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Production of Light Weight Ceramics Teils from Local Materials

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Abstract: This study covers the feasibility of production lightweight ceramics teils (light weight clay bricks) by adding local various types of combustible materials to the clay. It was found those substantial quantities of bagasse, sawdust, rice husks and straw are suitable for the production of lightweight bricks and distributed combustible materials finely was mixed with clay and molded into bricks. During firing in the kiln the combustible materials burnt out and leave air spaces, which contribute, to the high thermal insulation value of the bricks. It was possible to produce bricks with densities between 800 and 900 Kg m ^{3} and thermal conductivity between 0.19 and 0.22 Kcal mh $^{1\circ}$C. The thermal conductivities were comparable or better than those of existing insulation materials on the market.

Key words: Rice Husk, Light Weight Ceramics, Sawdust, Straw, Thermal Conductivity

INTRODUCTION

Lightweight ceramics teils are a clay product of low apparent density. These teils can be used as building materials.

The reason for the need of introducing building materials of low density is the increasing use of air conditioning in residential and commercial building [1]. In order to achieve an adequate indoor climate at reasonable cost it is necessary to supply the building with sufficiently low thermal conductivity. In air conditioning buildings energy consumption for cooling and heating is primarily a function of the thermal conductivity of the roof and of the external walls. Any reduction in thermal conductivity will reduce energy consumption for heating and cooling accordingly.

Improving insulation values are usually achieved by lowering the weight of the materials .The most common method is the introduction of air spaces [2].

In the case of ceramics, the bulk density has to be lowered to between 600 and 1200 kg m ^{3} in order to reach suitably low levels of thermal conductivity of a round 0.20 kcal mh $^{3\circ}$C.

This can be achieved by introduction of pores through additives of combustible materials or chemical aeration.

The bulk density of solid bricks is usually between 1400 and 2000 Kg m ^{3}.

There are a number of methods by which porous bricks can be produced.

The most important ones achieve purification by chemical means, through the addition of combustible materials or the incorporation of cellular inorganic materials.

In our experimental work we have chosen to use the second method of combustible materials.

Most standards for lightweight ceramics bricks require that compressive strength does not drop below 2.5 Nmm ^{2} and that density are kept between 600 and 1200 kg m ^{3} [3-5].

MATERIALS AND METHODS

Raw Materials

Clay: For production of the light weight ceramics teils, an ordinary clay bricks was obtained. The average chemical compositions is given in Table 1[6].

Table 1: Chemical Analysis of the Clay Used in our Research Work

Chemical composition	Content
SiO_2	43.0
Al_2O_3	14.3
Fe_2O_3	2.9
CaO	16.6
MgO	2.3
SO_3	0.9
L.O.I	20.4
Total Alkali (as Na_2O)	
Na_2O	0.29
K_2O	0.22

The material is plastic clay bricks with the following particle size distribution:

- More than 20 microns 35.5-34.5%
- 2-20 microns 22.5-25%
- Less than 2 microns 39.5-40.5%

Due to the presence of appreciable amounts of calcium carbonate the clay burns to a yellow color.

In addition to the chemical analysis the burning characteristics of clays depend upon the mineralogical composition which is usually determined by means of x-ray diffraction (XRD).

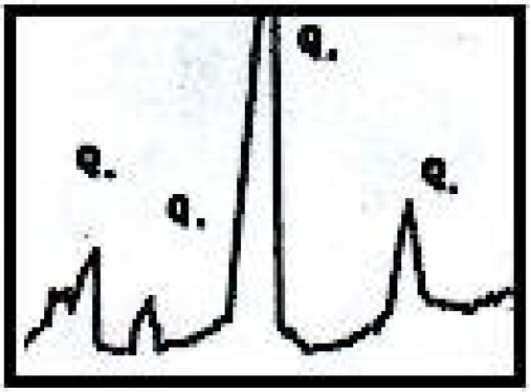

Fig. 1: X-ray Analysis of the Clay

A study of the clay used in our work was carried out by using (XRD). The XRD chart is shown in Fig. 1.

The Combustible Materials: The combustible materials used in our work were:

Bagasse: Crushed sugar can after the juice has been extracted.

