Evaluation of Acoustics Insulation and Thermal Conductivity Through Walls in a Building

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ABSTRACT

Anew type of porous clay bricks is proposed , this research studies the effect of adding industrial wastes admixtures with different percentages on the thermal and acoustics insulation properties of clay bricks . Different types of admixtures were used in this work ,including plastic cuttings ,wood saw dust ,palm fiber with (5% ,10% ,15% ,20) percent of weight of each one . Acoustics insulation , thermal conductivity ,specific heat capacity ,porosity and variation of density have been examined for each samples at all percent of admixtures and comparing with the reference clay bricks samples . Form the obtained test result show the admixtures effect on the properties of clay bricks , the best material which can used from this paper is palm fiber to get the best properties of acoustic insulation , thermal conductivity and density for 20% admixtures percentage comparing with the standard bricks .

Key word: porous brick, inorganic wastes , organic wastes , acoustic insulation ,thermal conductivity .

تقييم العزل الصوتى والتوصيل الحرارى خلال جدران البناية

الخلاصة

يهدف البحث الى دراسة نوع جديد من الطابوق الطيني المتسامي , تناول البحث دراسة تاثير اضافة المخلفات الصناعية بنسب مختلفة على الخواص العزل الصوتي والتوصيل الحراري للطابوق الطيني , تم اختيار مفروم البلاستك ونشارة الخشب وليف النخيل و اضافتها كل على حدة بنسب (٥% , ١٠% , ١٥% , ٢٠%) لكل منها , تم تقييم مقدار العزل الصوتى

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,التوصيل الحرارى , السعة الحرارية النوعي و المسامية ولكل نسبة من النسب اعلاه ومقارنتها مع الطابوق الطيني القياسي (بدون اضافة). تم استنتاج ان استخدام هذه المضافات يوثر عاى خواص الطابوق الطيني وان افضل مادة يمكن استعمالها من خلال البحث هى ليف النخيل لحصولها عاى احسن المواصفا ت العزل الصوتى و التوصيل الحرارى والكثافة و بنسبة خلط ٢٠% مقارنة مع الطابوق القياسى .تم تصنيع النماذج الطابوق فى معمل الطابوق فى النهروان و تم فحصها فى مختبرات اقسام الجامعة التكنولوجية .

INTRODUCTION

The widespread use of generators is a phenomenon in our life today ,due to the continuous electric power shortage (shut down). Therefore , acoustic enclosure for portable electric generator (5KVA) is constructed to control emitted noise from it which affect human (hearing loss , hypertension , cardiac disease ,stress ,worker productivity , ….etc). Noise is considered to be any unwanted sound that may adversely affect the health if it goes beyond certain level it may harm individuals or populations .This definition implies that a sound may be disturbing to one person may go unnoticed or even be liked by another [1]. However , when the sound level is too loud ; nobody can avoid being affected by it . In contrast to many other environmental problems , noise pollution is increasing , especially in the living environment [2].

The perception of sounds in day -to –day life is of major importance for human life . communication through speech ,sounds from playing children , music ,natural sounds in parklands , parks and gardens are all examples of sounds essential for satisfaction in everyday life [3].Physically ,there is no distinction between sound and noise ; sound is a sensory perception evoked by physiological processes in the auditory brain . In some situations noise may adversely affect health in the form of acoustical energy . Table (1). Lists dBA noise levels for common events in the environment. [4]

Table(1)Typical sound levels measured in the environment and industry .[18].

Noise source (feet)	Weighted sound level in dBA	Subjective impression
Civil defense siren (100) feet	130	Threshold of pain
Jet takeoff (200) feet	120	=
Rock music concert (50) feet	110	=
Pile driver (50)feet	100	Very loud
Ambulance siren (100) feet	90	=
Diesel locomotive (25)	85	Loud

feet		
Pneumatic drill (50)feet	80	=
Freeway (100) feet	70	Moderately loud
Vacuum cleaner (10) feet	60	=
Light traffic (100) feet	50	=
Large transformer (200) feet	40	Quiet
Soft whisper (5) feet	0-30	Threshold of hearing

Heat leak through building walls and ceilings consume substantial amount of energy . Since climate control units require a significant amount of electric energy , studies of heat leak has received considerable attention in the past decades .An accurate estimate of the heat leak through the composite ,walls accompanied with practical low cost method for reducing the heat leaks is an effective way of reducing energy consumption . Bricks are major wall elements where the modes by which heat transfer occurs are heat conduction in the solid section and natural convection with in the cavities. It is useful to show some previous studies related to the present research.

