Effect on Microstructure of Clay Bricks after Firing Temperature

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Abstract: - Many Experiments are done on clay Bricks to calculate its firing temperature on Bricks microstructure. For this reason different samples are equipped before firing and after firing. Properties of clay will be explained. Thermal analysis on raw clays will be explained .For explaining Microstructure of clay brick, Phase recognition process will be useful .To study Mechanical Properties of Clay Bricks; Water absorption test will be used in this chapter. At last Pore Structure of Clay Bricks will be discussed.

Keywords: - Bricks, Microstructure, clay, vitrification

1. Introduction:-

A brick is a block or a single unit of a Clay bearing soil, sand and lime or concrete material, fire hardened or air dried used in masonry construction. Light weight bricks are made from expanded clay aggregate. Fired brick are the most numerous types and are laid in courses and numerous patterns known as bonds collectively known as brickwork and may be laid in various kinds of mortar to hold the bricks together to make a durable structure. Brick are produced in numerous classes, types, materials, and sizes which vary with region and time period and are produced in bulk quantities. Two most basic categories of brick are fired and non fired brick [1].

2. Properties of Bricks

1. Thermal properties

The thermal proper ties of a wall are related to its ability to transmit or resist the movement of heat and to its capacity to store thermal energy.

2. Thermal transmittance

Thermal transmittance U value is measured in Watts (W) per square meter (m2) per degree Celsius/m2 oC as the rate of heat flow through an element e.g. a wall. The lower the U value the better the insulation proper ties of the wall, it has a greater resistance to the flow of heat. The U value not only takes into account the resistance offered by the wall but also the outside and inside surface resistance. Since the U value notionally provides a measure of the heat flow through a wall, it is the figure used to compare the performance of different constructions and to make energy-use calculations.

3. Thermal capacity

Thermal capacity is measured in Joules (J) per square meter (m2) per degree Celsius, J/m2 oC and is a measure of the degree of heat that can be stored by a wall. Clay brick walls with their high thermal capacity have the ability to store heat during the day and release this heat at night. In climatic regions where there are high temperatures during the day and low temperatures at night this results in thermally comfort table dwellings with a reduction in energy consumption to cool or heat the buildings.

4. Thermal movement

An increase in the temperature of a wall will induce expansion. The degree of movement is equal to the temperature range multiplied by the appropriate coefficient of thermal movements overcoming restraint in the wall itself [2] a decrease in temperature will result in the shortening of the wall that may induce cracks. However, the movement that actually occurs within a wall after construction depends not only on the range of temperatures but also on the initial temperatures of the units as laid their moisture content and the degree of restraint. To determine the effective free movement that could occur therefore some estimation of the initial temperature and temperature range has to be made. The effective free movement that is calculated should still be modified to allow for the effects of restraints.

3. Effect on Microstructure of Clay Bricks after Firing Temperature

During firing of clay brick a sequence of alteration occurs which decide the properties of the brick product. The main factors concerned in manufacturing bricks are the type of raw materials, fabrication method, drying procedure, firing temperature and firing profile. These factors influence the quality of the final product according to G. Cultrone et. Al [3]. However R. A. Livingston et.al [4] suggested that the durability and strength of bricks are linked to their microstructure and mineralogy. In unfired clay bricks the strength and water permeability are associated to the size and shape of the particles present and the forming process but ahead heating the nature of the mineral comprising the mass has a very significant influence because of the chemical reactions and partial fusing which occur then [5].

The porosity in brick unit depends on the type of clay used in manufacturing and temperature of firing. With reference to F. M. Khalaf [6] the porosity of the brick influences its compressive strength, water absorption and permeability. During the sintering process in the brick manufacturing process initial raw materials transform into complex compounds at high temperatures. New compounds are also shaped due to chemical reactions that take place.

These compounds have impacts on the steadiness of the material due to the reduce or increase in the volume of the system. A study by M. S. Tite and Y. Maniatis [7] showed that vitrification of ceramic material is a significant factor that influences the quality and physical properties of the end manufactured goods such as strength and permeability.

The method of manufacturing clay brick was adopted from the factories but the firing process is different. Heating rate, soaking time and firing schedule were constant. The firing temperatures used are varied, from 800oC to 1250oC.

