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Improvement of the Refractoriness under Load of Fire-Clay Refractory Bricks

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Abstract

A study of possibilities of using locally available raw materials for the production of refractory bricks has been carried out. The basic raw material was kaolinitic clay from Dewechla deposit; it was possible to produce Chamotte refractory bricks with the initial softening point (Ta) of 1180C°. The possibility of improving the refractoriness under load of the tire-clay refractory bricks as carried out through addition of varying percentages of Al_2O_3 to the Dewechla clay. An addition of 5% Al_2O_3 is sufficient to increase the temperature of commencement of subsidence (Ta) from 1180 **C°** to 1450 **C°**.

Keywords: bricks, clay, softening point.

1 INTRODUCTION

The refractoriness under load (RUL) is the resistance of refractory material to deformation when heated at high temperature and load is of more practical significance than its refractoriness. Very High pressure may by exerted by furnace wall on the bottom rows of the bricks. Distortion is the mobility acquired by the solid particles in the presence of the molten material, whereby the mass as a whole cannot resist the pressure due to its own weight and therefore becomes reduced in height and increased in width (subsidence) until a shape is reached at which the whole mass remains in a state of equilibrium .For a flue bricks structure. The pressure has been calculated to be 0.018 Nmm2 for every meter of wall height [8]. The mechanical properties of fire-clay refractory bricks depend on the chemical composition of the raw materials and porosity of the produced bricks. Most fluxing materials such as alkalis, Alkaline earth's, iron oxide and manganese oxide which are usually present in small amounts in fire clay tend to lower the resistance of the refractory bricks to deformation under load. The temperature of deformation of fire clay refectories increases with increasing alumina (Al_2O_3) content as indicated by fig (1), [7,8].

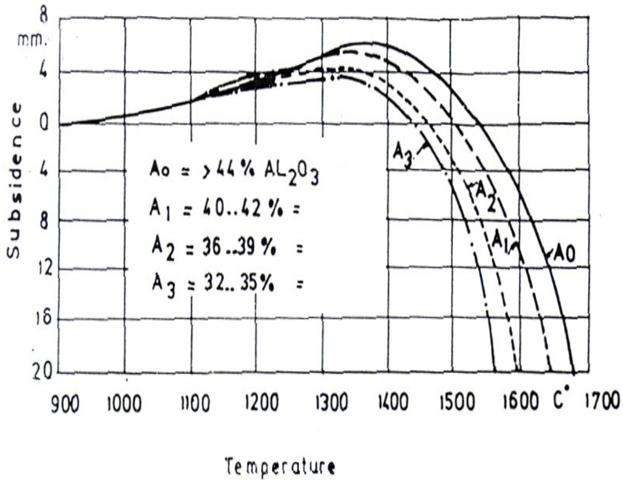


Fig.1 Influence of Al203 Content on the Refractoriness under Load of Fire-Clay Bricks.

Porosity greatly influences refractoriness under load values, actually in denser bricks, the deformation point occurs at relatively higher temperature than in less dense once, fig (2).

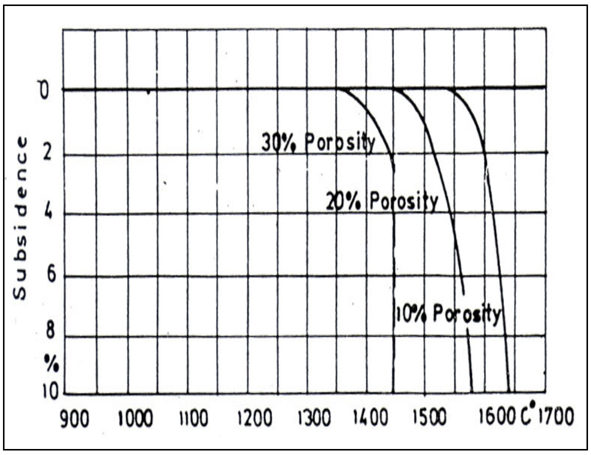


Fig.2 Influence of Porosity on the Refractoriness urder Load of Fire-Clay Bricks

The (RUL) refractoriness under load of refractory bricks is usually tested under a load of $0.2N/mm^2$ for dense refractories such as fire — clay bricks and $0.1\ N/mm^2$ for insulating (Porous) materials, by heating a test specimen at a gradually rising temperature in silicone carbide resistance or other suitable furnace [9],[4],[11]. The temperatures, at which the specimens start to deform as sag and eventually fail, are then reported. In practice it is common to draw a graph to show the rate of sagging of the material with temperature rise. Fig. (3), [2,11].