Lacarrier et al [5], analyzed numerically the vertically perforated bricks .They reported that walls can be constructed without any other materials than clay and mortar .They reported that heat transfer in these assemblies is not totally understood .For perforated brick construction, it is indicated that convection heat transfer is negligible in the perforations .Therefore, the thermal resistance of the brick increases.In a particular study of the ruptures it is concluded that the convection present in these regions is a local phenomenon since it breaks the thermal bridges created by the mortar fill.

DEL . Coz .Diaz [6,7] . Carried out an experimental and numerical study to investigate the thermal transmittance coefficient , of a wall made of Arliblock bricks . They observed that wall insulation decreases with the increase in the mortar and material conductivities . They also noticed that changing the profiles of the holes alters the rate of the heat transfer through the hollow blocks. Then, they studied major variables influencing the thermal conductivity of masonry materials and carried out an optimization study for different brick geometries based on both thermal resistance and weight .

Al-Hazmy[8] . Investigated the heat transfer through a common hollow building brick . I insulations assessment of the building blocks was examined based upon the heat transfer rate . Three different configuration for building bricks were studied including ages-filled and insulation -filled cavity .Results show that the cellular air motion inside blocks , cavities contributes significantly to the heat loads .The insertion of polystyrene bars reduced the heat rate by maximum of 36% .

Lee and Pessiki [9] .Carried out a study to investigate the performance characteristics of precast concrete sandwich wall panels with two or three withes separated by air layers .It was found that , in general ,the thermal performance of three-Wythe panels is better than that of two-Wythe panels due to the increased thermal path length.

Trent S.Dinn, E.I.T.[10] ".A petrochemical plant received noise community , which identified normal plant flaring and plant upset flaring as areas of concern . Tests were conducted to determine the effect of process flow condition and the pulsating flame on the flare stack generator noise from both a Refinery flare and process flare .It was concluded that the flare stack noise oscillations were greater for the process flare than for the Refinery flare stack.

Suebsak and Supphawat[11] , presented an analytical procedure to develop a noise contour map of work place . The procedure requires the input of ambient noise level , noise levels generated by individual machines .A set of mathematical equations is developed to estimate the combined noise level at any predetermined location of the work place floor . Contour lines are then drawn to connect points having equal noise levels . Although the developed method is based on estimated data , the resulting noise contour map may allow engineers to quickly construct the noise contour map and revise the map when changes is occurred in noise levels due to awork place re-layout.

Madbuli[12] , ,the goal of the research was measuring SPL in the factory at the old machine which was made in 1950 in Egypt and he found that the SPL arises to 103 dB at average 98 dB at frequency band 1200-2400 Hz in spinning department which the velocity of machines was 170-190 rpm but in weaving department the velocity of machines was 96 rpm the SPLarrive 94 dB at frequency band1200-2400 Hz.

Wu . et .al[13], studied vehicle sound signatures. The aim is to recognize these vehicle sounds by frequency vector analysis . They adopted eigenvector method to achieve simple and reliable acoustic identification . A collection of typical sound sample in used as the training data set in their system .Results showed that the developed methodology can provide essential information regarding the sound signature identification that is not provided by other traditional method.

Phonphuaka [14] ,studied the effect of adding charcoal on mechanical and physical properties of brick ,they found that an increase in porosity result from adding charcoal which result indecreasing in density ,water absorption and compressive stress .

The proposed method maintains a high compressive strength , which result in high load bearing wall , enhancement of thermal insulation and acoustic insulation properties , lower densities , lower transport costs ,and higher brick production per tones of clay Plastic cuttings Plastic brick consist of , aggregate plastic and water at various proportions . Since the plastic have low density ,the product has the property of light weight , the size of plastic particles

varies almost pass through sieves, and analysis was made at Babylon tires factory . The chemical compositions of admixtures are as shown in Table(2).

Table(2) Chemical composition of plastic cuttings.

Composition	Content %
Plastic cuttings hydrocarbon	51
Carbon black	32
Actone extract	11
Ash	2
Residue chemical balance	4

Grading

The grading of plastic cuttings, wood sawdust and palm fiber is the same of grading of sand according to the limit of Iraqi specification No.45/ 1984 (% by weight) and second grading zone, the physical properties of plastic cuttings as shown in Table(3).

Table(3)Physical properties of plastic cuttings.

