A Comparative Study of Thermal Insulations and Physical Properties of Lightweight Concrete Using Some Raw Materials

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ABSTRACT

In this work, no-fine lightweight concrete was produced by using crushed bricks, thermostone as coarse aggregates to produce lightweight concrete. For both, superplasticizers were added to the mixture, the specimens were then cured in water for (7, 28, 60) days respectively.

Compressive strength determine the mechanical properties, Physical properties of these concrete types were examined through thermal conductivity and fresh density. The compressive strength test showed that the compressive strength of the concrete was about (8-15.7) N/mm^2 by using natural gravel aggregate, (4.8-8.1) N/mm^2 by using crushed bricks, and (3.14-5.4) N/mm^2 by using thermostone aggregate. After 28 days, the thermal conductivity were (0.58),(0.41),(0.26) W/m.k, for the natural gravel ,crushed bricks and thermostone concrete.

Besides; these concrete types are characterized by their low cost, environmentally friendly, high production rate, fire resistance, thermal insulation and light weight.

Keyword: lightweight concrete, cellular concrete**,** compressive strength of lightweight concrete.

INTRODUCTION

The American concrete institute(ACI 211-2-98)**[1]**, defined lightweight concrete as "the concrete with less than (1840 kg/m^3) air-dry density "According to ACI , the lightweight concrete is the concrete with clearly lower density than the concrete made of crushed stone or normal coarse aggregate. **Al_soadi** [2]studied the mechanical and physical properties of the concrete that contains the muddy crushed bricks as coarse aggregate by replacement rates ranged between (0-100%) instead of normal aggregate to clarify the effectiveness of increasing crushed bricks ratio and decreasing broken coarse aggregate in the concrete. She found a decrease in bulk density in 28 days' time with a noticeable enhancement in some features like modulus of thermal conductivity. The results indicated that the density of muddy crushed bricks concrete ranged between (1845-2405) kg/m^3, compressive strength in time of 28 days for this concrete ranged between (24.15 -52.43) N/mm, and lower thermal conductivity by (23.13-27.06%) compared with the normal concrete.

Experimental part
Materials used

Cement:

Iraqi ordinary Portland cement manufactured by (tasloga factory /trademark AL_jeser) cement factory was used throughout this investigation. It was stored in a dry place (air-tight plastic containers) to reduce the effect of humidity and temperature. Tables [(1), (2)] show the chemical and physical properties of cement respectively.

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Table (1)

Abbreviation of Oxide	% by weight	Limits of Iraqi SpecificationNo.5/1984
SiO_2	21.95	-
CaO	63.32	-
MgO	1.48	≤ 5.0
Fe_2O_3	4.66	-
Al_2O_3	3.76	-
SO_3	1.78	≤ 2.8
Loss on Ignition	0.83	≤ 4.0
Insoluble residue	0.77	≤ 1.5
Lime saturation factor	0.96	0.66-1.02

Chemical composition of the cement used in this investigation

Chemical tests were made by the National Center for Construction Laboratories and Research (NCCLR)

Table (2) Physical properties of the cement used in this study

Physical property	Test Results	Limits of Iraqi Specification No.5/1984
Specific surface area (Blainemethod),m^2/Kg	295.2	≥ 230
Soundness (autoclave method) %	0.035	≤ 0.8%
Setting time (vicat'smethod) Initial: by minutes Final: by minutes	121 230	ASTM C191 ≥1hr ≤ 10hr

Chemical and physical tests were made by the National Center for Construction Laboratories (NCCL).

Natural gravel:

Coarse aggregate crushed to 14 mm maximum size was used. It was obtained from AL–Nebai source. Maximum size aggregate was used for all of the mixtures in order to produce low-density no-fine concrete. (Table 3) shows the grading of course aggregate which conforms the Iraqi specification (IQS No.45 / 1988)**[3].**

Table (3) some properties of coarse aggregate used throughout this work.