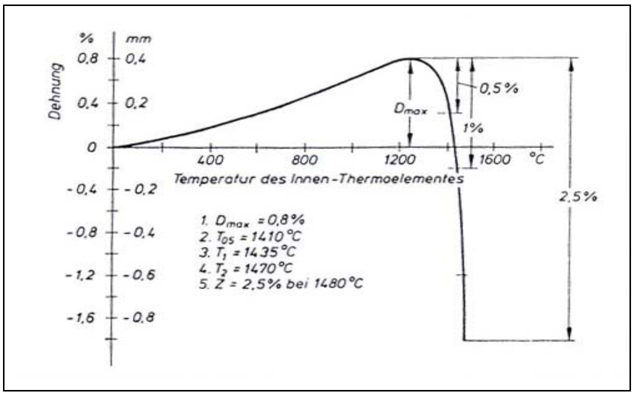


Fig.3 The Rate of sagging of the Brick with Temperature Size.

2 EXPERIMENTAL PART

The identification of the day- mineral 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. (4).the other compartment benign filled with an inert material which has no thermal reaction over the range of temperature of the test the specimen holder ,which is made of sintered alumna ,fits into the lower half of a refractory block the lid of which completes the cylindrical shape .thus enabling it to be used in a tubular furnace. Thermocouples, which are usually chromel-alumel wire, are arranged in the specimen holder.

A chromate alumel junction is located in the center of both the test and the inert sample compartments. The suitability of clay for refractory work depends primarily on its sintering or softening point, in this respect the chemical analysis is of great importance. Usually refractory clays are classified by their alumina content it must be ranged between (25 to 45%). The TiO_2 content in clay normally ranges between 1 and 4%. The content of iron oxide (Fe_2O_3) which acts as a Flux should not exceed 2.5%. Earth alkalis, which also lower the melting points, are usually found in only small quantities The total content of flux in refractory clays (Na_2O+K_2O +CaO+MgO) should not exceed 6%, [3]. Table (1) shows the chemical analysis of the clay used in our developed work

Al_2O_3	37.0%
SiO_2	57.8%
TiO_2	1.6%
FeO_3	1.45%
CaO	0.7
K_2O	0.4

It indicated that the Dewechla clay is suitable for manufacturing of Chamotte refractory bricks. In addition to the chemical analysis the burning characteristics of clays depend upon the mineralogical composition which is usually determine by means of x-ray diffraction(XRD) The XRD chart is shown in fig (5).The results indicate that the clay consists of 14% quarts and 86% kaolinite. Another important property is the softening point of the clay during heating. Ceramists usually list the softening points in pyrometric cone equivalent (PCE) which is designation of the standard cone which has a comparable softening point as a cone prepared from the material to be tasted. In this investigation Seger cones(SK) have been used. Dewechla-clay gave SK 30/31(1680-1695 c). The softening point was also determined in the heating microscope. The instrument used was from Leitz/ Wetzlar. The heating microscope fig. (6), consists of an electric furnace with a service temperature of up to 1550 C^0, [5].

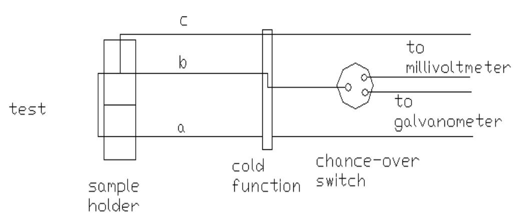


Fig.4 differential thermal analysis apparatus. The Specimen holder and the chromo-couple arrangement.

