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# Effect of Wood-Particles Aggregate Percentage on Some Physical Properties of Concrete

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**Abstract.** This paper is focused on light-weight aggregate concrete with wood particles and its issues according to physical and thermal properties. The experimental work for the estimation of density, absorption and thermal conductivity of light-weight wood-particles aggregate concrete is presented. Wide range of wood-particles percentages were used in the experimental work. The thermal conductivity is related to the air-dry density of wood-particles aggregate concrete. The relation is lied closely within the predictions presented in ACI 213 committee report. The range of air dry density was about 1400 to 1900 kg/m<sup>3</sup>.

## 1. Introduction

There are several advantages of Light-weight aggregate concrete (LWAC) in comparison to normal weight concrete (NWC). The most important is lower bulk density and corresponding lower dead load of a construction that can result in smaller cross-section of construction elements, and buildings foundations. This is especially beneficial for high-rise buildings when lesser loading for columns is needed. The reduction in transportation costs for precast elements is also an advantage.

Applying light-weight concrete in structures reduces construction costs, makes construction easier and leads to green, sustainable construction (Tommy Y. LO et al. 2006).

The light-weight concrete has lower thermal conductivity as well. This ability makes LWAC more suitable for heat insulating constructions and for precast panels. There are also disadvantages. LWAC has higher porosity. It can result in higher absorbing capacity of water and lower compressive strength (Bayan et al. 2004). Light-weight aggregate outer shell thickness, macro porosity and broken grains percentage all affect the aggregate strength (Y. Ke et al. 2009).

A Recent work (I. Asadi et al. 2018) reviewed research works conducted to measure thermal conductivity of normal and light weight concretes. They concluded that using light-weight concrete as building envelopes reduces the amount of heat transfer and energy consumption owing to the lower thermal conductivity of light weight concrete compared to normal weight concrete.

## 2. Research significance

This paper presents an experimental investigation on thermal conductivity of a sustainable light-weight concrete: wood-particles aggregate concrete. Wide range of wood particles percentages as concrete aggregates were used to investigate the thermal properties which would be beneficial in production of heat insulation components made of wood particle aggregate concrete (Bayan et al. 2004). Some other physical properties of wood-particle aggregate concrete such as density and water absorptions are studied. Wood particles are



abundant. They are available wherever carpenters are available. Instead of treating them as waste materials, they can be useful in producing sustainable thermal insulated concrete components, especially in precast concrete factories.

### 3. Experimental work

#### 3.1 Materials: cement, sand, wood particles

Ordinary Portland cement was used in the experiment. The physical and chemical properties of the cement are shown in the tables 1 and 2, respectively. They comply to Iraqi standards [IQS1984].

Table 1. Physical properties of cement

Physical Requirements		Limitation (IQS 1984)	Test Result
Finesse ( Blaine)	$m^2/kg$	Not specified	398
-Initial setting time	min	$\geq 45$	180
-Final setting time	hour	$\leq 10$	3:45
Soundness (expansion)	mm	$\leq 10$	0.0
Compressive strength is not less than (MN/ $m^2$ )	2 days	$\geq 20.0$	23.0
	28 days	$\geq 42.5$	49.9

Table 2. Chemical properties of cement

Chemical Requirements	Limitation (IQS 1984)	Test Result
<b>Sulfate content (as SO<sub>3</sub>) %</b>	2.5 if C3A $\leq 5$ 2.8 if C3A $\geq 5$	2.16
<b>Chloride content %</b>	$\leq 0.10$	0.02
<b>Magnesium oxide ( as Mgo) %</b>	$\leq 5.0$	3.18
<b>Loss on ignition (Lol) %</b>	Not specified	8.19

River sand was used in the experiment. Table 3 shows the sand properties, and Fig.1 shows the grading (sieve analysis) of the sand. Sand (Table 3, Fig 1) was added in amount such that same consistency shall be gained in every mix. W/C ratio was accordingly varied mixes with incorporated sand, to ensure same workability as the control mix. Table 4 shows the various mix of this work.

