hydraulic universal testing machine of 1000 kN capacity and the load was applied at a stress rate of 15 N/mm^2 per minute, according to BS.1881: part 116:1989[13]. The average compressive strength of three cubes was recorded for each testing age (3,7,28,60,and 90 days).

3) Splitting Tensile Strength Test

The splitting tensile strength of 100×200mm cylindrical concrete specimens was measured in accordance with ASTM C496-86[14], using a universal testing machine at stress rate of about 1.5 N/mm^2 per minute. The average splitting tensile strength of three cylinders was recorded for each testing age(3,7,28,60 and 90 days). The splitting tensile strength was calculated as follows:

$$\mathbf{F_{ct} = 2p/\pi dL} \text{ …….(3)}$$

Where:
F_{ct} = splitting tensile strength, (N/mm^2)
P = maximum applied load, (N)
d = diameter of the specimen, (mm)
L = length of the specimen, (mm)

Results and discussion

1) Design Strength and Unit Weight

Reference lightweight aggregate concrete was designed to have a 28-day compressive strength of 28 N/mm^2 with cement content of 550 kg/m^3 and w/c of 0.41 to maintain equal workability, slump 50 ± 5mm. The 28-day compressive strength and air–dry unit weight of reference and structural lightweight concrete are illustrated in Table (4)

2) Compressive Strength

Results demonstrate that in general, all concrete specimens exhibited continuous increase in compressive strength with increase in curing age. Table (5) and Fig.(3) show that the compressive strength of LWAC decreases with the addition of fine pumice aggregate as a total replacement of natural sand. The main reason is that the addition of fine pumice aggregate to LWAC increases the water required for the mix to get a suitable workability and as a result, the strength decreases. The percentage decrease in 28-day compressive strength of Ref_2 concrete compared with Ref_1 concrete (without fine pumice aggregate) was 4.39%.

The percentages increase in compressive strength at 90 days of curing of RHA-$HRWRA_1$ and RHA-$HRWRA_2$ concretes relative to reference concrete were 7.76% and 12.8% respectively.

Table (4): Design strength and unit weight of various type of WAC

Type of LWAC	Mix symbol	HRWRA (%)by wt.of cement	Cementitious materials contents		w/c or w/cm to give slump 50 ±5mm	Water reduction (%)	28-day compressive strength, N/mm^2	28-day air dry unit Weight (kg/m^3)
			Cement content (kg/m^3)	RHA content (kg/m^3)				
Sand LWAC	Ref_1	--	550	--	0.41	--	29.6	1875
	RHA-$HRWRA_1$	6	506	44	0.324	20.97	32.8	1940
ALL-LWAC	Ref_2	--	550	--	0.495	--	28.3	1835
	RHA-$HRWRA_2$	6	506	44	0.399	19.39	29.4	1895

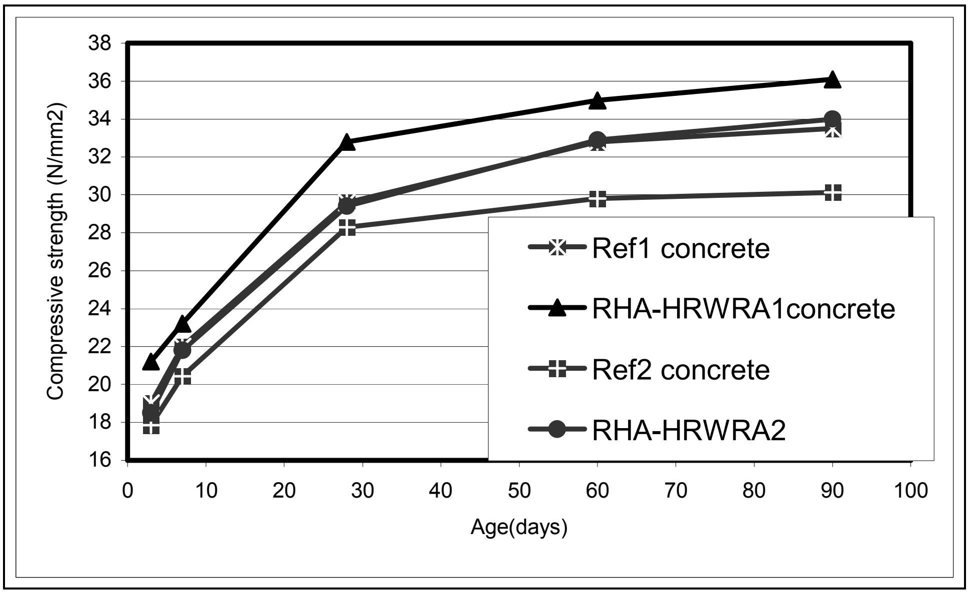

Fig. (3): Compressive strength of various types of LWAC with curing ages

3) Splitting Tensile Strength

The results indicated that in general, all types of concrete specimens exhibited continuous increase in splitting tensile strength with development of curing ages, as shown in Table (6) .

