Manufacture of Light Weight Ceramic Bodies as Thermal Insulator From Local Material

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Abstruct

The research work covers a study of the feasibility of producing lightweight ceramic thermal insulation bodies used for lining the furnaces by adding saw dust and AlF_3 to the Dewechla clay (Kaolinite).AlF_3 is a chemical waste materials in the Akashat–factories in Rutba to the Dewechla clay (kaolinite). Finely distributed Saw dust and ALF_3 were added to clay with different weight percentages (0, 15, 25, 35 & 40) Wt%. Cylindrical shape samples (30mm diameter and 30 mm height) were prepared by using the semi–dry method, moulding pressure was (500Kg/cm²). After drying at (110C◦), the samples were burnt at (900, 950, 1000, 1050&1100) C◦. The fired samples were investigated to obtain their properties, bulk density, porosity ,compressive strength and thermal conductivity. It was possible to produce ligh-weight ceramic thermal insulators with bulk density between (700 and 1300) Kg/m³ compressive strength not less than (25) Kg/cm² and thermal conductivity between (0.2 and 0.4) Kcal/m.h.c.

Keywords: thermal insulator, porosity, thermal conductivity, AlF_3, Kaolinite.

تصنيع اجسام سيراميكية خفيفة الوزن كعازل حراري من مواد محلية

الخلاصة

يتطرق البحث الى امكانية دراسة امكانية انتاج اجسام سيراميكية خفيفة الوزن عازلة حرارية تستعمل لتبطين الافران من خلال مزج نشارة الخشب وفلوريد الالمنيوم (AlF_3).وان فلوريد الألمنيوم تنتج عرضياً في معامل عكاشات في الرطبة . الى اطيان دويخلة(من نوع الكاؤولينايت) تم إضافة مسحوق ناعم لكل من نشارة الخشب و فلوريد الالمنيوم(ALF_3) بنسب وزنية (40 & 35 ,25 ,15 ,0)%. تم تحضير نماذج اسطوانية بأبعاد(30*30)mm وبطريقة التشكيل شبة الجافة وضغط التشكيل(500Kg/cm²) وكانت كمية الماء المضافة تتراوح بين% (12-9) نسبة وزنيه. بعد عملية تجفيف النماذج بدرجة (110) درجة مئوية. تم حرقها برجات حرارية(1100 &,900,950,1000,1050) درجة مئوية.
بعد عملية الحرق تم تحديد خواص النماذج المحروقة مثل الكثافة الحجمية ,المسامية ,مقاومة الانضغاط والموصلية الحرارية.
لقد تم التوصل إلى كثافة تتراوح بين(1300 -700)kg/m³ ومقاومة إنضغاط لاتقل عن (25)Kg/cm²وموصلية حرارية تتراوح بين (0.4- 0.2) Kcal/m.h.C.

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Introduction

Ceramic thermal insulation materials are ceramic bodies which produced with low bulk density. There are a number of applications where it is desirable to make a structure of a good thermal insulator, ranging from domestic buildings to high–temperature kilns and furnaces. Light weight ceramic bodies are a clay product. Depending on the type of clay used. The produced light weight ceramic bodies are used in building or as refractories in furna- ces. The ceramic bodies of low density (light-weight bricks) are used as thermal insulators in building and as light-weight refractories for lining the furnaces .They decrease the heat losses though the walls. The energy consumption in furnaces is a function of the thermal conductivity. Any reduction in thermal conductivity will reduce energy consumption.The red- uction in thermal conductivity can be achieved by production of porous ceramic bodies. There are a number of methods by which porous ceramic bodies can be produced.The additives used and processes employed are outlined briefly below(1).

1- Incorporation of cellular inorganic material. Diatomaceous earth vermi - culite or other natural or manufactured airfilled inorganic cellular materials By bonding these materials with plastic clays excellent intermediate temp. insulators can be made .

2-The addition of combustible materials to the raw clay. When adding combustible materials to the clay the porosity is created during the burning process in the Kiln where the organic material burns off and leaves small pores throughout the clay.