Table 3. Sand properties

Properties	Fine aggregate
Specific gravity	2.63
Water absorption	1.07%
Density	1755 Kg/m <sup>3</sup>

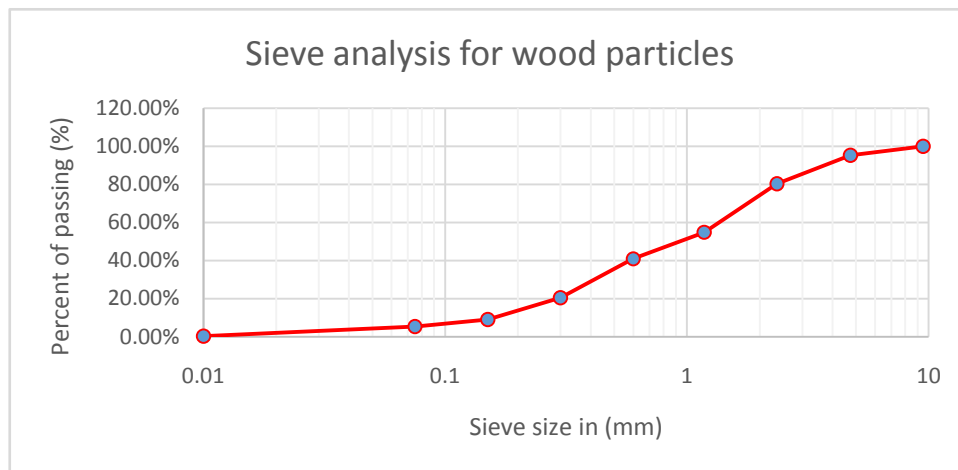


Figure 1. Sieve analysis for wood particles

Wood particles were obtained from the carpentry workshop of Ishik University. The wood is softwood, and the particles were collected from the sawing machine shown in Fig.2. The coarser particles were taken and the smallest dimension (thickness) distribution is shown in Fig.3. The mean thickness is (1.1) mm. The specific gravity is 0.5.



Figure.2. The sawing machine that the waste particles were collected from

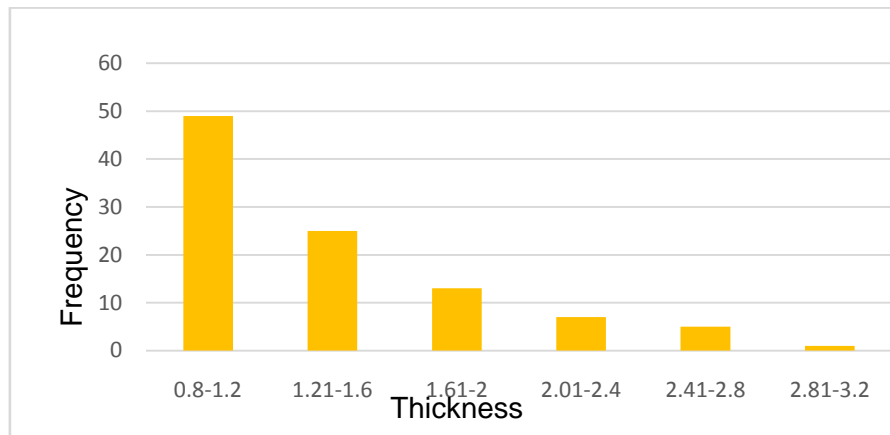


Figure 3. Wood particles size (thickness) distribution

Table 4. Light-weight mix design (mix proportions by mass kg)

	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5
Cement	100	90	80	70	60
Sand	200	180	160	140	120
water	50	45	40	35	30
Wood particles	0	9	16	21	24
w/c	0.5	0.5	0.5	0.5	0.5

Light-weight wood-particles concrete mixing method consisted of weighing of materials and mix them dry with hand mixer. Then, adding about half of the required water and mixing continued for 1 minute. Then mixing continued with adding the remaining water for 1 minute.

### 3.2 Specimens

Mixture was cast in prismatic cylindrical molds (40mm diameter and 10mm thickness), for thermal conductivity plates with dimension (40mm diameter and 10mm thickness), were prepared. Molds were filled and then evened with trowel.

Fresh light-weight wood-particle concrete properties were determined. Plunger penetration test method was performed for all five concrete mixes and was tested according to BSEN 1015-4.

### 3.3 Density of wood particles concrete

Table 5 presents the physical properties of wood particles concrete. Air-dry, dry, and saturated densities are listed for all the tested mixes. Respectively, these were ranged (2340 – 1520), (2112 – 1270), and (2400 – 1680) kg/m<sup>3</sup>. Absorption values ranged (13.6% – 32.3%) for control mix to 40% wood particle mix.