Rice Husks: The outer coverings of the rice grains, which are removed during the processing.

Straw: The dry cut stalks from grains, usually wheat. In most cases it is compressed into bales after trashing in harvesting machines.

Saw Dust: The by-product available from processing wood at a carpenter shops. Most of the saw dust is from soft wood.

The ash content in the various combustible materials products is given in Table 2.

Table 2: Ash Content in Ccombustable Materials Used

Combustible materials	Ash (w%)
Bagasse	0.8
Rice Husks	22.7
Straw	14.0
Saw Dust	7.9

The ash in rice husks consists mostly of pure silica which is expected to react with free lime in the clay forming calcium.

Silicates of the wollastonite group. It may have a stabilizing influence on the bricks. The ash found in straw contains appreciable quantities of alkalis, which may act as a strong flux depending on the naturel of the clay. The most satisfactory materiel is bagasse where the ash content is extremely low.

Experimental Design and Procedure: Initial trials indicated that most organic waste materials had to be grounded prior to their use.

Otherwise, the resiliency of the fibrous materials prevented an efficient compaction of the bricks by compression or extrusion.

Besides, the presence of larger particles and fibers in the mix resulted in rough and torn edges in the extruded bricks and in difficulties in cutting the clay column after extruder. Organic materials ground to pass a 50 mesh screen was found to give a satisfactory performance in the process and with regard to end product properties.

Table 3: Physical Properties of Lightweight Bricks Produced with Rice Husks

Firing Temp.(°C)	Content of rice husks %	Buylk density kg m ^{3}	Compressive strength kg cm ^{3}	Water absorption % by weight	Porosity % by volume
950	5	1431	163.5	25.6	36.7
	10	1219	112.8	34.2	41.2
	15	1067	73.5	47.9	50.8
	20	1030	49.2	47.2	48.7
	25	940	46.2	56.3	52.2
	30	830	24.5	37.0	55.6
1000	5	1448	149.8	25.1	36.4
	10	1217	106.3	34.3	41.7
	15	1095	64.3	41.2	45.2
	20	1050	51.7	47.6	50.0
	25	950	45.6	55.8	53.1
	30	350	27.4	68.1	57.9
1050	5	1384	172.1	27.1	37.7
	10	1210	98.6	34.8	42.1
	15	1070	67.0	41.7	44.7
	20	1020	48.4	49.2	50.2
	25	940	37.3	57.5	53.9
	30	810	27.1	68.3	55.3

Mixes of clay and organic waste were prepared. The percentage of waste material in the dry mix was varied between 0 and 30. After addition about 20% of water according to pfefferkone test, a mix of proper plasticity the mix was molded. For molding of small specimens laboratory extruder was used, in which items with a cross section of up to 2.5 * 5.0 cm, could be produced.

After drying the bricks were burnt in an electric furnace, on the specimens the following physical properties were determined:

- Drying and firing shrinkage
- Water absorption determined by immersion the specimen in water for 24 hours and boiling
- Compressive strength, determined on 10 2.5 5 cm., extruded specimens
- Porosity, determined by weighting the specimens, dry water saturated and water submerged
- Thermal conductivity, determined by the hot plate method according to German standard DIN 52612, using 25x25x3 cm, slabs

One basic test series was performed with each of three additives rice husk , straw , saw dust using additions amounting to 5 , 10 , 15 ,20 , 25 and 30% of the total mix .In case of the fourth additive (bagasse) test results are available for 15% addition only which in general gave optimum performance. Specimens of each mix were fired at 950, 1000 and 1050°C. firing temperature in excess of 1050°C were tried on rice husk mixes in order to determine the optimum firing temperature. In general, the firing temperature of 1050°C proved to produce the best results.

RESULTS

The basic result are presented in Tables 3-6. Table 3 gives the results of full test series using rice husk in various percentages and employing firing temperature of 950,1000 and 1050°C. In addition a test series was carried out combining the addition of combustible waste. The data listed are mean values of 3 tests. Since a firing temperature of 1050°C proved to give the best results as far as mechanical strength is concerned the data for all four additives given in Table 4 were obtained at a firing temperature of 1050°C Table 5 contains the results of a limited number of tests in which the density was reduced by the introduction of perforations in addition to the incorporation of organic waste in the green mix. In the absence of our own testing facilities for determination on the thermal conductivity only a limited number of test results are given on this property Table 6.