3-Development of gas bubbles by chem- ical reaction. The principle of theaerat- ion process is that two substances are Distributed evenly throughout the clay. The substances will then react with each other and evolve a gas . The gas is entrapped in the clay lowe- ring the density and improving thermal insulation properties. In our experime- ntal work the methods of the addition of combustible material and development of gas bubbles by chemical reaction are chosen.

Using Saw-dust and waste materials as performance enhancing additives in the brick industry is gained more and more ground recently (2,3,4).The additives, mixed in the brick clay are burning out during the firing process producing extra energy, and decreasing the total energy need of the industrial furnace.The ignition of the additives provides extra thermal energy from inside the brick product, and deceases the required energy by the furnace .Beside of saving energy , the combustion removes the addiitives, creating pores, further decreasing the thermal conductivity and decrease the mechanical strength of the final product. The other method for production of light-weight ceramic bodies is the incorporation of chemical substance to the clay in order to produce gas bubbles by chemical reaction. For development of gas bubbles different weight percents of AlF_3 is added to the Dewechla clay-type (Kaolinite).

Under condition of burning process of the Kaolinite, the effect of firing temperature on the Kaolinte can be done in the two reaction stages (5).Firstly, at the 575◦C the crystal water of the **Kaolinite will be removed.**

$$Al_2O_3.2SiO_2.H_2O \xrightarrow{575°C} Al_2O_3.2SiO_2 \rightarrow +2H_2O$$

Kaolinte meta-Kaolinite

Secondarily the meta-Kaolinite will be decomposed to Al_2O_3 and SiO_2

$$Al_2O_3.2SiO_2 \xrightarrow{870°C} \gamma\text{-}Al_2O_3 + 2SiO_2$$

The resulted SiO_2 reacts with AlF_3 and a porous mullite will be produced

$$13SiO_2 + AlF_3 \rightarrow 2(3Al_2O_3.2SiO_2) + 9SiF_4$$

Gas

Experimental work

Our work has been based on clays from Dewechla deposites. The samples were supplied by the Iraqi Minerals company. As a basis for experiments to be conducted, a thorough investigation of the clay raw materials were indicated. Information about physical properties and chemical composition of the clay provide important clues for the proper planning of the experimental program- me.

Table(1) shows the chemical analysis of the clay from the Dewechla deposits .The analysis was carried out at the research institute for refractories in Bonn, West Germany. (6) The identification of the clay minerals used in this research work was carried out by using differential thermal analyses (DTA). A fixed weight of the sample is packed into a silica glass crucible Fig(1),The other compartment using filled with an inert material which has no thermal reaction over the range of temperature of the test. A deseription of equipment , procedure and evaluation of the result is described in detail in (7). The (DTA) curve, Fig(2) indicates that the clay used in this research work is of Kaolinite – type (6).

Preparation of ceramic thermal insulators

Sawdust and the clay are ground separately and each pass a 50 mesh screen (mesh opening 0.3mm) was found to give a satisfactory performance in the process and with regard **to end product properties.**

Mixes of clay with Sawdust and AlF_3 are separately prepared. The percentage of these additives in the dry mix was varied between 0 and 40.

To the additive – clay mixture water was added to obtain a mouldable mix. The amount of water depends on the amount of plastic binder clay. It ranged between 9% and 12%.The green samples were prepared by the semi-dry method using a hydraulic press and moulding pressure of ($500 Kg\backslash cm^2$).The samples had cylind- erical shape (30mm diameter and 30mm height) for testing according to DIN[8].

After moulding and drying the samples were burnt at (900, 950, 1000 and 1050 &1100)°C. for 24 hours with soaking time of 1hr. The fired ceramic bodies were investigate for bulk density, poro- sity compressive strength and thermal conductivity. Thermal conductivity dete- rmined by Lees Disk Apparatus.

Results & Discussion

The basic result are presented in tables (2,3). the results of the full test series using Saw-dust and AlF_3 the results are presented in tables(2,3) in various percentages and employing firing temperatures of (900, 950, 1000,1050 and 1100) C. Since a firing temperature of 1050 C proved to give the best results as far as mechanical strength is concerned the data for the two additives given in table (4) were obtained at a firing temp. of 1050°C. No major problems wereexp- ected during the mixing and forming process which can be carried out in existing standard equipment. The prese- nce of the additives in the green samples reduced the drying shrinkage from 7.9% to 4.1% (linear). Thus, lightweight bricks show less sensitivity to cracking in the driers . Therefore, it is possible to reduce the drying time substantially compared with ordinary normal ceramic bodies.

