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Improve the Acoustic Impedance and Thermal Conductivity of Mortar by Adding Recycled Rubber

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Abstract: *Because of environmental problem associated with the disposal of waste automobile tires we need to find an environmentally friendly solution.In this research different mixes were prepared with Cement-Sand ratio (1:3) and Water- Cement (0.5). Two sets were prepared by partially or full replacing the sand with crumb rubber to fabricate the rubberized mortar mixtures. The first set include fine crumb rubber with particles size (0.3-1 mm), The second set include coarse crumb rubber with particles size(1.18-2.36 mm). Each set was consist of different percentage of replacing the sand by crumb rubber (10,30,50,100%) by volume. Tests were conducted, including density, Ultrasonic Pulse Velocity,Thermal Conductivity, and measuring Acoustic Impedance. several results obtained including. The full replacement (100%) of sand by crumb rubber was the highest insulation properties(acoustic impedance and thermal conductivity), while it was the lowest in density. addition of recycling rubber decrease the density of mortar, the increase in percentage of recycling rubber cause increase in insulation properties, different particles size of recycling rubber effects on the behavior of the measuring properties.*

Key Words: *rubberized mortar, crumb rubber, Thermal Conductivity, Acoustic Impedance.*

I. Introduction

The disposal of used tires in landfills is becoming unacceptable because of the rapid depletion of available sites for waste disposal.Landfill has been one of the most convenient ways of disposing of waste tires.Which are filled with tremendous amounts of scrap tires. As rubber tires are extremely durable and not naturally biodegradable, they will remain in landfill with very little degradation over time, presenting a continuing environmental hazard.[1,2]

These stockpiles are dangerous not only because they pose a potential environmental threat, but also are fire hazards and provide breeding grounds for mosquitoes.[3]

A great tire fire can burn for several weeks or even months, at times with marked effects on the neighboring environment. The air Contaminants from fires include polyaromatic hydrocarbons, CO, SO_2, NO_2, and HCl. The hightemperatures of tire fires causes also the partial breakdown of the rubber into an oily material. Long lasting burning boosts the likelihood of surface and groundwater pollution by this oily material. Scrap tires present both a challenge and an opportunity. The challenge is in how to dispose them in a safe and sustainable manner, while the opportunity is to turn a waste stream into a resource.[1,2]

The solutions adopted worldwide include:(i) reuse of re-treading tires and second-hand market, (ii) material recovery from whole, chopped, shredded and micronized tires, and (iii) energy recovering.[4]

Another way of taking advantage of the residue, through the civil construction, is the use in cement kilns, artificial reefs or its incorporation in mortars and concretes.[5]

Several projects utilize waste/scrap rubber tire such as asphaltic concrete mixture, construction materialsand sound barriers. Implementation of recycled rubber for acoustic application is of high interest since basically, crumb rubber has good absorption coefficient and presenting good resistance to severe weather conditions. In acoustic composite, crumb rubber is often used for reinforcement and mixing material. [6]

The crumb rubber concrete exhibits superior thermal and sound properties than plain concrete as measured by the decrease in thermal conductivity coefficient and the increase in sound absorption coefficient and noise reduction coefficient . The coefficient of thermal conductivity is the main indicator of the thermal insulation property for any structure.[7]

II. Aims

This work investigates the influence ofthe percentage and particles size of crumb rubber, obtained from used automobile tires, on the thermal conductivity and acoustic impedance properties of mortar.

III. Experimental Procedure

3.1.Materials

3.1.1 Cement:

The cement that used is ordinary Portland cement produced at northern cement factory (Tasluja-Bazian). It was stored in dry place to minimize the effect of humidity on cement properties and it was tested by (National Center for Laboratories and Construction Research). Tables (1) show the chemical composition and physical properties of the cement used throughout this work. It is matched by the Iraqi Reference Guide indicative number (198) and the Ministry of Planning / Central Agency for Standardization and Quality Control Manual 198/1990.[8]

Table (1): Chemical and physical properties of Ordinary Portland cement.

Chemical composition			Physical composition		
Item	**Content %**	**Limit of Iraqi specification No.5/1984**	**Physical properties**	**Test result**	**Spec. Limit**
CaO	63.19	---	Fineness (m^2/kg)	370	230
SiO_2	20.60	---	Autoclave exp.	0.32	0.8%
AL_2O_3	4.10	---	Compressive strength (MPa) 3-days age	29.5	15.0
Fe_2O_3	4.48	---			
SO_3	1.98	< 2.8%	Compressive strength (MPa) 7-days age	35	23.0
MgO	2.28	≤ 5%			
L.O.I Loss on Ignition	2.45	≤ 4%	Time of setting Initial (min.)	35	45
I.R Insoluble Residue %	0.47	≤1.5%	Time of setting Final (hour)	5.25	10 Max.