Property	Specification	Result	Limit of I.O.S. No.45/1984
Bulk specific gravity	ASTM C-128-01	1.2	-
Absorption %	ASTM C-128-01	0	-

Wood saw dust

Wood saw dust have been used for making light weight bricks .Saw dust is abundantly available in most places but it often contains substance which retards the hydration and hardening of bricks .The extent of deleterious effect varies with the type of wood . High drying shrinkage of wood saw dust bricks limits its use to design where freedom of movement is possible .The chemical composition of wood saw dust are as shown in Table (4) and physical properties in Table(5).

Table(4) Chemical composition of wood saw dust (analysis was made at X-Ray diffract -Meter type XRD-6000) .

Oxide composition	Content %
Sio_2	86.2

$Casio_3$	2.8
Mgo	2.5
Al_2o_3	4.5
So_3	2.2
Lossof ignition	1.8

Table(5) Physical properties of wood sawdust.

Property	Specification	Result	Limit of I.O.S. No45/1984
Bulk specific gravity	ASTM C128-01	0.8	-
Absorption %	ASTM C128-01	Saturated surface dry	-

Palm fiber

Light weight brick using palm fiber as aggregate has been used for making precast bricks for walls and slabs for wall partitions . The wastes products of palm fiber generated from the accumulation of the outer covering of palm grains during the milling process .The chemical composition of palm fiber are as shown in Table (6) and physical properties in Table(7).

Table(6) Chemical composition of palm fiber(analysis was made X-Ray diffract- Meter type XRD-6000) .

Oxide composition	Content%
Sio_2	87
Cao	2
Mgo	1.7
R_2o_3	3.6
So_3	0.7
Loss on ignition	5

Table (7) Physical properties of palm fiber Clay.

Property	Specification	Result	Limit of I.O.S. No45/1984
Bulk specific gravity	ASTM C-128-01	0.4	-

Absorption %	ASTM C-128-01	Saturated surface dry	-

Table(8) Chemical composition of clay (analysis was made at X-Ray diffract –Meter type XRD-6000).

Oxide composition	Content%
Al_2o_3	20
Sio_2	60
Iron oxide	5
Lime	5
magnesia	10

Experimental test

The main idea in creating porosity in brick is that the industrial wastes will be mixed with wet clay and when the created wet brick enter the oven , the wastes(plastic cuttings , wood saw dust and palm fiber) will be burnt inside the brick after it occupies an original volume inside the clay and after firing process the volume of the wastes will be filled by the product of burning (ash and gases) .The voids volume will be filled by gases since the resulting ash will occupy about 6% of the original volume also the mass reduction is calculated and it is found to be about 90% .The wastes will be burnt which result in gases and ash that have negligible and density , the porosity of the brick can be controlled by the initial mass fraction of wastes that mixed with wet clay . Test have been made for solid ,hollow and proposed bricks to measure their apparent porosity ,density ,acoustic insulation and thermal conductivity. A simple procedure has been used to measure the density of the brick where dimensional and mass measurement are used to obtain density also apparent porosity can be obtained as conforms to ASTM standard C373-88 [15].The uncertainties are found to be around $\pm$ 0.2% . The samples which is produced in the factory in the Nahrawn city in Bagdad are as shown in Figs-1,2,3.

1.Brick manufacturing.

The raw material (clay) is crushed and grinded ,then the blend of ingredients desired for each particular batch is selected and filtered then the wet clay is

mixed with a proper mass of sawdust ,palm fiber and plastic cuttings before being sent to brick shaping processes (pressing) .Then the samples are dried to remove excess moisture that might cause cracking during the firing process. Next, they are fired in big ovens (900 ℃) for ten hours and then naturally cooled within two days.Fig-4, show the molded bricks and the heating and cooling of brick carried in the factory.

2.Density.

Table (9) show the values density of admixtures , knowing the density of porous brick and measuring mass and volume of the porous brick ,one can calculate porosity of the brick .

Table(9) The density of clay bricks samples with different admixtures type.

Add percentage Of admixtures %by wt.	samples	ρ Plastic cuttings	ρ Wood sawdust	ρ Palm fiber
		Kg/m^3	Kg/m^3	Kg/m^3
0	Solid bricks	1780	1780	1780
5	Sample-1	1512	1455	1419
10	Sample-2	1467	1380	1347
15	Sample-3	1391	1270	1228
20	Sample-4	1295	1200	1198

1.Porosity.