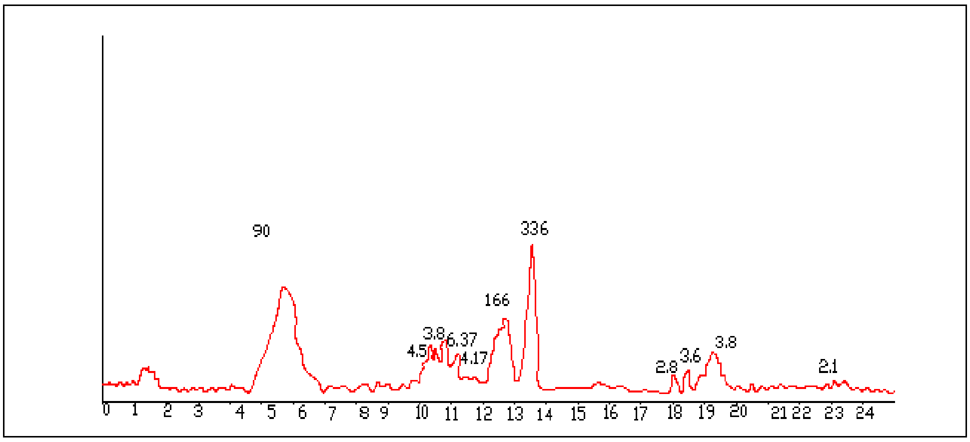


Fig.5 x-ray analysis of dewechis clay

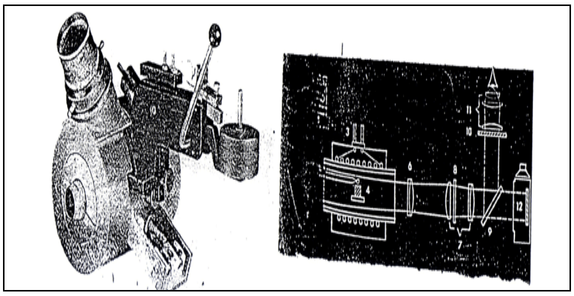


Fig.6 The heating microscope

At the entrance of the furnace a light source is arranged which project the enlarged contours of the specimen on a projection screen or a photographic film. Through accessories the droplet formation during melting can be observed. The specimen used in the instrument was made from regular raw material used in the preparation of the Chamotte bricks by means special manually operated press as shown in the photographic reproductions in fig (7), no deformation were observed in the sample up to temperatures of 1500c Slight changes in the dimensions are due to the firing shrinkage.