Table 4: Physical Properties of Lightweight - and Ordinary Brick Firing Temperature: 1050°C

	Content of organic waste %	Bulk density kg m^3	Compressive strength kg cm^2	Porosity % by volume
Ordinary Bricks	0	1460	245	28.0
Series with Rice Husks	5	1348	172.1	37.7
	10	1210	98.6	42.1
	15	1070	67.0	44.7
	20	1020	48.5	50.2
	25	940	37.3	53.9
	30	810	27.1	55.3
Series with Saw Dust	5	1240	122.0	39.5
	10	1110	72.5	47.0
	15	905	45.0	50.0
	20	760	27.0	58.5
	25	620	<25.0	67.5
	30	450	<25.0	74.0
Series with Straw	5	1190	104.0	44.0
	10	960	52.0	47.0
	15	860	39.0	53.0
	20	735	26.5	57.5
	25	675	<25.0	60.0
	30	540	<25.0	64.0
Series with Bagasse	15	810	38.4	n.a

Table 5: Physical Properties of Lightweight Brick Influence of Perforation Firing Temperature: 1050°C

Type Addition	Content of organic Waste %	Perforation %	Bulk Density Kg m ^{3}	Compressive strength Kg cm ^{3}
Rice Husks	10	0	1210	98.6
	10	15	1060	n .a.
	15	0	1070	67.0
	15	15	920	n .a.
	25	0	940	37.3
	25	15	850	30.0
Bagasse	15	0	810	38.4
	15	15	680	27.0

n.a. = not available

Table 6: Thermal Conductivity of Lightweight Bricks

	Content of Organic Waste %	Burring Temp.°C	Bulk Density Kg m ^{3}	Thermal Conductivity Kcal m ^{1}h°C
Ordinary Brick	0	1050	1460	0.450*
Series with Rice Husks	5	1050	1410	0.333
	15	1050	1110	0.284
	25	1050	620	0.226
Series with Straw	5	1050	1210	0.242
	15	1050	850	0.170
	25	1050	640	0.127

* from Literature

DISCUSSION

Processing: Prior to its addition to the clay combustible wastes have to be ground in order to eliminate larger particles and fibers. In the experiments the waste particles were ground to pass the 50-mesh screen. Otherwise no major problems are expected during the mixing and extrusion process which can be carried out in existing standard equipment. The presence of organic waste in the green bricks reduces 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 bricks.

During burning it will be essential to reduce the fuel supply to the kiln as soon as ignition temperature of organic waste is reached (around 400-500°C) [4].

The optimum firing temperature of our clay was between 1400 and 1450°C. Further increase in firing temperatures leads to beginning of sintering of the clay accompanied by a sharp increase in bulk density and a corresponding drop in porosity Fig. 2.

Bulk Density: The bulk density of ordinary bricks is 1460 Kg m $^{3.}$ The addition of combustible waste reduces the bulk density proportional with the amount added Fig. 3.

In quantitative terms, the density achieved depends not only on the quantity of the organic waste present, but also on its characteristics, such as ash content and density. The most efficient additive regarding reduction of density was bagasse where a 15 % addition produced a brick with a bulk density of a round 800 Kg m ^{3} .The most likely reasons is the low ash content of the materials. Slightly higher densities are obtained when using saw dust and straw as an additive. The reason is the high ash content of these materials Table 2.

Compressive Strength: The reduction of density achieved by adding a combustible waste is accompanied by a corresponding drop in compressive strength, from 250 kg cm ^{2} for regular bricks with a density of 1500 kg m ^{3} to around 25 kg cm ^{2} if the density is reduced to around 800 kg m $^{3.}$ There is a clear relationship between bulk density and compressive strength. This correlation Fig 4 is valid for bricks produced with all four types of additives as well as for those specimens, which are supplied with perforation.

In the density range between 800 and 900 kg m ^{3} a compressive strength of between 30 and 40 kg m ^{2} is achieved. This should be sufficient for most applications in which lightweight bricks are used.