Presence of admixtures may increase ,decrease or maintain the porosity of the main material depending on the aggregate sizes .The volume of liquid absorbed by a porous medium is an indication of its pore volume and it is a good approximate measure of its porosity. Hence, porosity (ϑ) is obtained with the relation . The values of porosity as shown in Table-10. The created voids brick reduce the effective thermal conductivity and acoustic insulation of brick .

$$\vartheta = V_f / V \times 100\% \qquad (1)$$

Table(10) The porosity of clay bricks samples with different admixtures type .

Add percentage Of admixtures	samples	ϑ Plastic cuttings	ϑ Wood sawdust	ϑ Palm fiber
0	solid	0.11	0.11	0.11
5	Sample-1	0.14	0.18	0.19
10	Sample-2	0.17	0.23	0.24

15	Sample-3	0.21	0.29	0.33
20	Sample-4	0.24	0.31	0.35

2.Acoustic insulation.

The experimental part was carried out in the laboratory of department of electro-mechanical engineering in university of technology to determine experimentally the acoustic insulation of clay bricks samples of admixtures with plastic cuttings , wood sawdust and palm fiber .

Sound transmission from walls of building elements have certain levels of insulation from air borne noise and impact sound. The weighted sound reduction describes the acoustic performance of a construction system . It is a single number quantity for the airborne sound insulation rating of building elements . As the acoustic performance or construction improves.

The weighted sound reduction are determined by laboratory tests of a samples(1,2,3 and 4) of the construction system . The samples is fixed with in a frame to form the wall between two test chambers. A high generated in one room and the difference in sound level between the source room and the receiver room represents the transmission loss through the test samples. The measured conducted over arrange of sound frequencies . The weighted sound reduction rating is then determined by comparing the results with reference curves. The values of acoustic insulation as shown in Tables- 11 ,12 ,13 ,this values means the transmission loss level measured experimentally and compared with many reference. [18].The process of measured the transmission sound level carried by construction of bricks walls which contain the industrial wastes for plastic cutting ,wood sawdust and palm fiber with different percentage ,the dimension of walls are meter square ,many instruments are used in this work .

1. Condenser microphone
2. Loud speaker
3. Noise generator type (1405 B&K)
4. Power amplifier type (2706 B&K)
5. Digital frequency analysis type(2131 B&K)

Table (11) The transmission loss(dBA) for palm fiber of clay bricks samples.

F(Hz) octave band	φ Sample-1 5%	φ Sample-2 10%	φ Sample-3 15%	φ Sample-4 20%	ϑ Solid 0%
70	7.9	8.5	9.3	10.2	2.2
100	8.7	9.3	16.7	17.6	5.4
250	13	15	19.6	21	6.5
500	15.9	17	22	24	7.7

1000	18.4	19	25	26.6	8.5
3000	20.2	25.3	30	38	10.6
5000	12	15.2	20	24	8.3
9000	11.5	13.7	18	20	7.9

Table(12)The transmission loss (dBA) for wood sawdust of clay bricks samples.

F(Hz) octave Band	φ Sample-1 5%	φ Sample-2 10%	φ Sample-3 15%	φ Sample-4 20%	ϑ Solid 0%
70	4.8	5.2	6.1	7.9	2.2
100	7.5	8.6	13.6	15.9	5.4
250	11.4	14.4	17.8	20	6.5
500	13.6	15.6	19.4	22	7.7
1000	15.7	17.2	21	23.1	8.5
3000	17.8	22.5	23.8	24.7	10.6
5000	10.3	14	19	20	8.3
9000	9.9	12.1	16	17	7.9

Table(13)The transmission loss(dBA) for plastic cuttings of clay bricks samples.

F(Hz) octave Band	φ Sample-1 5%	φ Sample-2 10%	φ Sample-3 15%	ϑ Sample-4 20%	ϑ Solid 0%
70	3.2	3.8	4.1	6.6	2.2
100	6.9	7.4	12.2	13.6	5.4
250	10.2	13	17.7	18.5	6.5
500	11.4	14	18	20.2	7.7
1000	14.5	15.2	19.2	21.5	8.5
3000	15.4	18.1	21.3	22	10.6
5000	9.2	13.2	17.8	18.6	8.3
9000	8.3	9.8	12	14	7.9

1.Thermal conductivity.

The experimental part was carried out in the laboratory of department of material engineering in university of technology to determine experimentally the thermal conductivity of clay bricks samples of admixtures with plastic cuttings , wood sawdust and palm fiber . The test apparatus (Less disc apparatus)

type (Griffin and George) with tested the sample of clay bricks and some accessories to measure the temperature of both sides of the sample in order to calculate the thermal conductivity as shown in Fig-6 .The values of thermal conductivity as shown in Table (14).