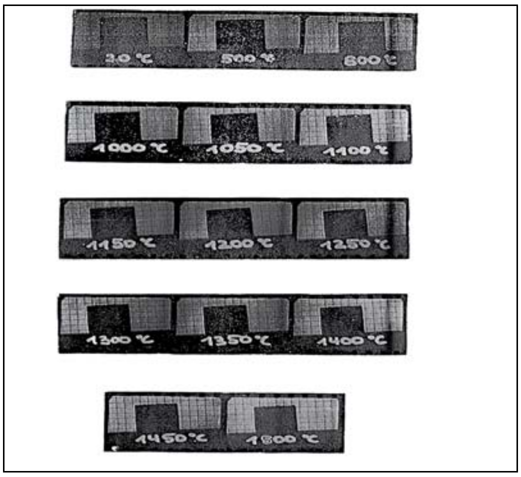


Fig.7 Thermal Behavior of Dewechla Clay in Heating Microscope

Preparation of Chamotte refractors as all clays are subjected to substantial volume changes during drying and burning. It is not possible to manufacture larger items from pure clay for the manufacture of item which are dimensionally accurate and free from warpage and distortion. The clay is mixed with Chamotte (grog) in order to reduce the shrinkage Chamotte is clay which has been burnt until all or nearly all combined water has been removed, in most cases it is burnt at or near sintering temperatures. The firing temperature of the Chamotte was 1450c. Time of burning was 24 hours in a high temperature electrical furnace. In most cases Chamotte fractions are prepared by crushing in suitable crusher aggregates.
The crushed chamotte is usually divided into three fractions.
Coarse from 2.5-6.0 mm, 30%
Medium 1.0- 2.5 mm,20%
Fine 0-1.0 mm,50%
The crushed chamotte fractions ere mixed and then combined with an optimum quantity of binder clay, in range of 50/50, 70/30 and 80/20 Chamotte/ plastic clay and water to obtain moldable mix. The binder clay was the same clay (Dewechla clay) which was still plastic. That means not burned. The chamotte was mixed with varying quantities of plastic clay and water. The amount of water depends on the amount of plastic clay used as a binder, it was ranged between 6 to 9% For the improving of the mechanical properties of the fire -clay bricks suitable quantities of aluminum oxide(Al_2O_3) 20-75 µm 82°o 6-20 µm 18% were added to the Chamotte clay mix The content of (Al_2O_3) was varied in the range of 5-10%
The green sample was prepared by the semi method using a hydraulic press and a molding pressure of 50 N/mm2. The sample had cylindrical shape (50mm diameters and 50 mm height) for testing according to [1]. After molding and drying the bricks were burned at 1250, 1300, 1350, 1400 and 1450 C^o. The fired

bricks were investigated to refractoriness under load and the porosity. The test on the samples produced without addition of Al_2O_3 was conducted according to DIN [11] The refractoriness under load test of refractor' materials are usually carried out on cylindrical specimen of 50 mm diameter and 50 mm height. A description of equipment. Procedure and evaluation of the results is described in detail in the previously mentioned DIN stranded [11].The characteristic temperature length curve of the sample tested is shown in fig(8).

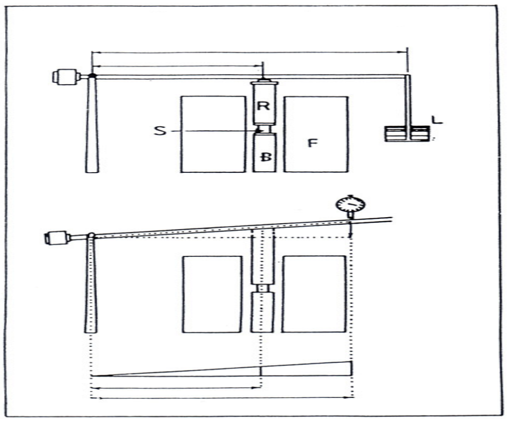
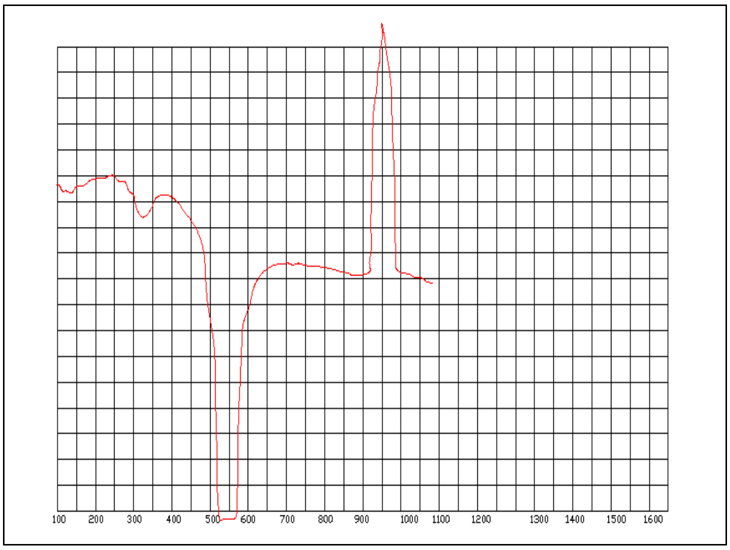


Fig. 8 Measuring Refractoriness Under Load.

Determination of RUL (refractor under load of the sample produced after addition of Al_2O_3 were carried out according to BSS [8]. The apparatus used for the determination of' the RUL is illustrated in fig(8). The sample was .placed on alumina block (B) in an electric tubular furnace (F) and a load (L) was applied to it by weight through a system of levers to an alumina thrust rod (R). The specimen was heated at a fixed rate (10c per min) until 1000c and(3-5c/min) between 1000C^o and 1450C^o and the changes in length was measured on a recording instrument . In the former test it was usual to record the initial softening point t_a the point of rapid failure (corresponding to a subsidence of 1% per min) and the temperature of complete failure(Te).