4. Preparation of test samples before firing

The clay was supplied by brick factories. Then the material collected was wet and in large chunks, and was then exposed to ambient sun and dried at maximum temperature of 35oC, with minimum 6 hours exposed time for 7 days. Identification of clay was proceeding out by the XRD technique using a Bruker D8 ADVANCE machine. XRD patterns were scanned in steps of 0.034o in a range of diffraction angles from 10o to 58o of 2θo for clay using Copper as X-ray source with a wavelength of 1.5406 Å.

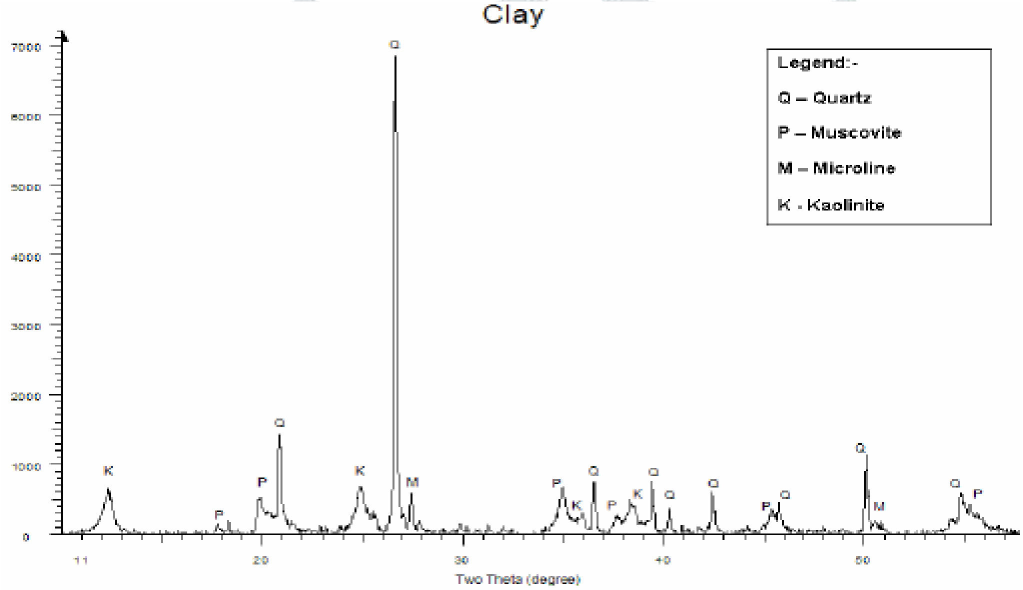

Fig.-1 XRD diffract gram of clay taken

The results are shown in Fig.-1. An X-Ray spectrometer mechanism was used to conclude the chemical composition of the clays. Samples were sieved passing 75µm before testing was conducted. 25g of a particular sample was collected in a dried state and then compacted inside a sample holder.

Loss of ignition value for the sample was prepared separately. For the Atternberg limit test and density test, the clays were sieved passing 425µm and the test was performed. Using a suitable amount of water for mixing, the sieved clays were extruded and wire cut to form brick shapes in the size of 67 x 33 x 20 mm3.

The raw bricks were air dried out for 24 hours in an ambient room temperature of 27oC and oven dried at 105oC for another 3 days. Before the firing process, the simultaneous thermo gravimetric analysis (TGA) and differential thermal analysis (DTA) techniques that permit the continuous weighing of samples as a function of temperature at desired temperature were carried out [8-10].

5. Preparation of test samples after firing

The dried raw bricks were fired in a muffle furnace 10 samples were fired for each firing temperature, from 800oC to 1250oC, with 1 hour soaking time, respectively. After the sintering process, the fired clay bricks' physical properties were observed. The particle morphology of the materials was performed by scanning electron microscopy (SEM). In this study, field emission scanning electron microscope (FESEM) with high resolution imaging was used to characterize the samples. The phase changes after firing were calculated using XRD technique. XRD patterns were scanned in steps of 0.017o in a range of diffraction angles from 6o to 90o of 2θo for clay bricks fired at different temperatures.

Then the clay brick samples were subjected to compressive strength, water absorption and porosity tests.

