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Production of Thermal Insulation Lightweight Concrete Using Manufactured Aggregate

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Abstract

This work aimed to produce lightweight concrete characterized with thermal insulation for using to develope lightweight aggregate (LWAC) from local material. Kaolin clay and a glass powder were mixed with ratio equal (20, 80%) respectively to produce the (LWA). The composite of the material was prepared and burned in a kiln up to (700 ℃) to manufacture the (LWA). The density of the aggregate was ranged of (559-588) kg/m3. The mechanical properties and thermal conductivity were investigated by using cube specimens of (100*100*100) mm at different ages. The 28 days compressive strength of the produced lightweight concrete (LWAC) was (8.6 - 30.6) MPa for the density of (1090-1880) kg/m3. Besides , the value of the thermal conductivity of this type of concrete was between (0.4947- 0.8872) W/m. K. The results showed a promise lightweight concrete with a good thermal insulation properties.

Keywords: Lightweight aggregate, Kaolin clays, Glass powder, Lightweight concrete, Thermal insulation of concrete**.**

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Introduction

The construction sector witnessed a tremendous development in the field of building materials, including concrete, which was characterized by its ease of operation and high load capacity[1]. At the same time, concrete used was accompanied by some disadvantages related to its properties such as a high thermal conductivity and a heat loss. These properties of building materials cause inconvenient to human without using heat insulation materials or air conditioner devices; especially in the area which suffer from a high temperature in the summer and a low in the winter [2]. Thermal insulation problems were a counted one of the major engineering problems that need further research in the field of residential buildings and other construction. In addition to the cost of electric energy used with air conditioner devices.

The mjority of the heat that seeps into our homes and facilities is across the walls and ceilings . It was estimated approximately (60-70) % [3]. In the countries of Middle East area like the Saudi Arabia and Iraq when they used a thermal insulation system and double glass for windows, it leads to achieving a saving in the power about (60%) [4].

On the other hand, the interest in lightweight concrete was increasing daily fast with all world countries as a result of economic reasons primarily. The lightweight concrete had a dry density usually range of (300-1850) kg/m^3 [5] less than the normal concrete which its density range of (2200-2600) kg/m^3 [6]. These features lead to reduce total effective load, which helped to use sections and foundations with smaller size, wherefore the templates will bear less pressure. The weight of materials in transportation would be less, which means higher production. As well as, it represented a good basis for the finishing work and a good for increased freeze and fire resistance.

As mentioned earlier, the thermal conductivity for concrete using a normal aggregate range of (0.69-0.94) W/m.K, and this value could be reduced to (0.22) W/m.K by using a lightweight and porous aggregate.

Exprimental Work

1. **The materials used and practical program.**

This part of paper deals with two main section. The first, a preparation of raw materials, a manufacturer of (LWA), and conduct the tests of density and absorption. The second section, involving the concrete works which containing the (LWA) and conducting the concrete tests that represents compressive strength, density, absorption, and thermal conductivity.

1. Materials.

1.1 Cement.

Cement has considered the basic bonding material when it interacts with water, it will have cohesive and adhesive properties that bind the granules to each other. In this paper, Portland cement used in concrete casting works. The cement properties are according to Iraqi Standard Specifications [7].

1.2 Fine and Coarse Aggregate.

The natural fine aggregate used from Al-akhaydir quarries area. Figure (1) has showed the sieves analysis and the limits of the specification. The coarse aggregate is outfitted from the Al-Tuz quarries. Figure (2) showed the minimum and maximum limits of the coarse aggregate. All the normal aggregate (fine and coarse) have been according to Iraqi Standard Specifications [8].

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1.3 Lightweight Aggregate Manufacturing.

Steps of the lightweight aggregates manufacturing are summarized by preparing the glass powder, Kaolin clay, and then mixing them to produce the (LWA).

1.3.1 Glass powder.

One type of glass (green glass) has used, and it is available in abundance as the bottles of juices and soft drinks which are made from green glass. Milling steps are summarized by three stages, but before the milling process, it must wash and clean bottles from the sticking materials and also from the affixed brands to get the net glass.