Table(14)The thermal conductivity of clay bricks samples with different admixtures type.

Samples	Add percentage %	K (w/m.k) Plastic cuttings	K (w/ m.k) Wood sawdust	K (w/ m.k) Palm fiber
		w/m.k	w/m.k	w/m.k
Solid brick		0.9	0.9	0.9
Hollow brick	0	0.62	0.62	0.62
Sample-1	5	0.71	0.68	0.61
Sample-2	10	0.68	0.62	0.58
Sample-3	15	0.63	0.53	0.52
Sample-4	20	0.58	0.51	0.48

The heater is switch on from the power supply with (V=6 vol and I=0.2 amp) to heat the brass disks 2 &3 and the temperature of the all disks increase in nonlinear relationship and at different rates with the heat source .And the temperature were recorded every 5- minutes until reach to the equilibrium of all disks .Fig-5 shows the sample used to measure the thermal conductivity using the (Lee,s Disk) method is in the form of adisk whose thickness (d_s=0.0035 m) is small relative to its diameter (D=0.04). Using athin sample means that the system will reach thermal equilibrium more quickly .The heat transfer across the thickness of the sample is given by :

$$Q = K . A [T_2 - T_1 / d_s] \quad (2)$$

And the thermal conductivity can be calculated by using the following equation [16].

$$K=e [T_1+ 2 / r (d_1 + 0.5 d_s) .T_1 + d_s.T_s] / (T_2 - T_1 / d_s) \quad (3)$$

And the value of (e) can be calculated from the following equation [17] .

$$I.V = \pi .r^2 .e. (T_1 +T_3) + 2 \pi .r.e [d_1.T_1+0.5 d_s (T_1 +T_2) + d_2 . T_2 +d_3 .T_3] \quad (4)$$

1.Specific heat capacity.

It is a measure of the thermal storage capacity of the material. The specific heat capacity of a clay brick indicates the relative amount of heat energy the wall built with it is capable of storing per unit mass, the values of specific heat capacity as shown in Table-15.Walls with high specific heat capacity can store more energy ,have a larger thermal and thus , generally be more effective for thermal storage and peak load shifting .This time lag effect contributes to shifting demand to off- peak periods and improves overall thermal efficiency specific heat capacity of the clay brick is determined from the classical heat capacity equation .

$$C = Q / M .\theta \qquad (5)$$

Table(15) The specific heat capacity of clay bricks samples with different admixtures type

Add percentage %	C Plastic cuttings	C Wood sawdust	C Palm fiber
	Kj /g.k	Kj /g.k	Kj /g.k
0	0.71	0.66	0.61
5	0.42	0.32	0.26
10	0.68	0.59	0.55
15	0.57	0.49	0.42
20	0.48	0.42	0.39

DISCUSSION OF THE RESULTS

1.Effect of admixtures on density

Figure (7) .Shows the density with different admixtures , concerning density a reduction is observed as mass fraction of admixtures in original wet clay brick increased ,this is clear since more volume will be occupied by dust before it burns leaving voids inside firing brick , this reduction in density will decrease cost and size necessary to achieve the task of insulation thermal conductivity reduced and increased the acoustic insulation

2.Effect on porosity

Figure (8).Shows the variation of porosity with percentage admixtures ,the results show that all the bricks with the admixtures are more porous than that of the control . This increase in porosity may be as a result of trapped air bubbles that are interconnected .

3.Effect on a acoustic insulation

Figures (9-10-11) . Show the relationship between the transmission loss and the frequency of three industrial wastes (plastic cuttings ,wood sawdust and palm fiber) with (5%, 10% ,15% and20%) admixtures. In this curves observed the

effect of the porosity on the transmission loss to the range of frequency , when the porosity is increased the transmission loss increased because the large amount of voids inside brick .

4.Effect of admixtures on Thermal conductivity

Figure (12) .Shows the relationship between thermal conductivity and admixtures percentages . It is clear that the increase of admixtures leads to decrease in thermal conductivity value .

5.Effect of admixtures on specific heat capacity

Figure (13) .The plot of the specific heat capacity against percentage admixtures ,indicates that all the bricks with the admixtures have slightly lower values except the 10%brick. Lower heat energy storing capacity and lower thermal mass .In tropical environment these bricks will lose heat gained the day faster.