Physical properties	Test results	Limits of Iraqi specification No.45/1988
specific gravity	2.63	-
sulfate content%	0.06	≤ 0.1%
Absorption%	4.5	-

Chemical tests were made by the National Center for Construction Laboratories and Research (NCCLR)

3-Crushed clay-brick:

Clay-brick is one of the widely-used construction materials in Iraq. In this research local

The property	Test result	Standard Specification
(saturated-surface dry)density	1225	ASTM C29-89
Specific gravity	2.15	ASTM C127-88 ASTM C128-88
Sulfate content%	0.44	B.S.3797:Part-2-81
Water absorption%	21	ASTM C127-88 ASTM C128-88

perforated clay-brick was used, it has been crushed into smaller sizes by using jaw crusher in order to get the proper sizes. The coarse aggregate was sieved by using sieves with sizes of (14, 10, 5, 2.36) mm respectively. The properties of the coarse crushed clay-brick aggregate are illustrated in table (4).

Table (4) some properties of coarse crushed clay-brick aggregate used in this work.

4-Thermostone:

Thermostone aggregate is considered as one of the industrial waste that accumulate during thermostone manufacturing. The thermostone was sieved by using sieves with sizes of (14 , 10 , 5 , 2.36) mm. The properties of the coarse thermostone aggregate are illustrated in table (5).

Table (5) some physical properties of the Thermostone aggregate.

The property	Test result
Specific gravity	0.29
Absorption, %	75

Within the limits of Iraqi specification No.45/1988**[3]**.

5-Superplsticizers:

This additive is considered as one of the water mitigating additives; actually it is the most affective one. It reduces the amount of mixing water required for the production of high strength concrete by (12%) at least. The super plasticizer, used in this work is commercially known as (TOPFLOW SP 603),with a percentage of (1.3%) of cement weight. TOPFLOW SP 603 complies with the requirement of the following standards (ASTM C494 Type A, B, D, F and G – BS 5075 Part 1) depending on the dosage used.

6- Mixing water:

Tap water was used for mixing and curing of all concrete specimens.

2.2 Lightweight Concrete Mix:
Group1:– (6:1) 100*100*100 mm cubes were used for the compressive strength test specimens including crushed clay bricks, thermostone, and coarse gravel.
The W/C ratio was 0.3 for each mixture. The content of superplasticizer was 1.3% of the cement content by weight. Fig (1) shows the cubic specimens after test

(Crushed bricks concrete)

(Thermostone concrete)

(Natural gravel concrete)
Figure: - (1) the cubic specimens after inspection

Instrument description:
Compressive strength test instrument:
The compressive strength test was determined according to B.S.1881, part 116**[4]**. This test was made on 100 mm cubes using an electrical testing machine (LARYEE), with power supply (220/380V, 50/60HZ). The test was conducted at ages of 7, 28 and 60 days. The compressive strength of the specimen was calculated by dividing the maximum load carried by the specimen during the test by the average cross-sectional area of the specimen.

Compression =force / area . . . . . (1)
Compression: [MPa].

Force: [N].

Fresh Density:

The no-fine concrete fresh density was found and measured by using cylindrical samples of size of (100* 200) mm in accordance with the (ASTM-C567-85) [**5**]. The adopted rate was three cylindrical samples per mixture.

Thermal Conductivity test:

This test was done in accordance with ASTM-C177, by using concrete cuboid with sizes of (300 * 300 *100) mm, as shown in Fig(2) ,the specimen engaged in the test is to be put in the device before closing it , after the temperature of the upper and the lower plate of the device are specified (e.g 30˚C for the upper and 10˚C for the lower) .

The device was operated until a thermal balance is achieved. The time needed to reach the thermal balance depends on the type and the thickness of the material, in addition to the temperature difference. The time needed can be up to 24 hours, and when elapsed, the thermal conductivity value can be obtained.

In this work the thermal conductivity device used was (Linseis HFM 300), made in Germany , and used to measure the thermal conductivity of insulating materials in the range of (0.005 – 0.5 W/m.K) such as glass wool , rock wool , thermostone , bricks , etc .This device shown in Figure (3).

Figure(2) Thermal conductivity specimens.

Figure (3) Thermal conductivity test machine.