6. Microstructure of clay Brick

Fig.-2 show the microstructure of the fracture surface of the clay bricks sintered from 800oC to 1250oC for 1 hour. The microstructure changes with the sintering temperature. At 800oC and 900oC, the brick has not yet experienced full solid state sintering process since the individual clay particles are still existent

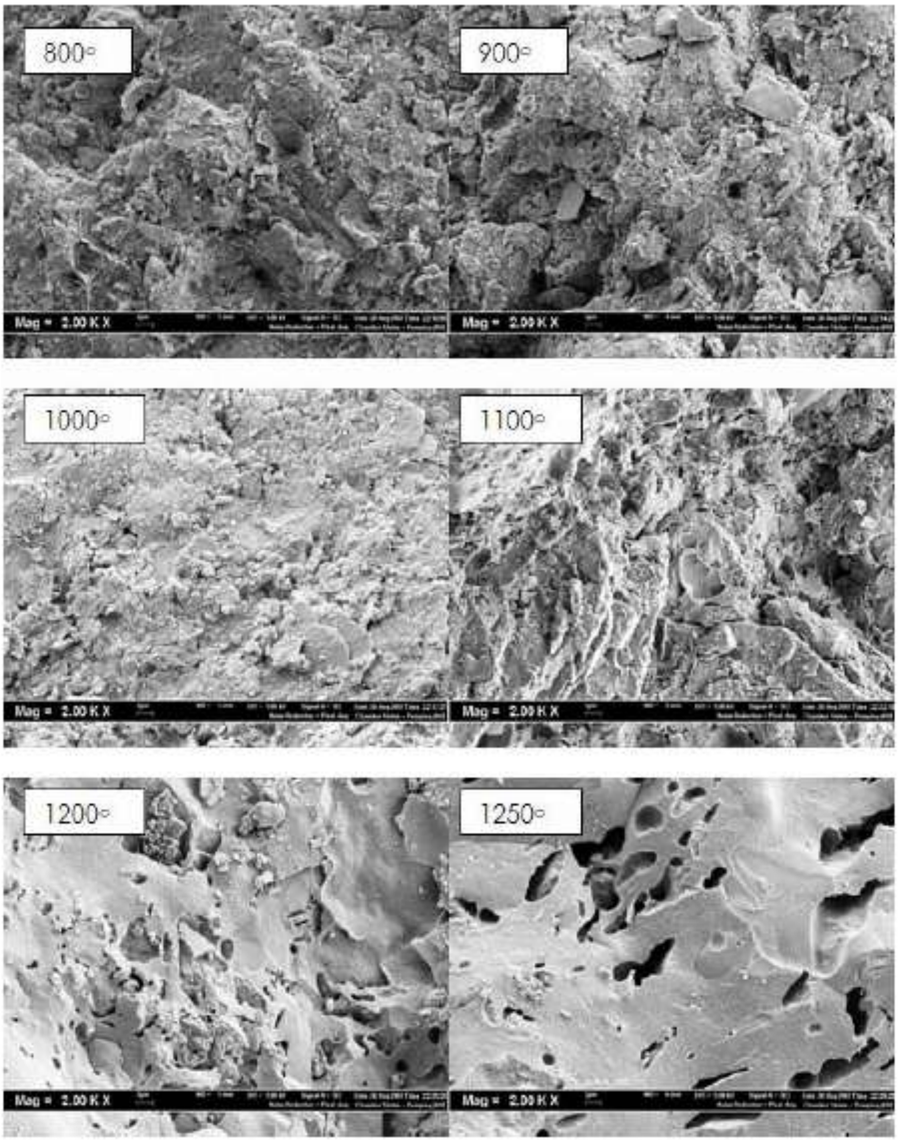

Fig.-2. Micrographs for the clay fired at different temperatures

This performance is consistent which shows that the brick structure formed at lower temperatures (840-960 oC) remained essentially the same until temperatures of over 1080oC are reached. The porosity of brick shows an increment of 1.4% and 0.1% from 800oC to 900oC and 900oC to 1000oC, respectively presented in Fig.-3. The increasing in porosity was the result of diffusion at relatively low temperature without significant shrinkage. The shrinkage value for temperature 800oC, 900oC and 1000oC is 0.31%, 0.50% and 1.04%, respectively.The surface also looks rough and a bit dusty. The bricks that were sintered until 1000oC are considered as having a porous structure since their water absorption rates are higher than 25%, as shown in Fig.-4