The bulk density reduced proportional to the weight percentages of saw-dust added. It is ranged between (1792) Kg/m³ without addition of saw-dust to (720) Kg/m³ with addition of saw-dust of 40% fired at1050C table (2).

In otherwise the addition of AlF_3 reduces the bulk density to (1098) Kg/m³,table(3).

According to the international standard, bulk density of lightweight ceramic bodies ranged between (600) and (1200) Kg/m³.The results are well in line with the requirements specified in the stand- ard The reduction of density achieved by adding Saw- dust and AlF_3 is accomp- anied by a corresponding drop incompr- essive strength, from (46.7) Kg/cm² to (25.6) Kg/cm² by adding (35)% saw-dust and fired at (1100) C, table(2) and to (43.7) Kg/cm² by adding (35)% of AlF_3 and fired at (1100) C table(3). There is a clear relationship between bulk density and compressive strength .

This correlation Fig.(4) is valid for lightweight ceramic bodies produced with addition of AlF_3.

In the density ranges between (600) and (1200) Kg/cm² a compressive strength of between (30)and (40) Kg/cm² is achieved. This should be sufficient for most applications in which lightweight refract- tory bricks are used.

According to the international standard ,The compressive strength of lightweight ceramic bodies not less than (25) Kg/cm².The mentioned results of compr- essive strength are well in line with the requirements specified in the standard.

The compressive strength is increased by increasing bulk density, Fig.(4).

As mentioned the thermal conductivity of solid bricks can be lowered by the introduction of air space. The lower coefficient of heat transfer is due to the fact that conductivity of air is only one hundredth (0.02Kcal/m.h.C)of the cond- uctivity of the solid phase (2.0Kcal/ m.h.C). The conductivity of light weight ceramics bodies must be expected to be between these two extremes, depending on the volume fraction of air (porosity) in the material. Table (2) and Fig.(3) indica- te the expected values of thermal conduc- tivities in light weight ceramic bodies made by adding Saw-dust and AlF_3. Thermal conductivities of samples prod- uced with Saw-dust are consistently lower than those measured on samples with AlF_3. In general ,we may conclude that the thermal conductivity of light- weight ceramic bodies with densities between (800 and 900) Kg/m³ will be in the range of between (0.19 and 0.22 Kcal/m.h.C). The material with lowest thermal conductivity will be the most economical one as the wall thickness of furnaces can be reduced when using a material of lower the thermal conduc- tivity.

Conclusions

1-The Kaolinitc clay from the Dewechla deposits is suitable for the manufacture light-weight ceramic bodies.

2-Optimum firing temperature was (1050C).

3-The density of produced ceramic bodies can be lowered by the addition of Saw-dust and AlF_3.

4- The bulk density of ceramic bodies produced by addition of Saw-dust is lower from (1682) Kg/m³ to(720) Kg/m³ and to (1098) Kg/m³ produced by addition of AlF_3 and the compressive strength not less than (25)kg/cm².

5-most standards for light- weight ceramic bodies require that the bulk density ranged between (600 to 1200) Kg/m³ and the compressive strength not less than (25) kg/cm².The produced light-weight ceramic were found to be suitable for practical applications.

6-The thermal conductivity is lower-ed to (0.13 Kcal/m.h.C) by addition of Saw- dust and (0.26 Kcal/m.h.C) by addition of AlF_3.

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Table(2):physical properties of lightweight ceramic bodies produced with addition of saw - dust

Table (1): chemical analyses of the Dewechla clay

COMPOSITION	WEIGHT PERCENTAGE %
Al_2O_3	37.0
SiO_2	57.8
TiO_2	1.6
Fe_2O_3	1.45
CaO	0.7
K_2O	0.4

Table (2):physical properties of lightweight ceramic bodies produced with addition of saw - dust

Content of AlF_3%	Content of Kaolinite %	Bulk density {g/cm3}	Porosity %	Compressive strength {kg/cm2}	Thermal conductivity {Kcal/h.m.c◦}
100	0	1.83	12.24	50.1	0.46
15	85	1.62	18.97	46.2	0.41
25	75	1.42	19.19	44.4	0.38
35	65	1.28	26.77	42.3	0.31
40	60	1.09	30.2	40.1	0.26

Table (3): Physical properties of light weight ceramic bodies produced with addition of AlF3.