The splitting tensile strength of LWAC decreases when the natural sand is replaced by fine pumice aggregate, fig.(4). The percentage decrease in 28-day splitting tensile strength of Ref_2 concrete relative to the Ref_1 concrete (without fine pumice aggregate) was 11.09%.

At 90 day curing the percentages of increase in strength of $RHA\text{-}HRWRA_1$ and $RHA\text{-}HRWRA_2$ concrete relative to reference concrete were 12.85% and 16.52%.

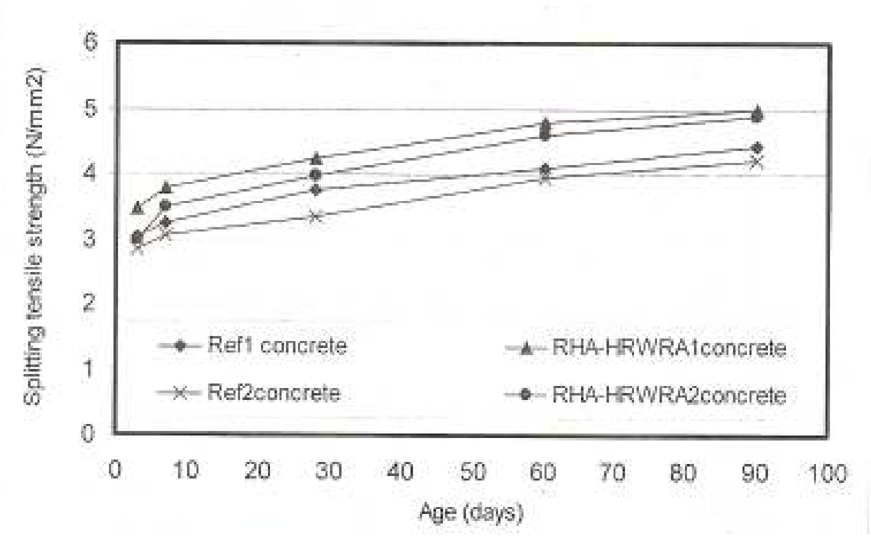

Fig. (4): Splitting tensile strength of various Types of LWAC with curing age

Table (5): compressive strength of various types of LWAC and curing ages

Type of LWAC	Mix symbol	HRWRA (%) by wt. of cement	Cementitious materials contents		w/c or w/cm to give Slump 50±5mm	Water Reduction (%)	Compressive strength ,N/mm^2 at curing ages				
			Cement content (kg/m^3)	RHA Content (kg/m^3)			3 day	7 day	28 day	60 day	90 day
Sand LWAC	Ref_1	--	550	--	0.41	--	19	22	29.6	32.8	33.5
	RHA-$HRWRA_1$	6	506	44	0.324	20.97	21.2	23.2	32.8	34.98	36.1
ALL-LWAC	Ref_2	--	550	--	0.495	--	17.85	20.43	28.3	29.8	30.14
	RHA-$HRWRA_2$	6	506	44	0.399	19.39	18.5	21.8	29.4	32.9	34

Table (6): Splitting tensile strength of various types of LWAC and curing ages

Type of LWAC	Mix symbol	HRWRA (%) by wt. of cement	Cementitious materials contents		w/c or w/cm to give slump 50±5mm	Water reduction (%)	Splitting tensile strength ,N/mm^2 at curing ages				
			Cement content (kg/m^3)	RHA content (kg/m^3)			3 day	7 day	28day	60 day	90 `day
Sand LWAC	Ref$_1$	--	550	--	0.41	--	3.025	3.243	3.757	4.108	4.426
	RHA-HRWRA$_1$	6	506	44	0.324	20.97	3.471	3.789	4.243	4.8	4.995
ALL-LWAC	Ref$_2$	--	550	--	0.495	--	2.834	3.05	3.34	3.949	4.205
	RHA-HRWRA$_2$	6	506	44	0.399	19.39	2.981	3.503	3.98	4.61	4.9

Conclusions:

1- LWAC containing fine pumice aggregate has lower air-dry density than that of sanded-LWAC. On the other hand, RHA-HRWRA lightweight aggregate concrete has higher density than those of reference concretes .

2- At all ages of curing,RHA-HRWRA concretes exhibit noticeable improvement in compressive strength and splitting tensile strength .

3- LWA concretes containing fine pumice aggregate have lower compressive strength and splitting tensile strength at all ages of curing compared to sand-LWAC.

Suggestions:

1. A study is required to examine the mechanical properties of high performance fiber reinforced pumice lightweight aggregate concrete for structural purposes.
2. A research work is required to study the durability of fiber reinforced pumice lightweight aggregate concrete containing HRWRA and RHA as a partial replacement by weight of cement.
3. An investigation is required to examine the corrosion resisting characteristic of steel fiber reinforcement in pumice LWAC incorporating HRWRA and RHA as a partial replacement by weight of cement.

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