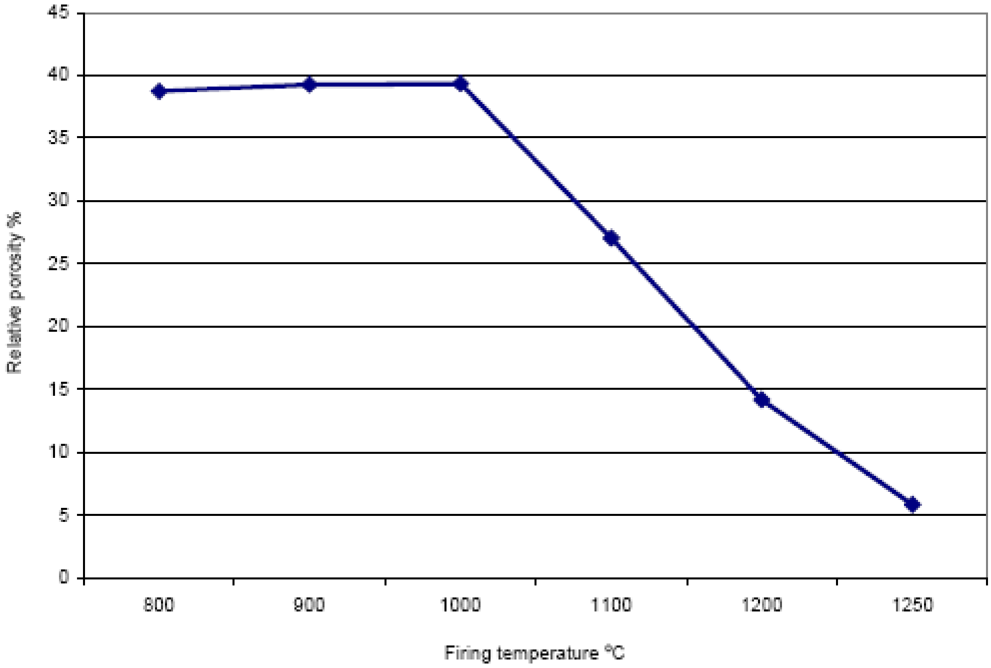

Fig.-3. Effect of firing temperature of the clay on the porosity

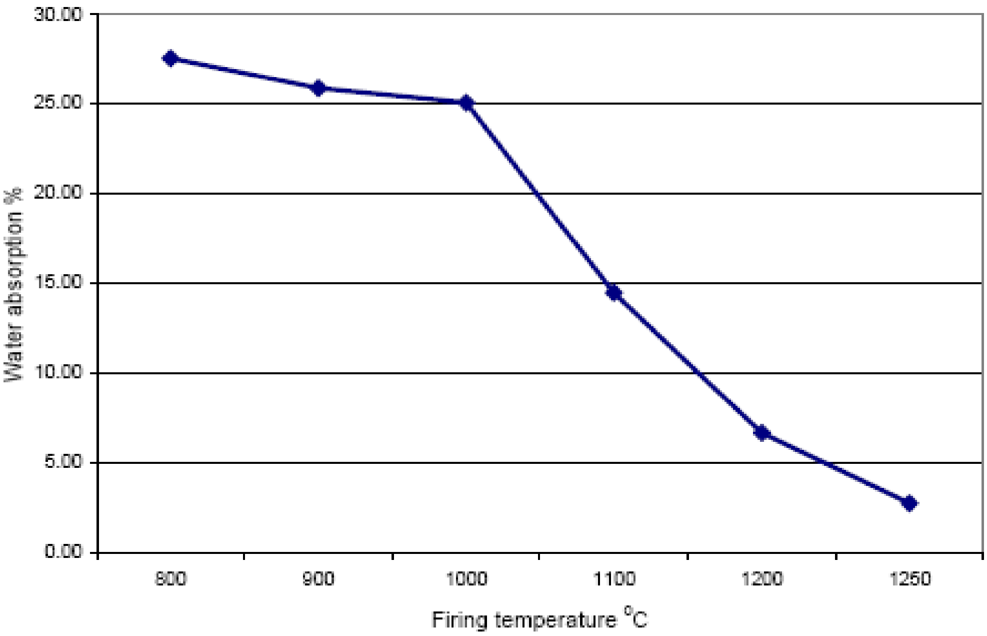

Fig.-4 Effect of firing temperature of the clay on the water absorption

Between 1000oC to 1100oC, the solid state sintering becomes very significant since the clay body had been fully sintered. Very few pores can be seen in the microstructure. Brick porosity value reduces significantly from 39.33% to 27.06% and it was 31% reduction. The purpose of the solid state sintering process is to develop atomic bonding between particles by a diffusion mechanism. This diffusion followed by grain growth will create a dense structure with significant shrinkage. The shrinkage value increases 74% causing the reduction in volume for brick sintered from temperature 10000C to 11000C. A progressive gain in strength can be observed on brick sintered at 11000C where the compressive strength increased from 25.4N/mm2 to 71.8 N/mm2. Starting from 11000C, the liquid phase sintering becomes a very important sintering mechanism. Emphasized that the liquid phase sintering was existent if there is a liquid phase that coexists with particulate solids during the sintering process. During this process, the reduction of pores becomes more significant as the compacted structure starts to increase its performances, such as strength and water permeability. The fired clay brick sintered at 1100oC begins to diffuse and shrink as the liquid phase starts to form and fill up the pores, creating smaller pores. The brick shrunk 37% when sintered from 11000C to 12000C causing the porosity to reduce 47.5%. The effect of firing also causes the water absorption value to reduce 42% lower than the value for brick sintered at 1000oC.