Firing Temp.◦c	Content of sawdust%	Bulk density {Kg/m^3}	Porosity%	Compressive strength {Kg/cm^2}	Thermal conductivity {Kcal/h.m.◦c}
900	0	1682	17.64	20.3	0.47
	15	1117	26.56	12.4	0.30
	25	996	36.57	11.2	0.23
	35	909	46.46	10.3	0.19
	40	858	55.56	7.8	0.13
950	0	1700	16.51	21.3	0.47
	15	1240	25.56	10.1	0.32
	25	1048	32.97	9	0.24
	35	922	40.77	8.1	0.20
	40	881	48.54	8	0.15
1000	0	1714	24.675	30.1	0.48
	15	1226	29.896	10.6	0.33
	25	1060	36.363	9.2	0.26
	35	872	45.098	8.8	0.21
	40	779	46.788	8.2	0..17
1050	0	1797	31.081	35.2	0.52

	15	1117	40.425	26.4	0.34
	25	952	46.84	24.6	0.30
	35	840	53.745	21.3	0.23
	40	720	43.220	20.4	0.21
1100	0	2015	22.22	46.1	0.53
	15	1765	32.81	30.7	0.32
	25	1320	38.46	27.3	0.31
	35	1067	46.75	25.6	0.26
	40	915	51.57	22.7	0.23

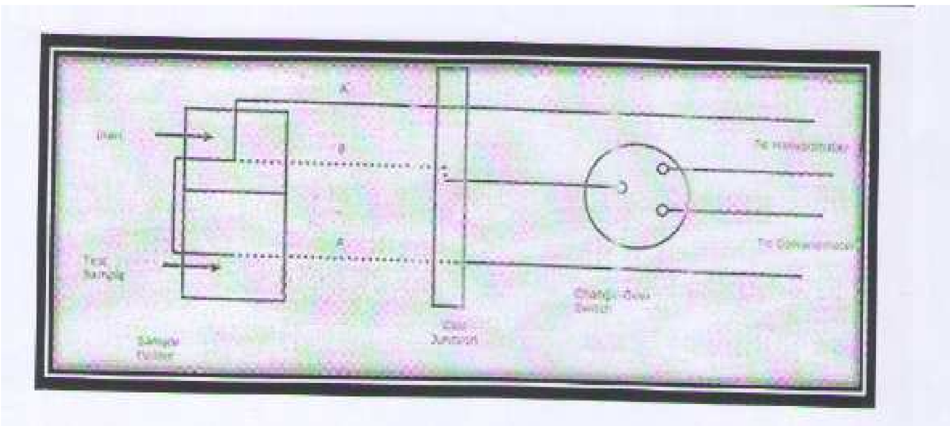

Figure (1):Differential thermal analysis apparatus ,the specimen folder and thermocouple arrangement.