Thermal Properties: 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 the conductivity of air is only in hundredth (0.02 kcal m ^{1}h°C) of the conductivity of the solid phase (2.0 kcal m ^{1}h°C).

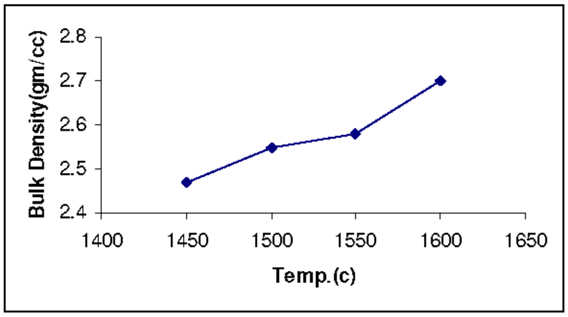

Fig. 2: The Temp. Effect on the Bulk Density of Clay

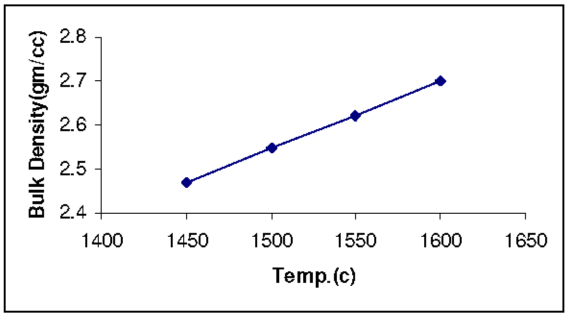

Fig. 3: The Temp. Effect on the Bulk Density of Clay with Addition of Combustible Waste

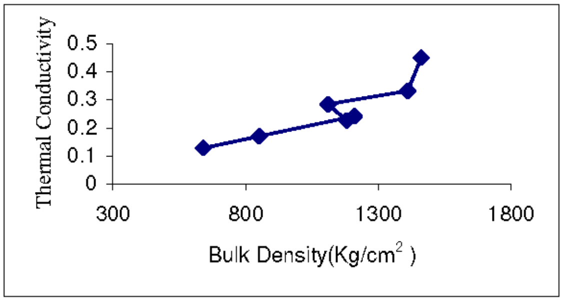

Fig. 4: Relationship between Thermal Conductivity and Bulk Dens

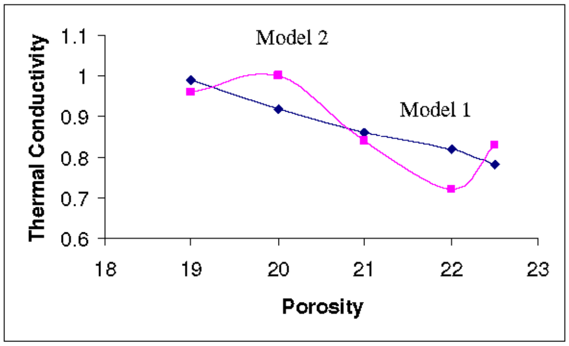

Fig. 5: The Thermal Conductivities of the Two Models

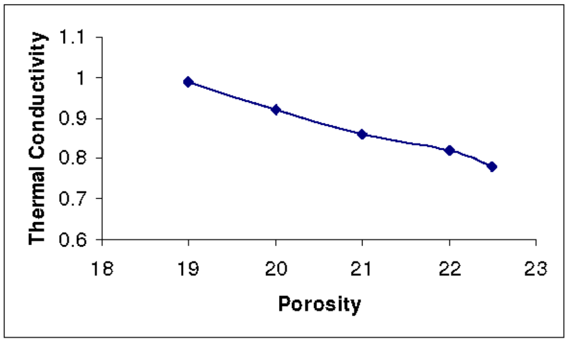

Fig. 6: Shows the Thermal Conductivity of Thermostone Type Materials

The conductivity of lightweight bricks must be expected to be between these two extremes, depending on the volume fraction of air in the material. The condition of small and narrow pores is met in most porous building materials. We may, then, assume that the heat flow in one case proceeds parallel to the direction of the pores (Model 1), in the other case heat flow is perpendicular to the direction of the pores (Model II), Fig. 5. For both models the thermal conductivity can be readily computed from data for the thermal conductivity of resting layers of air and the solid materials, the volume concentration of the solid (1-P) and of the air (p).