### 3.4 Thermal conductivity

Thermal conductivity is a property of materials that determines the rate of heat flow through the material. Measurement of thermal conductivity involves the flow of heat from one end of the specimen to the other end. The relationship between heat energy per unit time (power)  $Q$  and flowing down a specimen of a given cross sectional area  $A$  is

$$Q = k A (dt/ dx) \dots (1)$$

Where,  $k$  is the thermal conductivity of the material, W/m. C, and  $(dt/dx)$  is the temperature gradient. (Tritt, Terry M)

The test apparatus available in Department of Physics, College of Science, Salahadin University, Erbil, Iraq was used to generate an approximate one-dimensional heat flow through the sample (40 mm in diameter and 10 mm thick) and to achieve the desired mean sample temperatures, in order to obtain the sample thermal conductivity from steady state temperature measurements. The thermal conductivity values for the samples were ranged from 0.609 to 1.900 W/(m C) .

The thermal conductivity values were found displaying an exponential functional relationship with the air-dry density of the woo-particles aggregate concrete, as follows:

$$k = 0.068e^{0.0014w} \quad (2)$$

Figure 4 presents a plot of the results of thermal conductivity against air-dry density. The thermal conductivity ranged from about 0.609 W/(m C) to 1.900 W/(m C). The heat transfer is essentially one-dimensional through the samples.

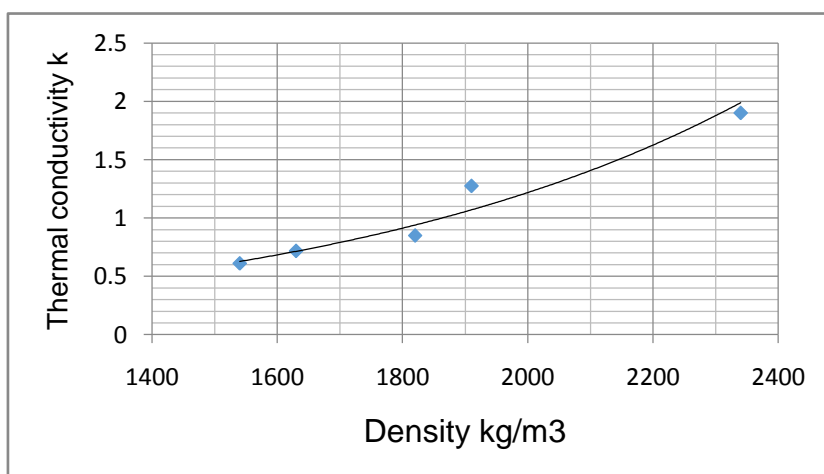


Figure 4. Thermal conductivity- air dry density relationship of wood particles concrete

Table 5 shows the results of air-dry densities and the corresponding thermal conductivity values. Also shown in the table the dry and saturated densities. The water absorption ranged between (%) for control mix to (%) for 40 % wood particle concrete.

Table 5. Physical properties of light-weight concrete with wood particles

Mix	Density (air dry) kg/m <sup>3</sup>	Density (dry) kg/m <sup>3</sup>	Density (saturated) kg/m <sup>3</sup>	Water absorption %	Thermal conductivity W/m C
0	2340	2112	2400	13.6	1.900
10	1910	1800	2084	15.8	1.274
20	1820	1624	1936	19.2	0.849
30	1630	1408	1766	25.4	0.717
40	1520	1270	1680	32.3	0.609

#### 4. Discussion

Light-weight concrete made from wood particles provides mechanical and physical properties which are influenced by selected concrete mix design. The varying of quantity of wood particles in concrete mix results in a corresponding varying in density, water absorption, and thermal properties of light-weight concrete. Significant difference of light-weight concrete properties between mixes 0 and 40 was observed. Concrete density decreased from 2340 to 1520 kg/m<sup>3</sup>, thermal conductivity – from 1.900 to 0.609 W/(m·C). Further increase of wood granules amount improved concrete thermal properties considerably. It should be under consideration, with an eye on economy, to use increased quantity of wood particles in mix design for gaining improved concrete thermal properties. Water absorption has increased from 13.6% to 32.3% as the density decreased from 2340 to 1520 kg/m<sup>3</sup>.

Thermal conductivity has been determined as mentioned in ACI213, for concrete with oven-dry density between (320 to 3200 kg/m<sup>3</sup>) [ACI 213]. Thermal conductivity values are found related to density of concrete. Fig. 5 shows such relationships for different references along with this work. The range of densities are 800 to 2400 kg/m<sup>3</sup>, however, the wood-particles concrete of this work ranged from about 1500 to 1900 kg/m<sup>3</sup> (air-dry), or 1200 to 1800 kg/m<sup>3</sup> (oven-dry). Different relationships are proposed by different investigators. Aggregate type, aggregate microstructure, as well as aggregate grading may be the reasons for these differences. Moreover, method of testing and size of specimen are also affecting the results.