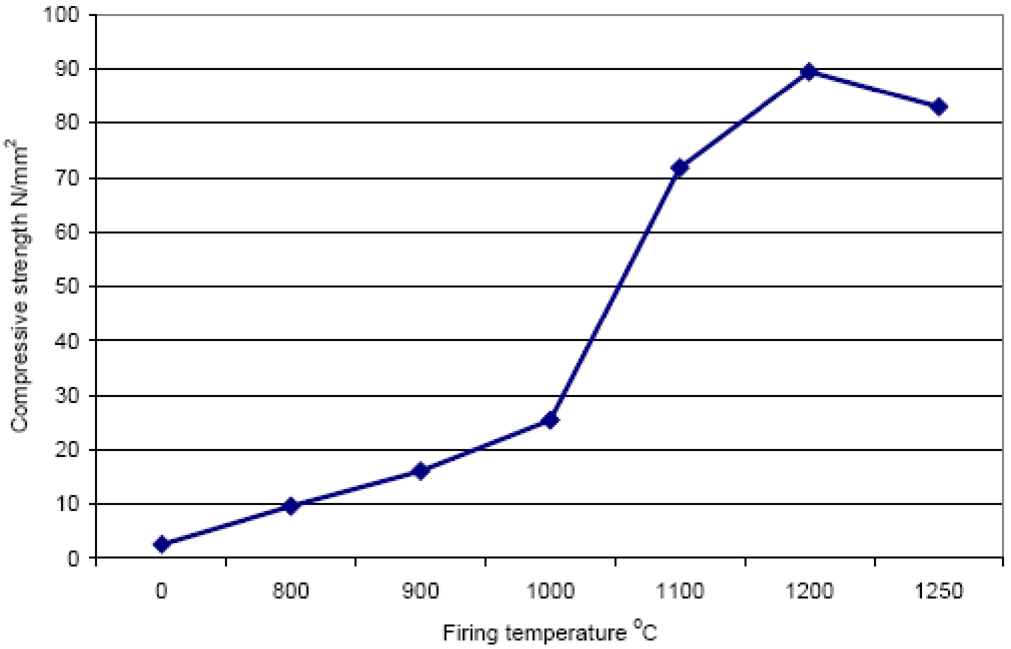

Fig.-5 Effect of firing temperature of the clay on the compressive strength

The internal surface of pores in bricks sintered at 12000C and 12500C has a "glazed" view Fig-. 4. The sintering process reached the optimum temperature at 12000C, whereby its microstructure contains minimum pores with porosity value 14.2 % and produces the highest strength, 89.5 MPa, as shown in Fig.-5. However, at 12500C, the microstructure shows larger pore sizes and lower porosity value which is 5.87% with brittle fracture behavior. The brick becomes more brittle due to a larger portion of glassy phase in the microstructure. Therefore, the strength of the sample becomes lower (83 MPa). Even though the porosity value is lower than the brick sintered at 12000C, this only effect on the water absorption properties where the value of water absorption for brick sintered at 12000C and 12500C was 6.63% and 2.71%, respectively.

7. Experimental outcomes

The pore structure parameters and dry thermal conductivity were determined for four types of clay bricks. The pore size distribution, the open porosity and the specific surface area of pores were studied using the mercury intrusion porosimetry (MIP): the high pressure porosimeter mod. 2000 and macro porosimeter mod. 120. This system enables determination of micro pores with the radius from 3.7 up to 7500 nm and of larger pores with a radius up to 0.06mm.

The porosimetry measurement was carried out by the fraction of broken dried up to 105°C samples. Specific surface area of pores was determined using the cylindrical model. The open porosity was also determined from the suction test.
The thermal conductivity was measured by transient pulse method. The used surface probe is suitable for thermal conductivities in the range from 0.3 to 2 W/m·K. The measurement is based on the analysis of the temperature response of the practically semi-infinite body to the heat flow impulse. The heat flow is generated by electrical heating using a resistor heater having a direct thermal contact with the surface of the sample.
The samples were conditioned under laboratory conditions: 28°C and 36% relative humidity and they can be practically considered as dry.