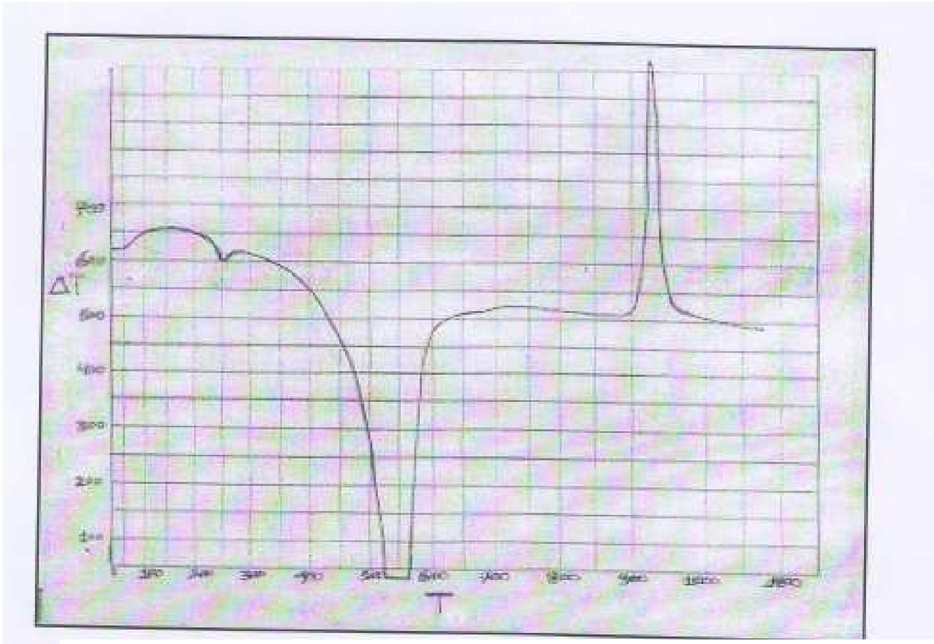

Figure (2): The DTA Curve (were ΔT & T measured in°C).

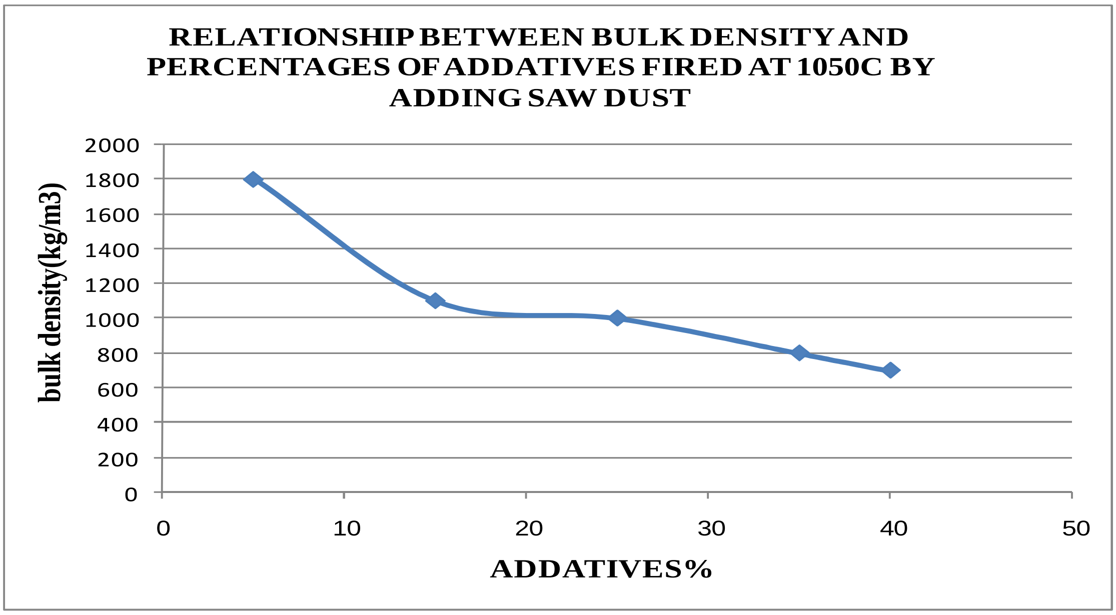

Figure (3)