Over 400 test results of density  $w$  against the logarithm of conductivity  $k$  were presented by Valore (1980) and suggested the following equation [ACI 213, 2014]

$$k = 0.072 e^{0.00125w} \quad (3)$$

For ordinary construction, however, a good estimate of  $k$  for concrete may be obtained in the oven-dry condition and, then, it may easily be obtained for air-dry conditions. Thermal conductivity of concrete is increased by the increase in moisture content. Valore (1980) suggested that for each 1% increment in moisture by weight,  $k$  increases by 6% in relation to oven-dry density. The adjusted conductivity is calculated as follows

$$k(\text{adjusted}) = k(\text{ovendry}) \times [1 + 6(w_m - w_o) / w_o] \quad (4)$$

where  $w_m$  and  $w_o$  are densities in moist and oven-dry conditions, respectively.

A simple constant factor can be used under conditions of normal protected exposure. The thermal conductivity values, when adjusted for moisture in ordinary exposure, are to be increased by 20% over standard values for oven-dry concrete. This results in adjusting Valore equation (equation 1), which now becomes (ACI 213, 2014):

$$k = 0.086 e^{0.00125w} \quad (5)$$

Asadi et al (2018) proposed a relationship of thermal conductivity-concrete density based on 185 experimental data available in literature for density range of (150 – 2350 kg/m<sup>3</sup>), as follows:

$$k = 0.0625 e^{0.0015w} \quad (R^2 = 0.81) \quad (6)$$

The proposed equation of this work related to wood particles light-weight concrete (equation 2) is shown in Fig. (5) together with ACI 213 equation, and Asadi equation. A comparison between these equations and the experimental equation proposed in this study clearly shows close results for the range of air-dry densities used in this work (1520 – 2340) kg/m<sup>3</sup>.

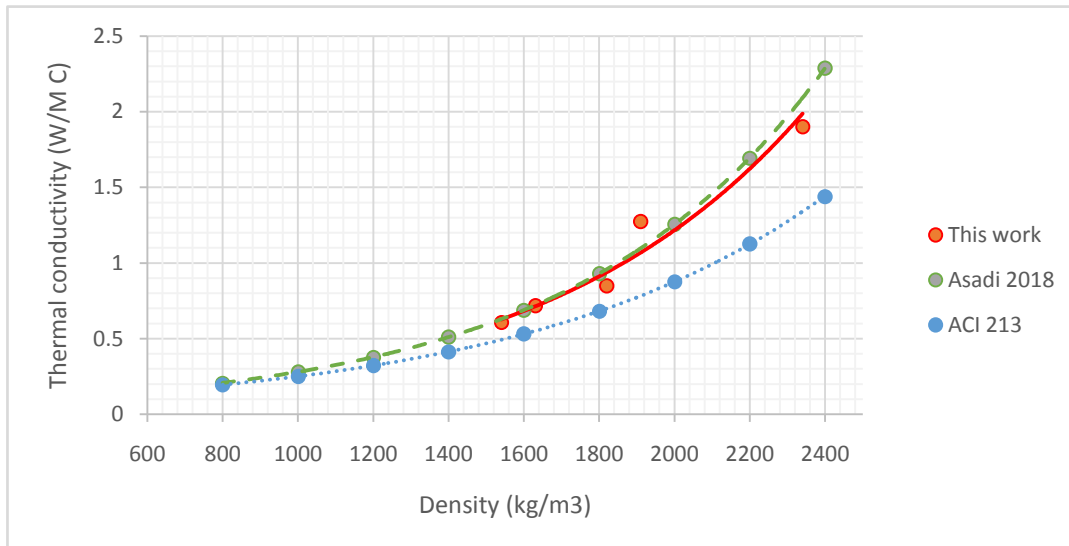


Figure 5. Equation developed for wood particles concrete relating thermal conductivity and density, compared with ACI 213 R-14 and Asadi 2108

## Conclusions

The light-weight concrete properties are influenced by the amount of wood granules in mix design. By varying the amount of wood particles in light-weight concrete mix various light-weight concrete properties can be resulted.



Thermal conductivity increases with the increasing of wood particles amount. Light-weight concrete made with wood particles can be used as an insulation material with low thermal conductivity. The thermal conductivity of light-weight concrete with wood particles is depended upon the thermal properties of cement paste and the wood particle properties.

It can be concluded that further increase of wood particle amount in mix design provides reduction in concrete thermal conductivity which is important for sustainability reasons.

By increasing wood particles amount in light-weight concrete its density could be reduced from 2340 to 1520 kg/m<sup>3</sup> and thermal conductivity from 1.900 to 0.609W/(m·C).

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