CONCLUSIONS

From this work it has been obtained that :

1.These measured data lead to obtain new type effective brick having good performance with no possibility of mortar to enter inside the holes of the common used hollow brick since the mortar has a determent effect on thermal properties of the wall.

2.The density of clay brick samples are reduced 27% for plastic cuttings than solid brick and 32% for wood sawdust also 20% for palm fiber .

3.The acoustic insulation of clay brick samples are increased 10% for wood sawdust block ,20% for plastic cuttings block and 34% for palm fiber block . .

4.The thermal conductivity of clay brick samples are reduced 35% of plastic fiber,43% of wood sawdust and 46% of palm fiber for 20% admixtures percentage.

5.The best material which can used from this paper is palm fiber to get the best properties of a acoustic insulation , thermal conductivity and density for 20% admixtures percentage.

NOMENCLATURE

V_f ---- volume of water absorbed (m^3)
V ----- volume of material sample (m^3)
Q ----- heat transfer rate (kj)
K ---- thermal conductivity (w/m.k)
A ---- area (m^2)
T ---- temperature (℃)
M --- mass of sample (kg)
C---- specific heat capacity (j /g.k)
dBA --- Transmission loss level
Greek

ϑ ---- porosity (%)
φ ----- transmission loss (dBA
ρ ------ density (kg/m^3)
θ ----- change in temperature (℃)

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20% 15% 10% 5%

Figure (1) Samples for bricks which contain of industrial wastes (plastic cuttings).

20% 15% 10% 5%

Figure (2) Samples for bricks which contain of industrial wastes(wood sawdust)

20% 15% 10% 5%

Figure (3) Samples for bricks which contain of industrial wastes(palm fiber).

Figure (4) the molded brick.

Figure (5) The small samples which are used when measured thermal conductivity.

Figure (6) The Lees Disc apparatus.

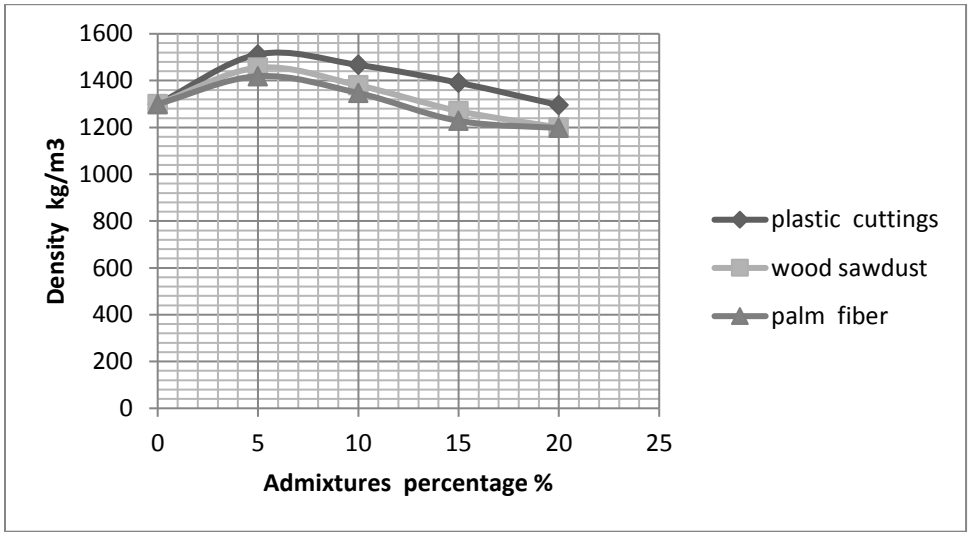

Figure (7) The density of clay brick with different admixtures percentage %.