3.1.2 Fine Aggregate:

Al-Ekhaider natural sand with fineness modulus of (2.84)and Specific gravity (2.65) is used as fine aggregatewith maximum size of (3.35mm) is used in making the specimens. The grading of the fine aggregate is shown in Table (2). Results indicate that the fine aggregate grading is within the requirements of the Iraqi Specification No.45/1984.[8]

Table (2): Grading of fine aggregate.

mesh size (mm)	% Passing by Weight	Specific Limit
4.75	95.3	90-100
2.36	83.7	70-100
1.18	71.9	55-90
0.60	51.8	53-59
0.30	21.2	8-30
0.15	4.7	0-10
Percentage of salts%	0.4	≤0.5

3.1.3 Crumb rubber:

The crumb rubber used in this work was provided byBabylon Tires factory. Two different sizes of crumb rubber were used, namely fine rubber its particlessize (0.3-1mm) and coarse rubber its particles size (1.18-2.36 mm) as shown in fig (1). The chemical and physical properties of crumb rubber used throughout this workare given in table (3).[9]

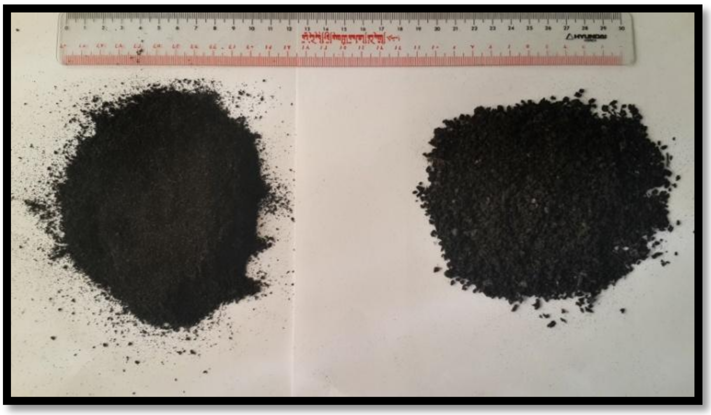

Fig. 1 different sizes of crumb rubber

Table (3): chemical and physical properties of crumb rubber•

Chemical composition		Physical composition	
Rubber hydrocarbon	**Content %**	**Physical properties**	**Test result**
Rubber hydro Carbon (SBR)	48%	Density	0.95 g/cm3
Carbon black	31%	Ultimate tensile strength	9 MPa
Acetone extract	15%	Elongation at break	150%
ash	2%	Hardness shore A	64
Residue chemical balance	4%		

•based on the results ofBabylon Tires factory laboratory

3.1.4 Water:

Distilled water was used for the specimensin casting and curing.

3.2.Experimental work

Different mixes were prepared with Cement-Sand ratio (1:3)and Water- Cement (0.5). Two sets were prepared by partially or full replacing the sand with crumb rubber to fabricate the rubberized mortar mixtures. The first set include fine crumb rubber with particles size (0.3-1mm),The second set include coarse crumb rubber with particles size(1.18-2.36 mm). Each set was consist of different percentage of replacing the sand by crumb rubber (10,30,50,100%) by volume. The rubberized mortar mixture are illustrated in table(4).

Table (4) mix design proportions for fine and coarse recycling rubber specimens.

Specimen No.	Rubber vol%	Cement Kg/m^3	Sand Kg/m^3	Crumb Rubber Kg/m^3	Water L/m^3
A	0	512.8	1538.4	-	256.4
B	10	512.8	1384.5	55.3	256.4
C	30	512.8	1076.8	166.2	256.4
D	50	512.8	769.2	277	256.4
E	100	512.8	-	554	256.4

To achieve a homogenous distribution of the materials ,Sand, cement and rubber were placed in the pan at the same time and dry-mixed by hands for 2-3 min.The materials were mixed with water by electrical mixer (Automix, Controls Co. Italy) for additional 4 minaccording to (ASTM C305)[10].After complete mixing, the rubberized mortar was poured in molds ,which were coated with mineral oil to prevent adhesion with rubberized mortar.rubberized mortarcasting was accomplished in three layers. Each layer was compacted by using a vibrating device (Viatest Co. German) for 1-1.5 minutes until no air bubbles emerged to the surface of the casting.