3DISCUSSION OF THE RESULTS

The Chamotte bricks produced in our research work had a yellow to brownish color. This is clue to the low content of iron oxide in the clay. The burnt bricks had a bright and clean sound when hit with a small steel hammer this is a clear indication of the quality of burning. Well burnt and faultless bricks produce clear metallic sound. Fig.(9) shows the peaks in DTA curve represent heat changes associated with specific reactions such as breakdown of combined water at 575 **C°** and a formation of mullite at 975 **C°.**



Fig, 9 Differential Thermal Analysis of our Clay.

The result indicated that our clay used in this work is a kaolinite. Porosity is of great influence on the mechanical properties. The DIN standard requires that Chamotte bricks have a porosity of between 15 and 25% fig.(10)shows that the porosity is reduced substantially with increasing filing temperature The porosity of the samples produced without addition of Al_2O_3 was 14.6% Table (2) shows that porosity increase with increasing of Al_2O_3 addition the data presented in the table (2) indicated that the bricks tested are in the line with requirement of this standard

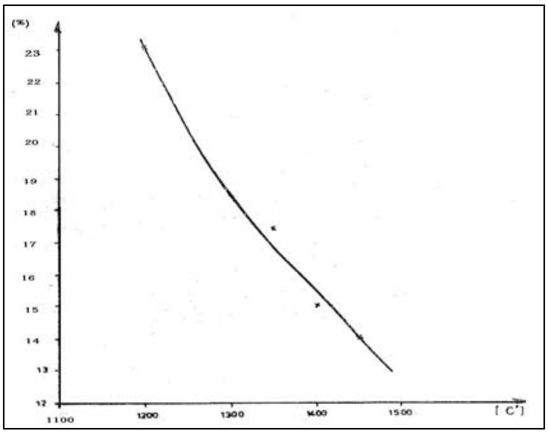


Fig.10 Relationship between the porosity and the firing temperature.

The characteristic temperature length curve of the sample tested. Which was produced without addition of Al_2O_3 to the raw fire-clay, is shown in fig (11). the following points on the curve are of special interest.

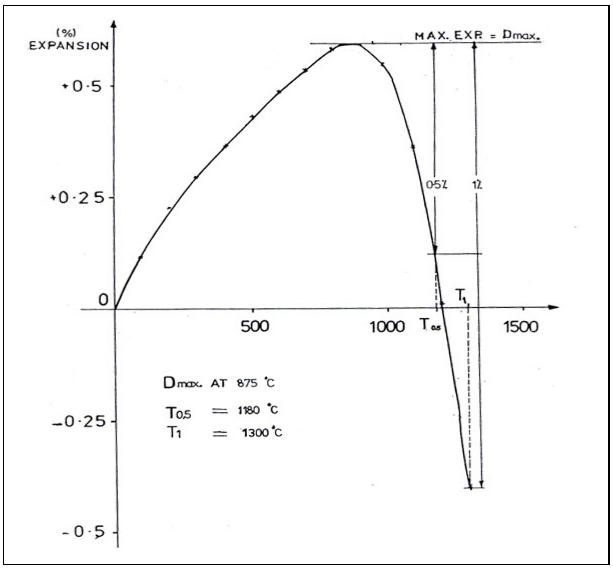


Fig. 11 Refractoriness Under Load of The Alumina Free Sample.

1. D_{max} is the maximum expansion of the specimen in percent of initial length.
2. $T_{0.5}$ or (ta) is the temperature of which the specimen shows a deformation of 0.5% (calculated on the initial length) in re1ation to the point of max expansion $t_{0.5}$ is considered as the start of the softening.
3. T1 is considered as the end of the softening range. For our chamotte brick the following results have been obtained.