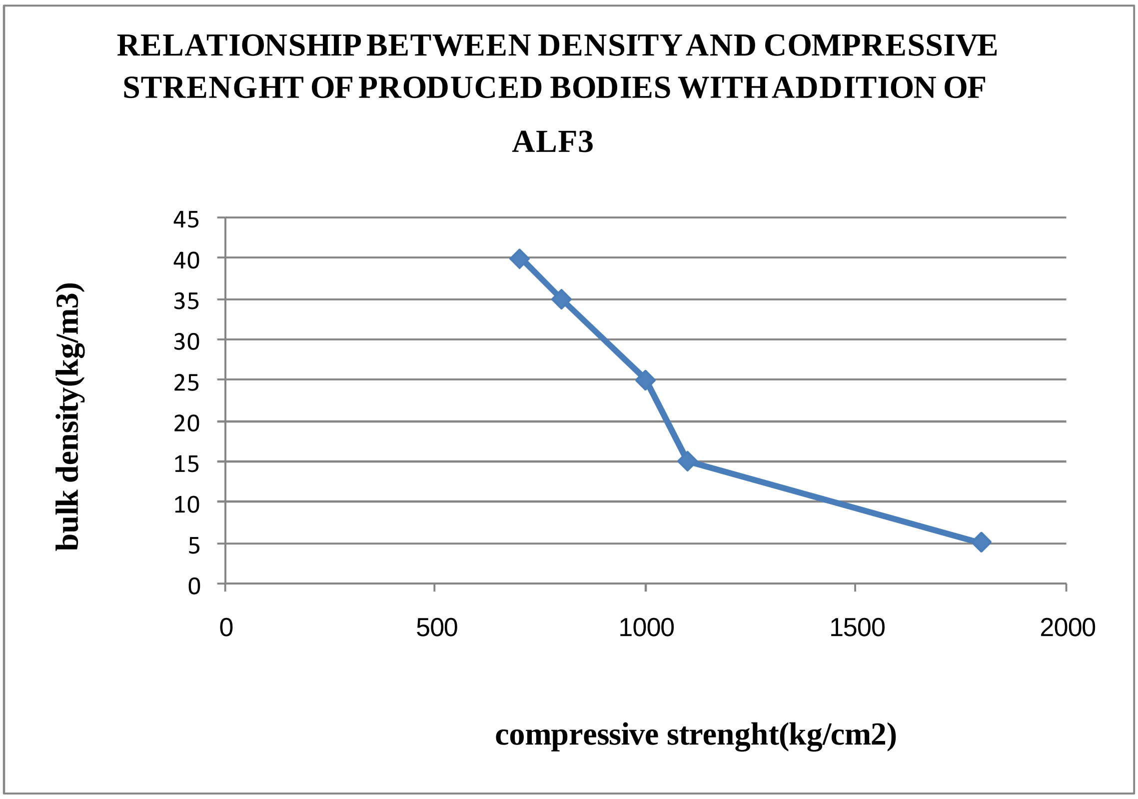
RELATIONSHIP BETWEEN DENSITY AND COMPRESSIVE STRENGHT OF PRODUCED BODIES WITH ADDITION OF ALF3
bulk density(kg/m3)
45
40
35
30
25
20
15
10
5
0
0
500
1000
1500
2000
compressive strenght(kg/cm2)

Figure (4)

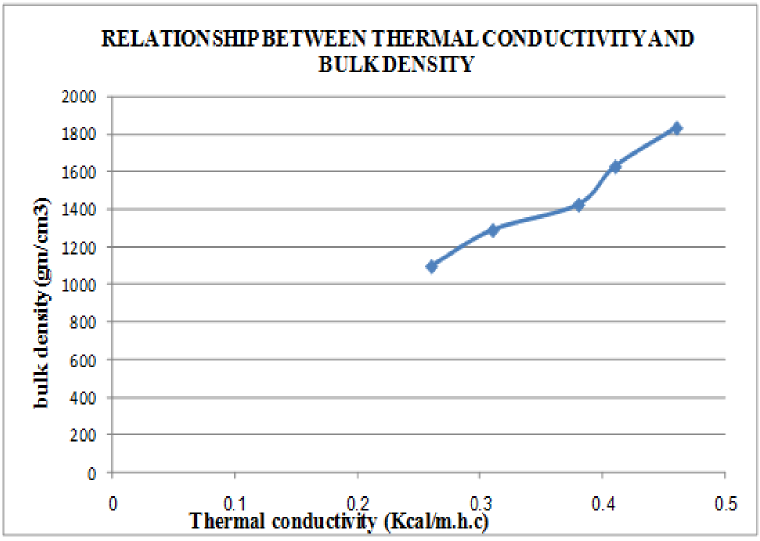
RELATIONSHIP BETWEEN THERMAL CONDUCTIVITY AND BULK DENSITY
bulk density (gm/cm3)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
0.1
0.2
0.3
0.4
0.5
Thermal conductivity (Kcal/m.h.c)

Figure (5)