Fig 2.Photo of Some specimens after de-molding.

IV. Tests

The tests were carried out on the specimens after 28 days which continuously cured at 20ºC.

4.1 Density Test

The density of the various mixes were determined according to standard procedures (ASTM C642)[11]in (kg/m^3)was found by weighing the specimens and dividing the values (mass in kilograms) by the volume of the specimen. (using 2-in. or [50-mm]cube specimens).

4.2 Ultrasonic Pulse Velocity Test

This test was carried out according to ASTM: C597[12],using the portable ultrasonic non-destructive indicating tester (PUNDIT Lab PROCEQ Co.) Switzerland, as shown in figure (3). Two transducers are fitted to the instrument cables, one acts as a transmitter for the ultrasonic pulses, and the second acts as the receiver. Both transducers are held against the surface of the specimen using coupling agent(such as water, oil, petroleum jelly, grease, moldable rubber, or other viscous materials) in this work apetroleum jellywas applied between the tested surfaces of the specimen and contact faces of the transducers to ensure good pulse transmittance. and pressure must be applied to the transducers to ensure stable transit times. In this test, a pulse of longitudinal vibration with resonant frequencies of 54 kHz was produced by an electro-acoustical transducer and then converted into an electrical signal by receiver transducer.The transit time of the pulse is applied by an electronic timing circuit. The pulse velocity (V) in (m/sec.) was calculated as follows:

V=L/t ……………………..(1)

where: L = distance between centers of transducer faces, m, andT = transit time, s.

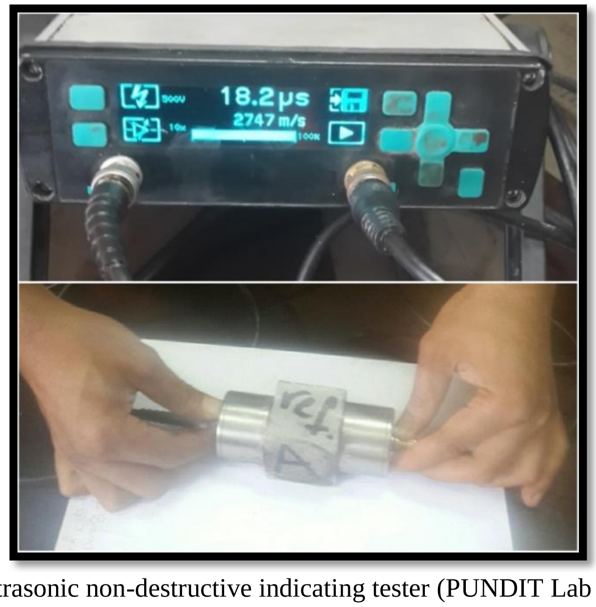

Fig.3. Photo of portable ultrasonic non-destructive indicating tester (PUNDIT Lab PROCEQ Co.) Switzerland.

4.3 Acoustic Impedance measurement

It is a measure of the amount by which the motion induced by a pressure applied to a surface is impeded.[13]The acoustics impedance of a medium is a measure of how easy it is to transmit sound waves through that medium. It is found that acoustic impedance depend on the velocity of the wave in the medium and the density of the medium. Since velocity and density vary between media, it follows that different acoustic impedances. When ultrasound meets an interface between different media, the wave undergoes reflection, transmission (refraction) and absorption.[14]The acoustic impedance (Z) of a material is defined as the product of the density (ρ) of the material and the velocity (v) of sound in it, as in equation(2).It depends on the density and elasticity of the material.[15]

$$(Z = \rho \times v) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

4.4Thermal conductivity Test

The thermal conductivities of the specimens(20×50×100mm) were measured by using (power supply; QTM 500 meter; Kyoto Electronics Manufacturing, Japan).It is range from0.023 to 12W/mk based on the ASTM C 1113-99[16] hot-wire methodbecause it is a fast and accurate method for measuring of thermal conductivity of insulating materials. Measurement range is 0.023 to 12W/mk.It involves placing the rectangular specimen in the probe box and then placing the sensor probe (PD-11) on the specimen surface. These specimens should be large enough so that the heat from the hot wire is not lost through the surrounding hence leading to errors in measurement. The sensor probe consists of a constantan (is a copper-nickelalloy) wire heater and a chromel- alumel thermocouple. The heating wire is used to supply heat to the test specimen and the thermocouple monitors the heat flow rate. The measurement result is shown on display immediately after the measurement is finished (after 60s).as shown in fig. (4).