Result and Discussion:

Compressive strength

The specimens that were made of crushed bricks as coarse aggregate which were kept (7) day in water showed about (38-41%) less compressive strength than the specimens that were made of natural gravel. After keeping the specimens immersed in water for (28) day, the results of crushed bricks concrete showed (47-48 %) less compressive strength, and at (60) day the decrease of compressive strength was about (48–50 %).

When comparing thermostone concrete with natural gravel concrete, the results showed bigger decrease in compressive strength than the decrease when comparing crushed bricks concrete with gravel concrete. The decrease percentage in compressive strength of concrete that made with thermostone reference to gravel concrete after (7) day was (60 - 61 %), at (28) day the decrease became about (63-64 %) and at (60) day it was (65-66 %).

In No-fine concrete, the fracture line passes through the cement mortar or through the bond that ties cement mortar and aggregate grains. This explains the dependency of compressive strength of concrete mixture on cement mortar resistance that covers coarse aggregate grains and the amount of contiguity resistance between aggregate grain surfaces and cement mortar.

Due to No-fine concrete structure and because of its being free of fine aggregate, transition zone between aggregate grains and cement doesn't exist. This zone is responsible for resistance development day by day due to the continuity of hydration result formation. The final resistance of the No-fine concrete specimens is therefore much weaker when compared with natural concrete specimens.

In addition, cellular structure that contains great number of voids and pores will definitely lead to large resistance decrease.

It can be clearly observed that the strength continuously increased with time due to the continuous hydration process of cement paste which forms a new hydration product within the concrete matrix then increases the bond between cement paste and aggregate. This results agree will with Al-harbi**[6]** .

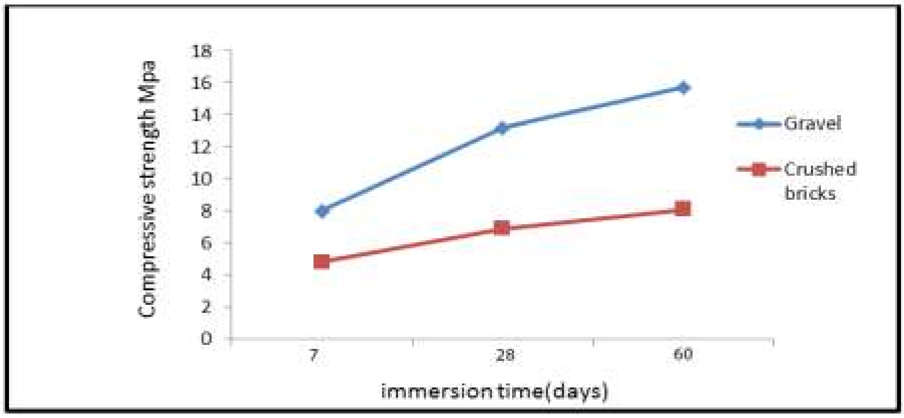
The results showed that gravel aggregate concrete compressive strength is larger than the compressive strength of concrete made with crushed bricks as coarse aggregate. This is because the fracture line passes through coarse aggregate particles due to three factors; the First one is weakness of grains resistance (as a result of its cellular structure) ,which makes the crushed bricks aggregate concrete having lower compressive strength than other gravel aggregate concrete.

The second is that , crushed bricks aggregate tends to (dusting) despite washing it with water several times which decrease the bond between the cement paste matrix and the brick particles, hence reduces the compressive strength.

The third is that the gravel aggregate strength is greater than the crushed bricks aggregate strength.

When comparing thermostone aggregate concrete specimens compressive strength with gravel aggregate concrete specimens compressive strength it can be seen that the thermostone specimens were much more less because of the thermostone cellular structure and the large number of pores and voids which make the thermostone aggregate weaker , as well as the lower strength of thermostone compared to gravel.

This reduction in compressive strength is because thermostone concrete needs more amount of water due to its large absorption ability which decrease compressive strength as a result of (air voids). These results are shown in Figures (4),(5).



Figure(4)Compressive strength results of No-fine concrete specimens that made with crushed bricks , gravel as coarse aggregate at different periods of immersion.