$$T_{0.5}= 1180\ C^o \quad T_1 = 1300\ C^o$$

Frequently, curves liar the values of refractoriness under load determined on large number of refractory bricks have been published by Dortmund -Harder Hutten Union A.G [13]. The t_a for various types of Chamotte bricks is not less than 1300 **C°** However, the results obtained on our bricks does not fail within these limits ,Fig(11).Therefore, Improving the load bearing capacity of such fire-clay bricks, Al_2O_3 (in the form of oxide) was added to the Chamotte-clay mix**.** The refractoriness under load of refractories is basically governed by their chemical and mineralogical composition i.e. by the presence of crystalline phases and nature of the structure, as well as by the amount of the vitreous phases and their viscosity. Refractory clay used for making fire-clay products under goes a number of transformations during firing, resulting in product made up of highly refractory crystalline ($3Al_2O_3.2SiO_2$) and a vitreous siliceous matrix (glass) of high viscosity.

As the alumina content of the product is increased, there is an increase in the amount of the glassy matrix. This change in phase composition causes an improvement of the physical and refractory properties of the final Products, therefore. The addition of 5-l0% alumina to our clay to bind the excess silica (SiO_2) release during transformation of the clay mineral kaolinite may increases the amount of mullite, in the product and reduces the amount of glassy matrix.

Accordingly, more mullite and less glassy matrix are present in samples no 2 and 3 table (2) which contains a relatively higher amount of Al_2O_3 than sample No.1.
The results are given in table (2).

Table (2) influence of Al2O3 content on the RUL and porosity of the fired bricks

Sample no	Al_2O_3 %	Porosity [%]	Beginning of subsidence (t_a) C^o	Subsidence [%]
1	0	14.0	1180	1.0
2	5	19.0	1450	1.1
3	10	22.0	1430	2.79

Chester [1] used a Fire — clay having a chemical composition similar to that of our clay and achieved value of 1490C^o for t_a**,** In the present work considerable variations in values and subsidence were observed depending on the amount of Al_2O_3 added comparatively higher t_a of more than 1450 C° and lower value of subsidence and porosity, namely 1.1% and 19% respectively The lowest t_a,(1430C° and highest subsidence (2.79%) and porosity (22%) were achieved for bricks produced by adding 10% of Al_2O_3table(2)

Normally increase of porosity leads to decrease t_a. The interaction of silica transferred from the fire clay with alumina to form mullite is usually accompanied by volume increase which leads to an increase in the porosity of the final products. Therefore, samples No .2 and 3 showed and relatively higher porosity than sample no.1 Table(3) shows the RUL and porosity of various fire — clay refractors made in various countries of the world [7] Actually, the results of the present work fall within limits specified by the above mentioned references. Table (3) shows the RUL and the porosity of fire Clay refractors made in various countries of the world.

Property / Country	RUL (C^o)	Porosity (%)
U.K	1200-1400	10-23
USA	1150-1410	9-12
Russia	1305-1390	14-22
Germany	1230-1430	11-26
France	1140-1300	21-30
Our produced refractors		
1-without addition of Al_2O_3	1180	15
2-with addition of 5% Al_2O_3	1450	19
3-with addition of % Al_2O_3	1430	23

4. CONCLUSION

The local kaolinitic clay is suitable for the manufacture of refractory bricks, which meet the requirements for medium heat materials (38% Al_2O_3). After addition of Al_2O_3 the produced bricks meet the requirements for high heat duty materials.
2- The clay can be used both for the preparation of the grog (Chamotte) and as a binder clay, and for the preparation of the grog. the day was calculated at 1450C°
After firing the grog is crushed and classified to the following grain sizes:

fine	0-1.0	50%
medium	1.0-2.5mm	20%
coarse	2.5-6.0 mm	30%

3- The method recommended for molding of the bricks is the semi-dry process with water content between 7 and 9%. Suitable compaction was achieved by molding at a pressure of 50N/mm^2 The firing temperature was 1400C°4- for improving the load- bearing capacity of the fire-clay bricks. Al_2O_3 amount in the range of 5-10% were added to mix of chamotte/binder binder clay ratio of 70/30. Addition of 5%, Al2O3 is sufficient of increase the temperature of commencement of subsidence (T_a) form 1180 Co to 1450C0
5-There is a clear correlation between the refractoriness under load and the porosity produced bricks. Higher porosity causes a decrease in the temperature of deformation of fine-clay bricks.

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