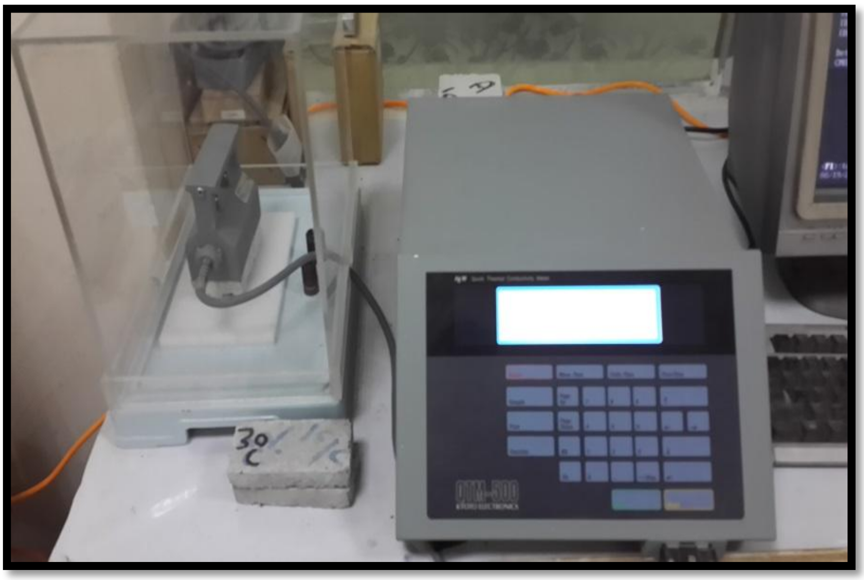

Fig.4.Photo of Thermal conductivity meter (QTM-500)

V. Results and Discussions

5.1 Density Test

The density of rubberized mortarspecimens were measured, as shown in fig (5). The results show that the control mortar is the highest densitythan rubberized mortar, This can explained by the density of rubber is lower than mortar.

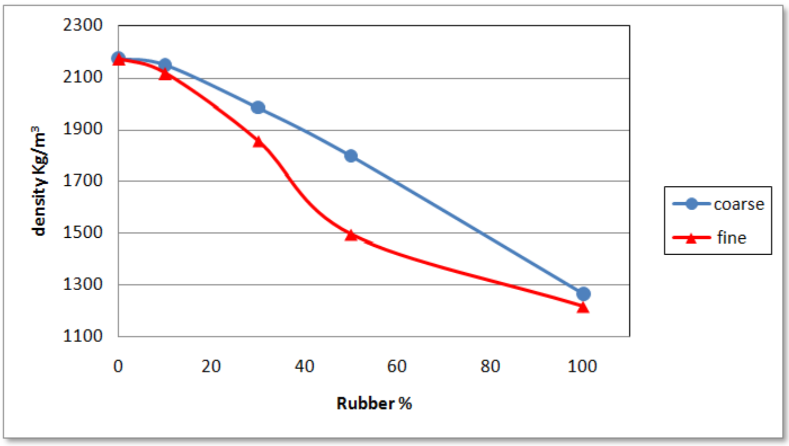

Fig. 5. Effect of different rubber percentage on density of rubberized mortar

5.2 Ultrasonic Pulse Velocity Test

The velocity of sound travel through the specimens can be detected by carrying ultrasonic test as shown in fig (6)and fig (7). The velocity of the specimens have different values according to the rubber percentages. Increase in rubber percentages cause decrease in velocity, and fine rubberized mortar have higher velocity than coarse rubberized mortar. This can be clarified bycapability of rubber on the sound absorption and distribution in different directions.