For Model I thermal conductivity K_1 is

$$K_1=PK_a + (1-p)K_s$$

Where K_a and K_s are the thermal conductivities of air and the soiled materials respectively.

In case of model II it is necessary to add the thermal resistance 1/k of the individual layers. Thermal conductivity K_{II} of a body represented by Model II can be calculated using the relationship [7].

$$1/K_{11}=(P/K_a)+(1-p)/K_s$$

As indicated in Fig. 5 the thermal conductivities of the two models conditions are radically different. The model I relationship between porosity and thermal conductivity is a straight-line relationship while the relationship for Model II is represented by a hyperbola which indicates that thermal conductivity drops steeply when the firit 25% of air are introduced [8].

The correlation line in Fig. 5 indicates the expected values of thermal conductivities in lightweight bricks made by adding rice husk and straw, Although no tests have been performed on mixes with bagasse and saw dust it is reasonable to assume that the results will fall within normal deviation from the correlation line.

Table 7: Thermal Properties of Lightweight Bricks and Other Building Materials

Material	Bulk density kg m^{3} (γ)	Specific heat Kcal kg ^{1}°C (c)	Thermal conduct Kcal m ^{1}h°C (λ)	Heat storage capacity Kcal °C ^{1} m^{3}	Heat diffusivity M^{2} h ^{1}
Light weight brick	900	0.20	0.22	180	0.00122
Heavy Bricks	1500	0.20	0.500	300	0.00167
Thermostone (gas concrete)	300	0.22	0.230	176	0.00131
Heavy concrete	2300	0.20	1.750	460	0.00380
Styropore (expand polystyrene)	20	0.33	0.030	6.6	0.00455

Heat storage capacity = γ C (Kcal °C ^{1} m^{3}) Heat diffusivity = λ / heat storage capacity = (m^{2} h ^{1})

In general the thermal conductivity of our produced bricks is well in line with data determined on other types of insulating materials of comparable densities, Fig. 6 shows the thermal conductivity of thermostone type materials. In general, we may conclude that the thermal conductivity of lightweight bricks with densities between 800 and 900 kg m ^{3} will be in the range of between 0.19 and 0.22 Kcal m ^{1}h°C.

Another factor is the ability of the material to absorb and store heat (heat storage capacity) before it is transmitted to the interior and to release the stored heat during the cooler evening and night hours. It can be shown that the indoor climate such as temperature amplitude, attenuation and optimum phase displacement between maximum outdoor and indoor temperatures is a complicated function of the heat diffusive, which is defined as the ratio between thermal conductivity and heat storage capacity.

In Table 7 we have shown the most important thermal properties of a number of common materials for wall construction. Thermostone and lightweight bricks show the best over-all performance among the materials listed, as far as heat diffusivity is concerned. The data for heavy concrete indicate comparatively poor performance. Despite high heat storage capacity its thermal conductivity is rather high. The opposite is applied to styropore, which can be used only in combination with other materials.

CONCLUSION

- The experiments indicated that the density of ordinary bricks can be lowered by the addition of various types of combustible waste materials.
- There is a clear correlation between bricks density and compressive strength independent of the type of combustible waste materials used.
- Bricks in the density range between 800 and 900 Kg m ^{3} were found to be most suitable for practical applications. They have a compressive strength sufficient for insulating masonry work and a thermal performance, which is comparable with or better than that of other insulation blocks. Thermal conductivity of lightweight bricks in the 800 to 900 Kg m ^{3} density range will be between 0.19 and 0.22 Kcal m ^{1}h°C.
- The different types of combustible wastes vary in their efficiency in reducing bricks density. In case of saw dust, bagasse and straw an addition of 15% is sufficient to lower the density to between 800 and 900 Kg m ^{3} In case of rice husks the addition level has to be raised to 25%.
- There are promising possibilities that bagasse and saw dust can be used without grinding. In this case, production costs of lightweight bricks will be dropped.
- In all cases, the production cost of lightweight clay bricks in expected to be below that of other insulation materials of similar performance.

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