The first stage, crushing the glass after collected and cleaned into large pieces by a normal hammer. These pieces have the size of (0.5-1.5) cm. The second stage starts after obtaining a quantity of crushed glass by the hammer, and place it in a big mill (disk mill) for a period of (15-20) minute to get a smaller sized powder. The third stage of milling process begins by using other a smaller mill from the first one (Ball Mill). Ball mill is a bowl of porcelain containing on balls which it makes from porcelain also. The glass powders produced from the first mill which is placed inside the smaller mill and closes it well. Ball milling has been running for a different period of (5-8) hours to compare the smoothness degrees for glass powder and choose the most appropriate with the time. It has been selected (7) hours period because the size of the glass particles was well fineness, and it has been the adoption this period to carry out grinding glass which it will use in the lab to produce a lightweight aggregate. We have found that the glass powder product from the above operations crosses from sieve number 140 (0.106 mm). This gradient of the glass powder reduces the effect of alkali-silica reaction (ASR) in the concrete [9][10][11][12]. In addition, the green glass that has been used contains about 1.0% chromium oxide, which is an important element in suppressive effect on ASR [13].

1.3.2 Kaolin clay.

The process of getting the mud starts from the source and it must be completely free from physical impurities. The mud is washed and passed from sieve number (75) Microns to obtain a clay are free from organic materials then placed in a drying oven with (78) ℃, and after (24) hours is taken out of the oven. After mud drying, It is well crushed by a hammer for the grinding, then placed inside the ball mill to continue grinding for (3) hours.

1.3.3 Mixing glass powder with Kaolin clay.

The resulting materials from the milling processes (glass powder, Kaolin clay) are mixed well with ratio (80, 20) % respectively. The mixture is passed from the sieve number (600) Microns several times to ensure that the material is mixed well, then the water is added by (4-6) % of the mixture weight. This water ratio is enough to make the mixture take appropriate consistency. The mixture of the appropriate consistency is placed in the hydraulic sampling device. A sufficient number of specimens are extracted and placed inside a furnace at a (700) °C for one hour, and then stored in plastic containers for use in the concrete mix.

The samples are crushed to obtain a different gradient to use in the production of lightweight concrete, this gradient according to ASTM C330/C330M [13]. The dry density, absorption, and thermal conductivity testing have been conducted for (LWA) see table (1). Figure (3) shows the compact samples before and after crushing.

2. Method of pouring and concrete processing.

The manual method has used in concrete mixtures on layers form to avoid isolation. The weight ratios are mentioned in the table (2). Standard cubes have cast with dimensions (100,100,100) mm, three cubes have for each age and mixing ratio. The density, absorption, and compressive strength test were conducted on cubes either for the thermal conductivity test (hot and cold plate test) has use the circular templates with diameter (100) mm and thickness (25) mm, it has one sample for age (28) days only. Table (3) shows the tests results of produced concrete in the different mixtures.

Result and Discussion

The main objective of this research is to produce a lightweight and thermal insulation concrete by producing an (LWA) from local materials. The local materials are kaolin clay and glass waste. The laboratory tests of the (LWA) and the concrete which produced from this aggregate has acceptable as shown in the table (1) and table (3). The density of the (LWA) has between (559-588) kg/m^3; it was less than the normal aggregate which was between (2550-2650) kg/m^3, and the absorption rate of (LWA) ranged of (19.57 - 26.6) % compared with normal aggregate which is very high.

On the other hand, the density of an (LWAC) produced using (LWA) has values between (1090-1880) kg/m^3, which is small compared with the concrete produced using normal aggregates at a value of (2.240) g/cm3 table (3). The absorption values for the lightweight concrete range of (8.13-19.36) % compared with the normal concrete which has (6.09) %. See Table (3) and figure (6)

In addition, the compressive strength value of lightweight concrete has less than normal concrete, but these value are acceptable as in figure (4), where the compressive strength value of lightweight concrete has lower than the reference mixture (M0) by (19.8 - 40.1 - 16.1 - 60.6 -76.4) % for concrete mixtures (M1 - M2 - M3 - M4 - M5), respectively. This is accounting scientifically acceptable due to the relatively low density of the above mixtures. See the table (3) and figure (4).