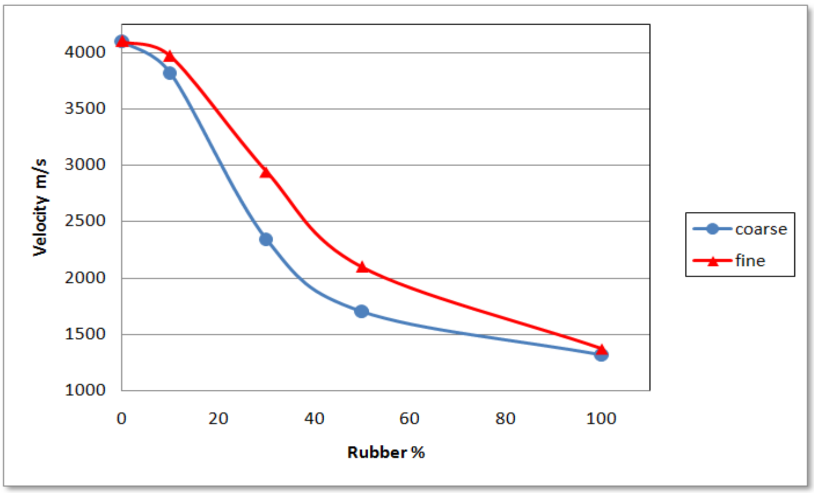

Fig. 6. Effect of different rubber percentage on the ultra sonic velocity of rubberized mortar

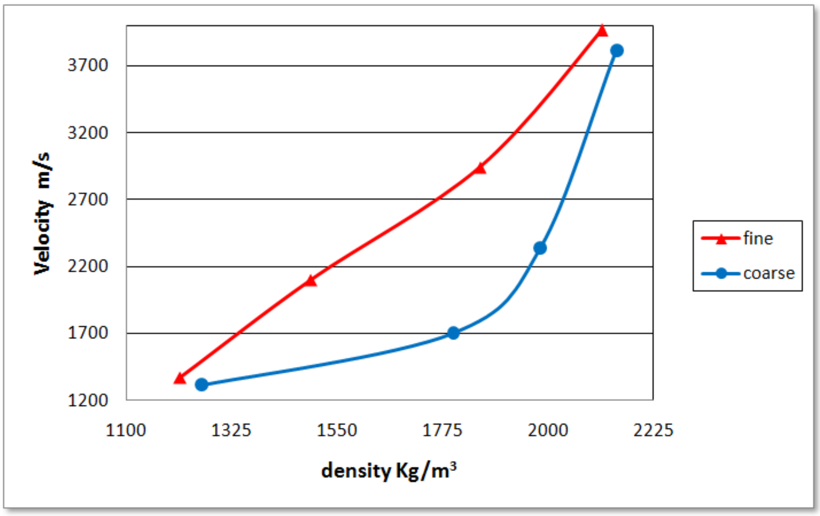

Fig. 7. Effect of density difference on the ultrasonicvelocity of rubberized mortar.

5.3 Acoustic Impedance measurement

The Acoustic Impedance of the rubberized mortar specimens have different values as shown in figure (8) and (9). Increase in rubber percentage cause decrease in Acoustic Impedance values, unlike decrease in rubber percentage cause Increase in density and acoustic impedance values.

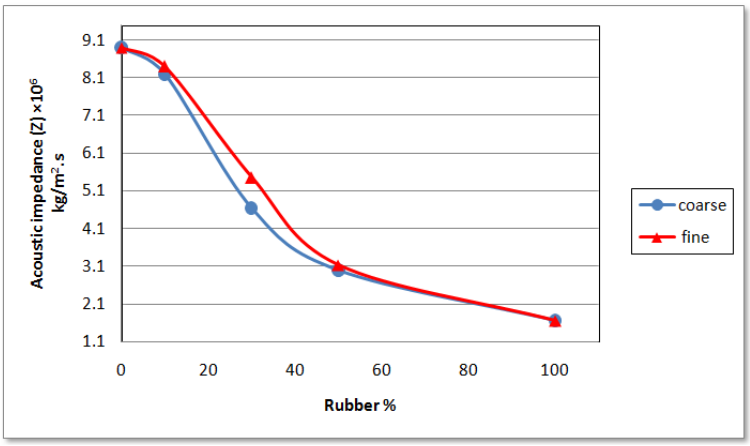

Fig. 8. Effect of different rubber percentage on the acoustic impedance of rubberized mortar