8. Results

The values of open porosity, determined from suction test, bulk and true density and the measured values of thermal conductivity .Because for the clay bricks the values of open porosity and total porosity are practically identical [11], the values of open porosity were used in the following analysis of the relationships between the thermal conductivity and microstructure.

In Fig-6 the relationship between the total porosity and thermal conductivity of tested bricks is compared with the previous measurements of CHS materials and the empirical relation. As can be seen from the figure the dependence thermal conductivity/porosity dependence of bricks can be in the first approximation expressed by empirical relation similarly like in case of CHS materials.

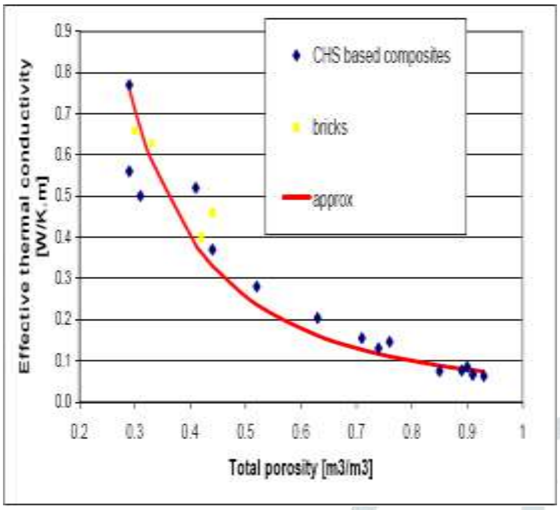

Figure.-6 Thermal conductivities of clay bricks and CHS based materials vs. total porosity Comparison of the measured values and empirical approximation

9. Conclusions

The relation between microstructure and effective thermal conductivity was investigated for four types of clay bricks The effective thermal conductivity of dry clay bricks can be similarly, like thermal conductivity of CHS based mortars, plasters and insulation boards, modeled by serial configuration of solid and porous low thermal conductivity phases In the model the degree of the dispersion of low thermal conductivity phase is expressed by a power low. The exponent contains the pore space fractal dimension. The fractal dimension can be determined with the use of image analysis.

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References:-

[1]. Coomands, Thomas; VanRoyen, Harry, eds. (2008), "Novii Monasterii, 7", Medieval Brick Architecture in Flanders and Northern Europe, Koksijde: Ten Duinen
[2]. Salmon, D., Brandt, R. and Tye, R., 2010, “Pyroceram 9606, A Certified Ceramic Reference Material for High-Temperature Thermal Transport Properties: Part 2- Certification Measurements,” Intl. J. Thermophys., 31(2), pp. 355-373
[3]. G. Cultrone, E. Sebastian, M. J. De la Torre, Constr. Build. Mater. 19 (2005) 39
[4]. R. A. Livingston, P. E. Stutman and I. Schuman, Conservation of Historic Brick Structure, 11 (1998), 105
[5]. A. Bremner, Origin and effect of Cryptoflorescence of FEB. PhD Thesis, Leeds University, London, 2002
[6]. F. M. Khalaf, A. S. DeVenny, J. Mater. Civil Eng. 14 (2002), 334
[7]. M. S. Tite and Y. Maniatis, Nature 257 (1975) 122
[8]. S. Weber, Annalen der Physik, 21:325-356 (1917).
[9]. J J Healy,J J de Groot, J Kestin, The theory of the transient hot-wire method for measuring thermal conductivity, Brown University, Providence, R.I. 02912, U.S.A Physica B+C 04/1976; DOI: 10.1016/0378-4363(76)90203-5
[10]. K. Misra, A. K. Shrotriya, N. Singh , R. Singh and D. R. Chaudhary, Prediction of heat storage coefficient of two phase systems with spherical inclusions, J. Phys. Applied Phys., 27 (1994) 1823-1829
[11]. Dondi, M. et al. (2005) Water vapour permeability of Clay Bricks. Construction and Buillding Materials. Vol. 17, pp. 253-258
[12]. Wang, M., Wang, J., Pan, N., Chen, S., He, J.: Three-dimensional effect on the effective thermal conductivity of porous media. J. Phys. D Appl. Phys. 40, 260 (2007)