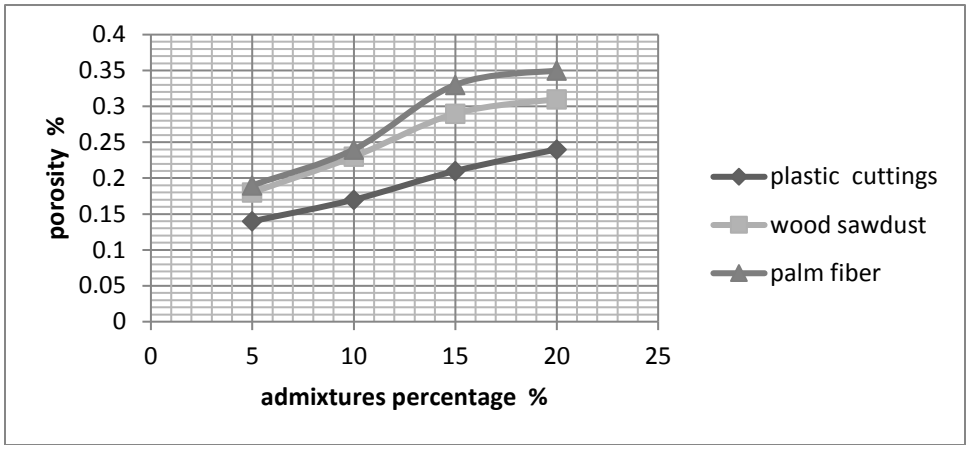

Figure (8) The porosity of clay brick with different admixtures percentage %.

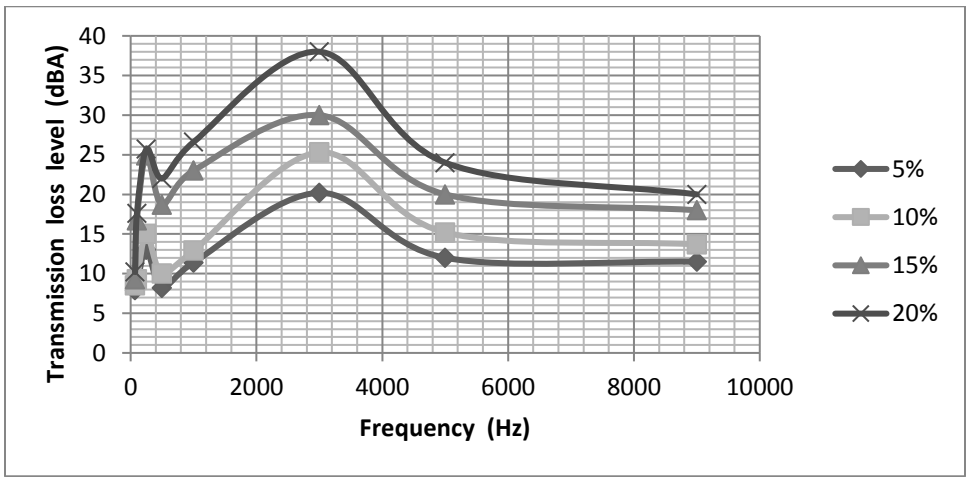

Figure (9)Transmission loss level with frequency of palm fiber.

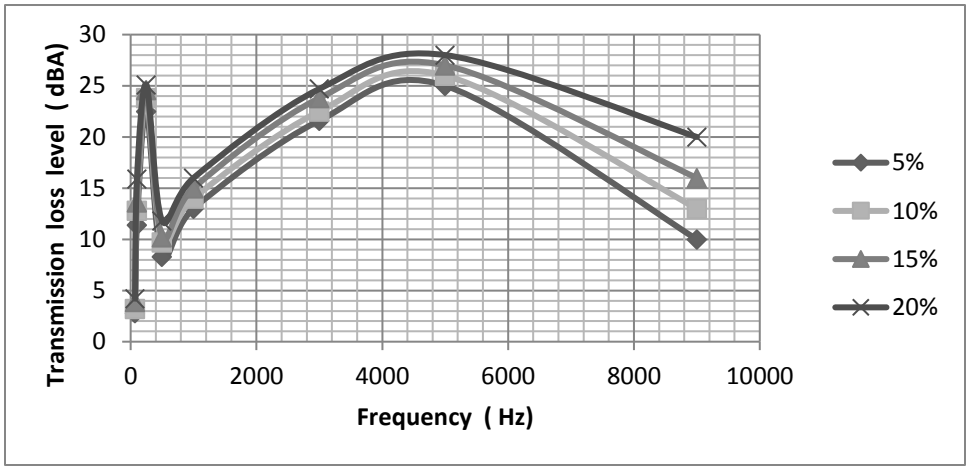

Figure (10) Transmission loss with frequency of wood sawdust.