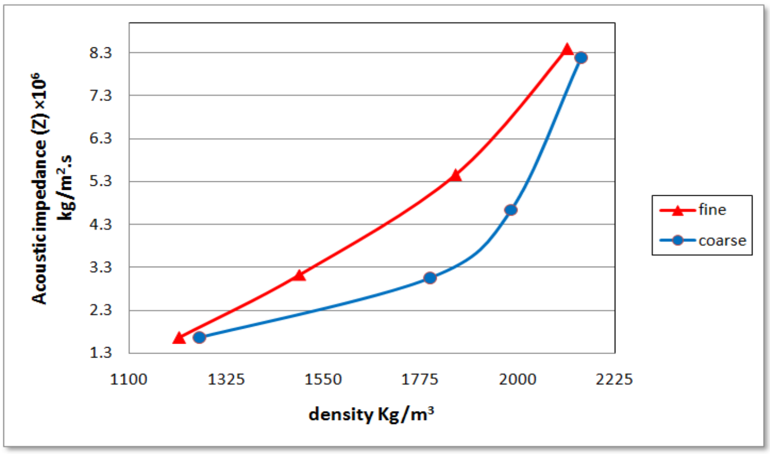

Fig. 9.Effect of density difference on theacoustic impedance of rubberized mortar

5.4Thermal conductivity Test

The thermal conductivity of the rubberized mortar shown in figure (10) and (11). The thermal conductivity decrease with rubber percentages increase, and fine rubberized mortar had higher effect on the thermal conductivity than thecoarse rubberized mortar. This behavior is because the rubber has a low thermal conductivity coefficient than mortar, which make better in thermal insulation.

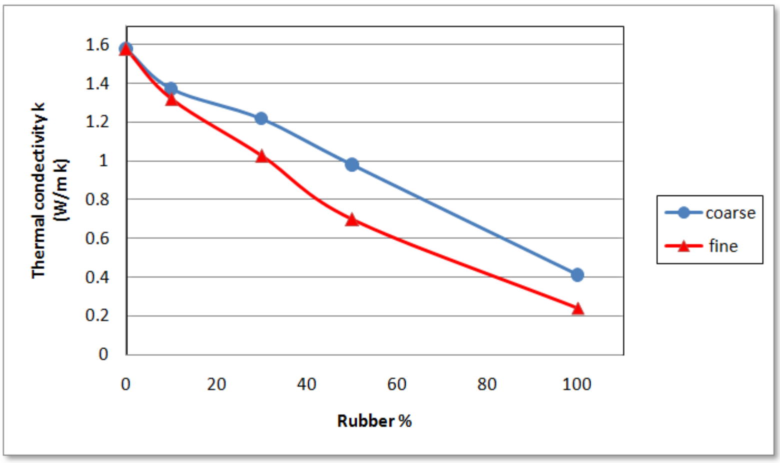

Fig. 10.Effect of different rubber percentage on the Thermal conductivity of rubberized mortar

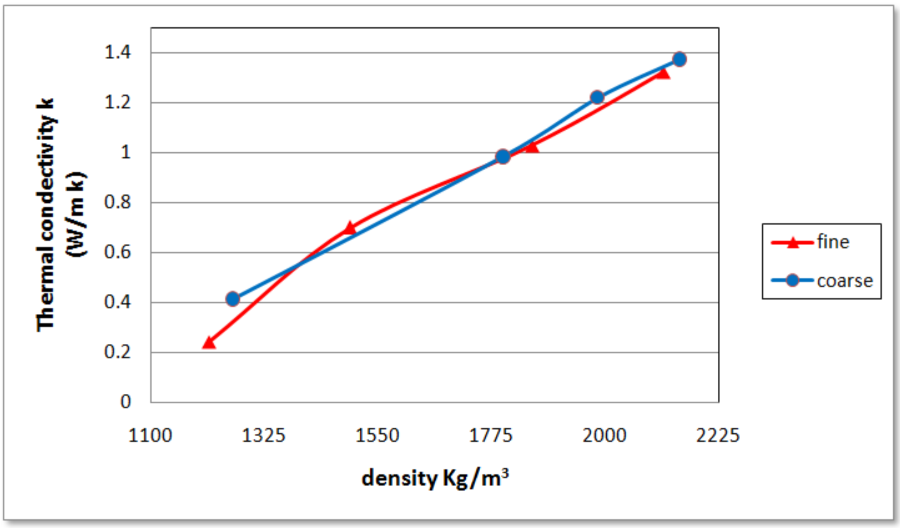

Fig. 11.Effect of density difference on the Thermal conductivity of rubberized mortar

VI. Conclusion

The following main conclusion were achieved from this work, improve the Thermal conductivity and acoustic impedance of mortar by adding recycling rubber, the addition of recycling rubber decrease the density of mortar, the increase in percentage of recycling rubber cause increase in insulation properties, different particles size of recycling rubber effects on the behavior of the measuring properties.

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