Finally, the most important advantage of manufacturing (LWA) is obtaining a lightweight concrete with good thermal insulation, where the thermal conductivity of this concrete has between (0.4947- 0.8872) W/m. K. It is good values compared to the thermal conductivity values of normal concrete. See the table (3), and figure (5) has showed the relationship between dry density and thermal conductivity.

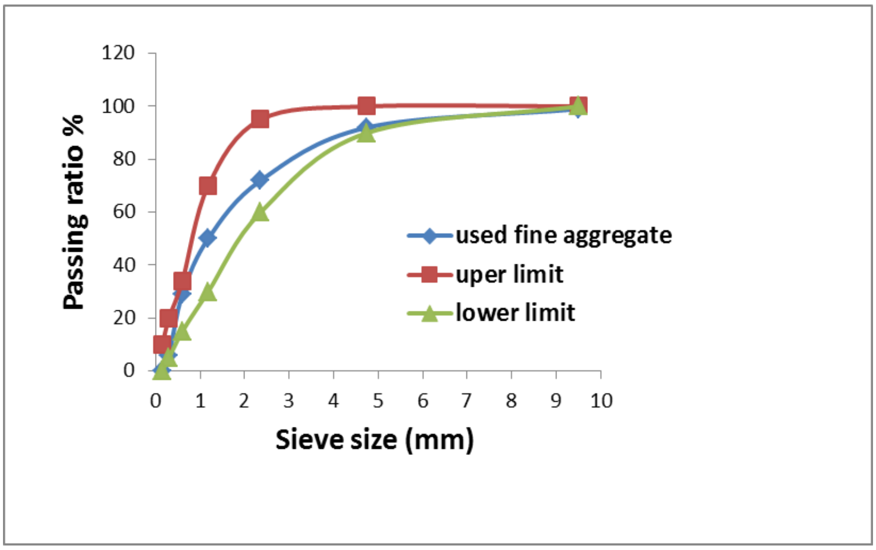

Figure 1: Limits of fine aggregate according to the Iraqi Standard No. (45/1984).

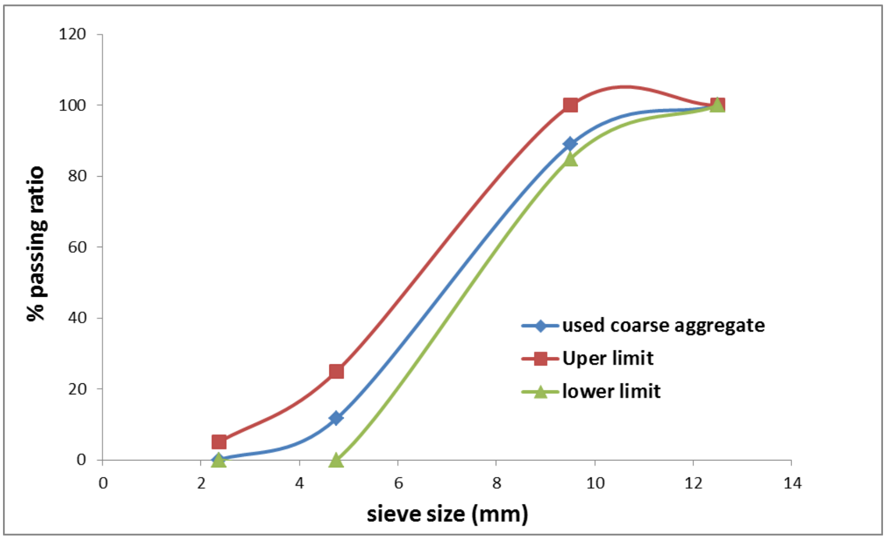

Figure 2: Minimum and maximum limits of the coarse aggregate gradation according to the Iraqi Standard No. (45/1984).