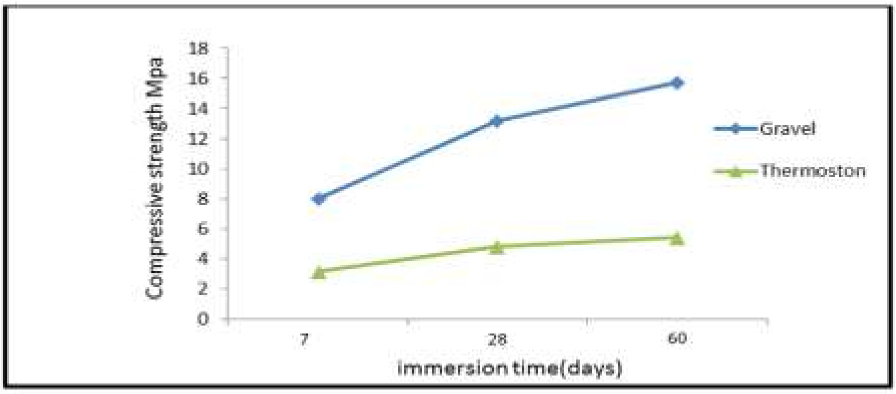


Figure (5) Compressive strength results of No-fine concrete specimens that made with thermostone , gravel as coarse aggregate at different periods of immersion.

Fresh density

Table (6) shows the results of fresh density at ages of (7, 28 and 60) days for all of the no-fine concrete mixtures. Figure (6), shows the relationships between the fresh density and the type of aggregate for the gravel concrete, crushed bricks concrete and thermostone concrete respectively.

In this work, the concrete that was made of natural gravel as coarse aggregate was considered as the reference concrete. The concrete specimens that were made of crushed bricks as coarse aggregate showed less fresh density relative to reference of about (20 – 25) % .

This decrease in fresh density of the specimens was due to the crushed bricks density being less than the density of the natural gravel because the crushed bricks contain more pores than gravel.

While, when thermostone were used as coarse aggregate, the fresh density of the concrete decreased to about (50 – 55) % relative to the concrete that was made of natural gravel as coarse aggregate.

Again, the decrease of the specimen's fresh density was a logical result of the thermostone being less density than the gravel due to the higher porosity of the thermostone as compared to the gravel.

Table (6) Fresh density results for No-fine lightweight concrete specimens by (kg/m^3).

Type of aggregate	Natural gravel	Crushed bricks	Thermostone
Results of fresh density	1980	1550	950

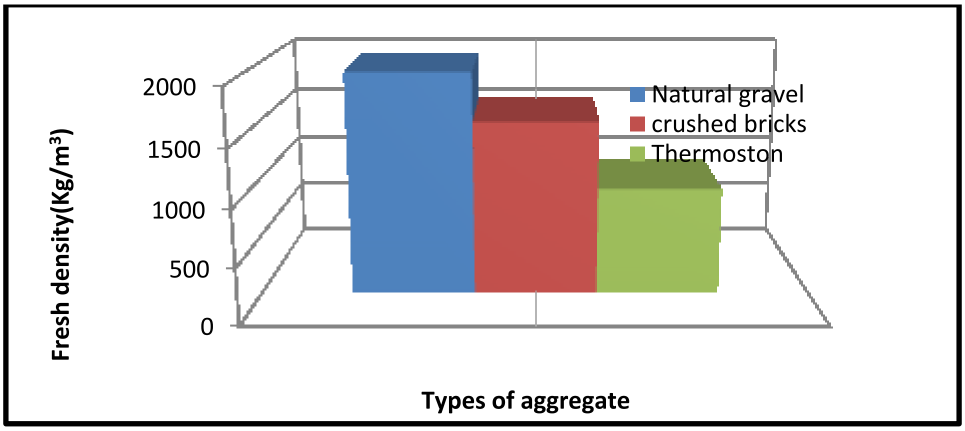


Figure (6):- Fresh density results for No-fine lightweight concrete specimens made with different types of coarse aggregate.