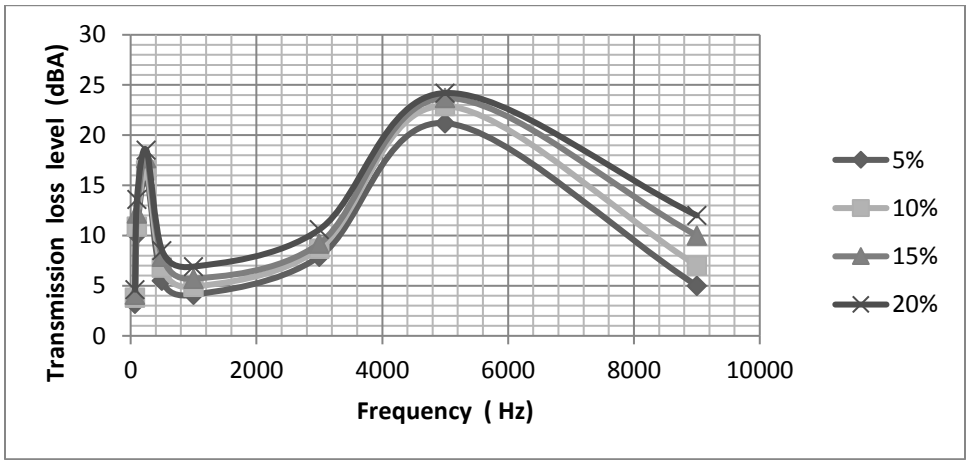

Figure (11) Transmission loss with frequency of plastic cuttings.

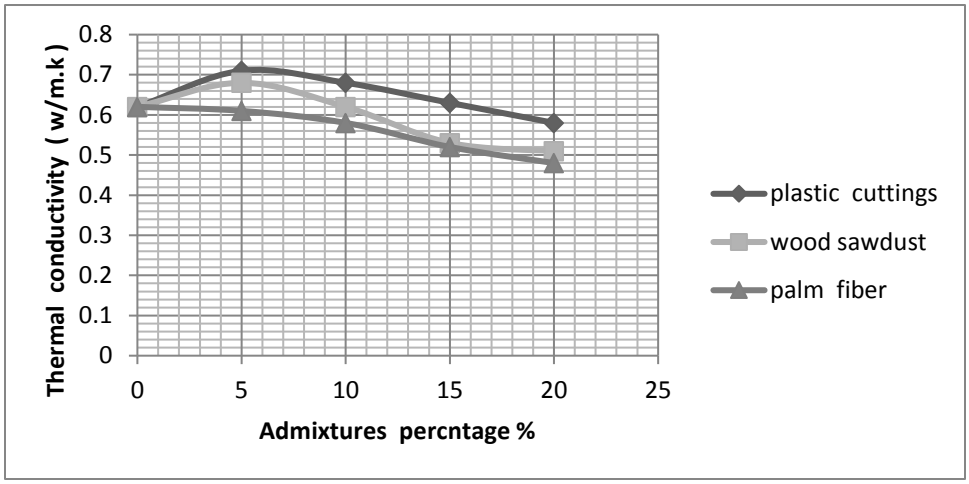

Figure (12) Thermal conductivity of clay brick with different admixtures percentage %.

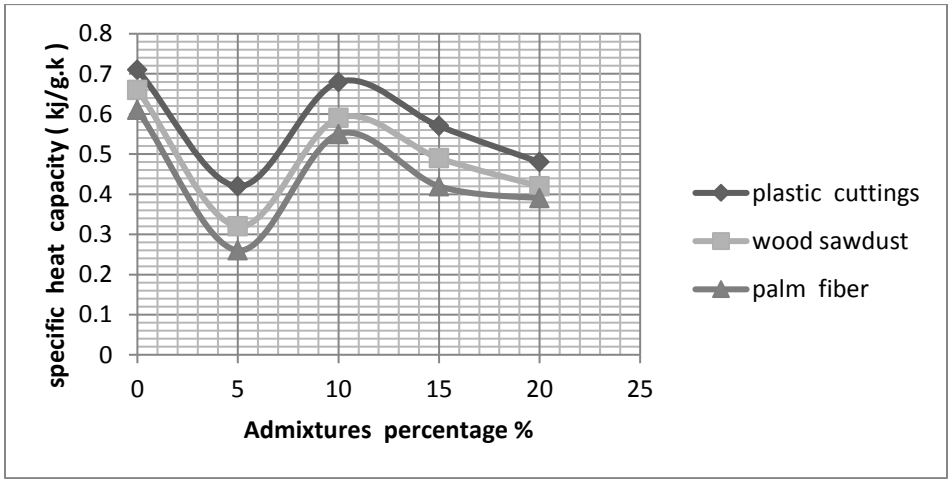

Figure (13) Specific heat capacity of clay brick with different admixtures percentage%.