Figure 3: Illustrates the compact samples before and after the cracker.

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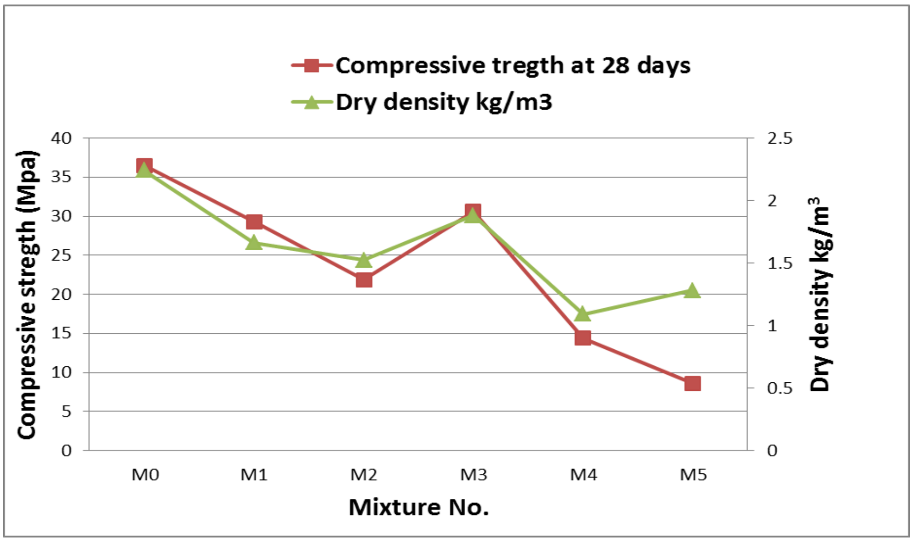

Figure 4: Relationship between compressive strength at 28 day and dry density.

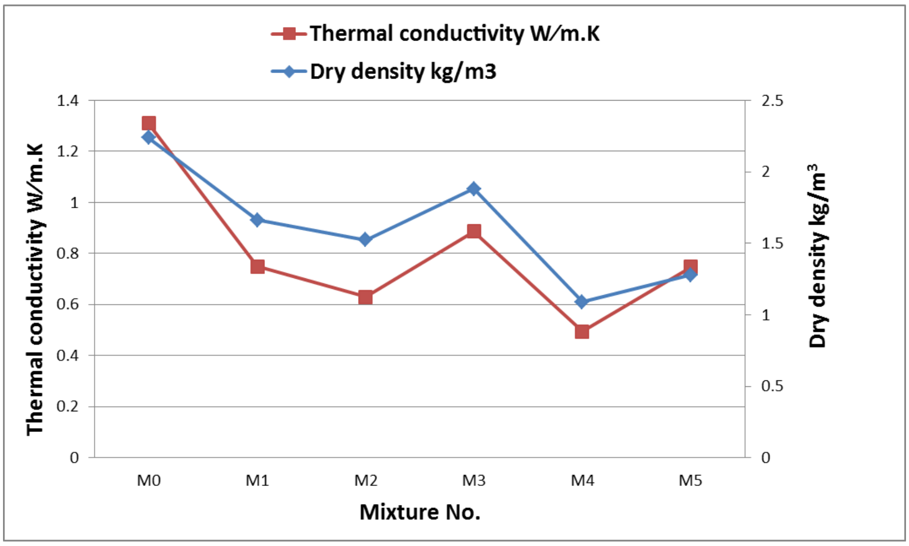

Figure 5: Relationship between thermal conductivity and dry density.