Thermal conductivity

Building materials vary in their ability to transfer heat. Thermal conductivity is defined as the amount of heat transmitted through the unit area by the unit of thickness.

It is necessary to provide good thermal insulation in construction that help the environment conditioning systems in buildings to give the best of what it has .

No-fine concrete is considered as one of the most affective concrete types in thermal insulation because it contains large number of air voids that affect thermal conductivity.

In general, most of the published research about the thermal properties of lightweight concrete has been concerned with thermal conductivity. The reason for this is that thermal conductivity is agood indicator of the likely thermal performance of concrete. Unlike normal weight concrete that exhibits thermal behavior which is independent of density, many studies have pointed out that the thermal conductivity of lightweight concrete varied with the density. This is normally due to the lower thermal conductivity of air, which occupies a considerable mass with in lightweight concrete.

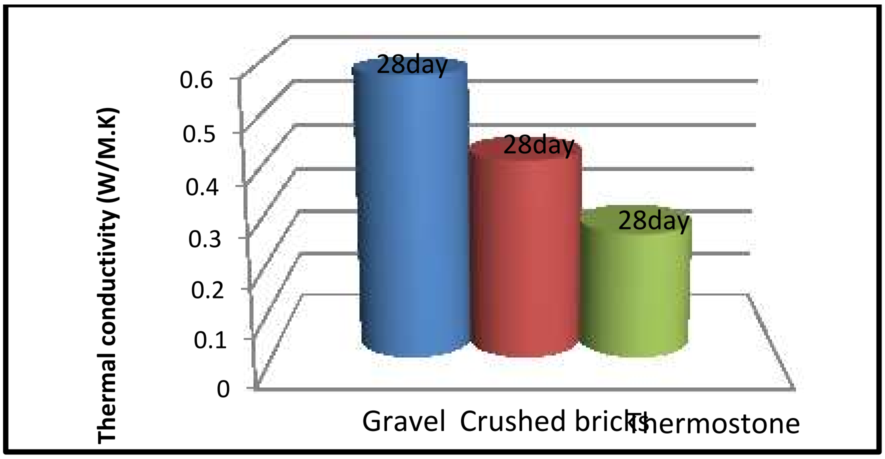
Table (7) and figure (7) show the results of thermal conductivity test for specimens cured in water for (28) days. These results showed that the concrete made with crushed bricks as coarse aggregate have lower thermal conductivity than the concrete that made with natural gravel as coarse aggregate; (0.41) W/m.K for crushed bricks concrete and (0.58)W/m.k for natural gravel concrete.

On the other hand these results also demonstrate that the concrete made with thermostone as coarse aggregate has lower thermal conductivity than the concrete made with crushed bricks as coarse aggregate and the concrete that made with natural gravel as coarse aggregate. (0.26) W/m.K was the thermal conductivity of the thermostone concrete specimen.

The main Reason behind this result is due to the density of the concrete specimens. It is well known that by lowering the density of concrete, a lower thermal conductivity is achieved. In addition, increasing of porous and voids number in the specimen decreases thermal conductivity because those porous and voids obstruct thermal transmission through the specimen.

Table (7) Thermal conductivity results for No-fine lightweight concrete specimens made with different types of coarse aggregate at 28 age

Thermal conductivity results of No-fine lightweight concrete W/m.K	
Mixtures	**28 day**
Natural gravel concrete	0.58
Crushed bricks concrete	0.41
Thermostone concrete	0.26



Figure(7) Thermal conductivity results for different types of No-fine concrete specimens at 28 day age of cured.

CONCLUSIONS:

Depending on the extensive experimental program and the performed tests on various types of lightweight concrete the following conclusions are drawn regarding the influence of various relevant variables on the properties of concrete:

1- It is possible to produce lightweight concrete by using two types of locally available materials, crushed bricks and thermostone as coarse lightweight aggregate.

2- Compressive strength of concrete decreases with the decrease of density.
3-The compressive strength and density increases by decreasing the porosity percentage.
4-Lightweight concrete has low thermal conductivity.

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