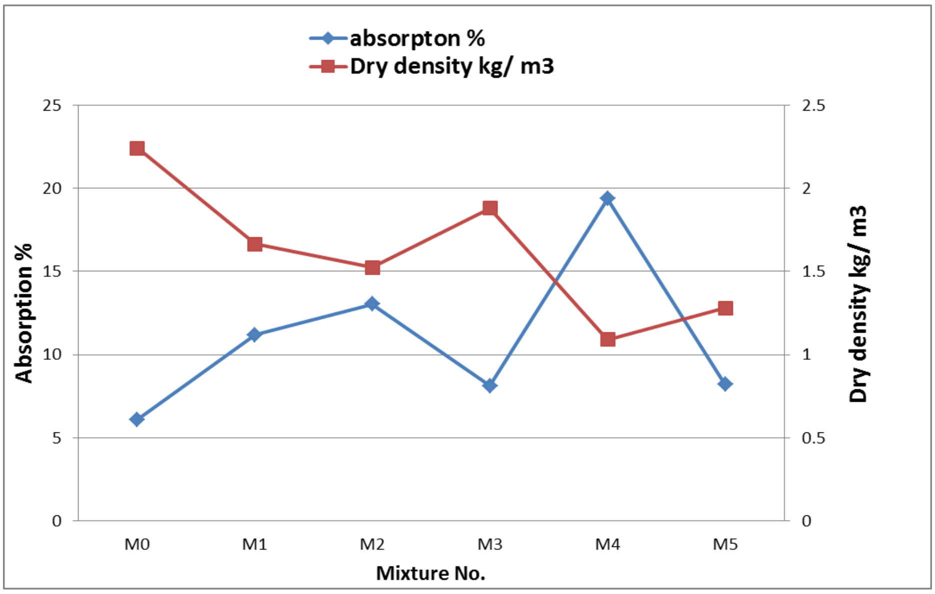

Figure 6: Relationship between absorption rate and dry density.

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Table 1 Tests results for samples of mnufacture aggregte.

Sample NO.	Dry Weight (gm.)	Dry density (kg./m^3)	Absorption ratio %	Thermal conductivity (W/m. K.)
1	9.9	559	25.25	0.1819
2	9.4	584	26.60	0.1912
3	9.4	588	22.34	0.1905
4	9.3	581	21.50	0.1835
5	9.2	579	19.57	0.1881
6	9.1	576	19.78	0.1822
Avg.	9.4	578	22.50	0.1862

Table 2 Mix proportions for the concrete mixture

Mix. No	Cement content (kg/m^3)	W/C %	Fine agg. (Kg/m^3)	Coarse agg. (Kg/m^3)	Manufacture Agg. (Kg/m^3)	Water (Kg/m^3)
M0	480	0.46	720	864	0	221
M1	580	0.4	0	0	70	232
M2	580	0.4	0	0	110	232
M3	580	0.4	840	0	160	232
M4	480	0.4	0	0	320	221
M5	480	0.4	840	0	320	221

Table 3 Tests results of produced concrete for the different mixtures

Mix. No.	Average of compressive strength (Mpa.).		Absorption %	Dry density (Kg/m^3)	Thermal conductivity (W/m.K)
	7	28			
M0	22.4	36.51	6.09	2.241	1.3098
M1	17.32	29.27	11.2	1.664	0.7492
M2	13.09	21.84	13.04	1.525	0.6297
M3	25.30	30.6	8.13	1.880	0.8872
M4	9.05	14.37	19.36	1.090	0.4947
M5	5.15	8.6	8.21	1.280	0.7473

Conclusion

1. The lightweight aggregate has successfully manufactured through the burning of the mixture of Glass Powder and Kaolin Clay at 700 °C. This process has overcome the difficulties in producing light aggregates from the use of high-temperature ovens up to 1300 °C.

a) The density of the produced lightweight aggregate has ranged between (559-588) Kg/m3.

b) The absorption rate of this aggregate has (19.57 - 26.6) %.

2. The produced concrete by using this lightweight aggregate has good properties that competes the normal concrete, where the density is lower, the thermal insulation is greater, with acceptable compressive strength.

- The density of produced concrete has ranged from (1090 to 1880) Kg/m3.
- The absorption rate of produced concrete was ranged between (8.13-19.36) %.
- The compressive strength of the produced concrete has ranged between (8.6-30.6) MPa.
- The thermal conductivity value has (0.4947-0.8872) W⁄m. K.

3. The utilization of glass waste will contributes to improve the environment through the recycling of these wastes.

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