Cooling Effect of Some Materials in Clay Composite Bricks for Tropical Region

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Abstracts

Thermal resistive effect of embedded materials in composite bricks resulting in cooling have been investigated. Different particulate materials and continuous aligned polyethylene fibers were used as supposed thermal resistors in preparing the bricks for houses in tropical region. The face change in temperature {Outside temperature(T_1) – Inner Temperature (T_2)} across the brick insulated with particulate wood dust, paper, PVC, palm kernel, glass and no-material are 27.9, 27.5, 19.0, 24.0, 25.5 and 26.6 °C respectively after 90 minutes and 26.2, 26.3, 17.9, 22.9 , 22.8 and 24 °C respectively after 120 minutes. It is observed that ΔT°C after 90 and 120 minutes are higher for wood dust and paper than brick with no-material but lower for PVC, palm kernel and glass. A high face change in temperature indicates a drop in temperature T_2, resulting in cooling effect if used in building bricks. The same cooling effect was observed when continuous and aligned polyethylene fibers were used to make fiber – clay composite bricks. A side of each sample was subjected to heat of about 70°C and heat transferred measured at the other side as done for particulate embedded bricks. Change in temperature ΔT°C was found to increase with increasing quantity of polyethylene fibers embedded in the samples 34.2°C (0%), 35.4°C (0.5%), 35.5°C (1%), 35.7°C (1.5%), 36.6°C (2%) and 37.4°C (2.5%), these show that heat transfer decreases due to decrease in T_2 with quantity of fiber. The result shows that the effect is continuous and tends to equilibrium and the change in temperature becomes steady with time.

Introduction

The clay brick is one of the oldest and most enduring building materials in the world. Clay bricks have a long history dating as far back as 3000BC, and today they continue to offer a durable and classically timeless appeal to either traditional or contemporary architecture. With the popularity of using organic materials in the architecture and interior design, clay brick is experiencing a resurging popularity. Currently, exposed brickwork is a major trend in modern interiors. In the move towards loft apartments and business units, it is often the material of choice – for its industrial-type feel, as well as its durability and its great insulating qualities. A home that is warm in winter and cool in summer – clay bricks are well noted for their remarkable thermal insulation properties (Desi, 2011). (http://www.property24.com/articles/clay-bricks-offer-many-benefits/13301).

Composite bricks are materials composed of two different materials bonded together in such a way that one serve as the matrix surrounding the reinforcing material. The materials were combined together but remains uniquely identifiable in the mixture. This is not the same as making an alloy by mixing two distinct materials together, where the individual component became indistinguishable. Clay building products have a very long lifetime, require little or no maintenance and help minimise heating and cooling costs; they therefore provide optimal economic performance. As a result of these benefits, buildings made from clay building products have a very positive CO_2 balance over their lifetime. Last but not least, they are flexible in use and provide excellent living conditions and indoor climate due to their porous structure, their mass and high resistance to fire and moisture.

Heating and cooling costs incurred over the lifespan of a residential building are significant. This is not only due to monetary considerations but also to the need to reduce CO_2 emissions from residential heating systems - seen by EU-member states as important constituents in meeting their Kyoto targets (TBE, 2005). Clay bricks are inert and are not prone to off-gassing of volatile materials. Clay brickwork and its constituents are non-toxic. Clay blocks are unique in offering high thermal insulation with equally high heat retention properties. This natural air conditioner ensures a relatively constant indoor temperature as well as protection from the heat in summer. No other building material is capable of the same. Worldwide it has already been studied the possibility of improving block wall insulation by increasing porosity of bulk material or by addition of different ceilings into block voids. Heavy clay blocks are one of the most frequently used basic materials for construction in Serbia as well as worldwide, so concerning the increasing tendency to reduce costs production and installation, and at the same time to achieve better insulating properties, it is necessary to come to new solutions, which would then be presented to the producers. Existing solutions to this problem are different systems of walls as well as layers addition like sandwich panels, polystyrene, thermal insulation mortars, etc., but it significantly increases the cost of objects construction (Arsenovic *et al*., 2010).

The inside door temperature of building is affected by the three modes of heat transfer: convection, conduction and radiation. The major portion of heat is transmitted into the building by conduction mode through the walls in addition to heat losses by air leakage. The composite walls involve several layers of different materials with different thermal conductivities.

Thermal conductivity of bricks containing different weight percentages of insulating materials are experimentally determined and compared with thermal conductivity of the bricks which do not contain any insulating materials. The most effective material among the tested insulating materials in reducing thermal conductivity is found to be glass wool and natural cork, followed by wood dust and polystyrene 330, then polyethylene 952 and polyethylene 218. The least effective insulating materials in reducing the thermal conductivity of the building bricks are polycarbonate and rock wool (Othman, 2010) .

Porotherm Thermo Brick has borrowed the principle of thermal insulation from nature, to become a unique walling material - one that keeps the interiors cool in summer and warm in winter! Clay bricks have been imperative, healthy and efficient construction material for time immemorial. Wienerberger, the world's No.1 in clay building material with 232 plants in 27 countries, actively seeks to bring sustainable, environmental & energy efficient building materials. Against this backdrop, Wienerberger India has developed India's first thermal insulated brick -Porotherm Thermo Brick www.wienerberger.in/wall/porotherm-thermo-brick..

POROTHERM THERMO BRICK has been packed with special insulating material to achieve lowest 'U' value of 0.6 W/m^2K thus reducing transfer of heat from external environment to the interior of the building. Unlike walls built with traditional bricks, use of Porotherm Thermo Brick results in interiors being cool in summer and warm in winter, when compared to the external temperatures. Consequently this results in savings in energy costs, by reducing artificial cooling and heating.

Thermal Insulation

Clay brick is traditionally the best building material and Porotherm Thermo Brick is a highly improved version of clay bricks. Specially formulated insulating material gives Porotherm Thermo Brick a 'U' Value** of 0.6 W/m²K compared to 1.8 W/m²K for a solid clay brick and 2.0 W/m²K for a solid concrete block. Which means superior thermal insulation that greatly improves the efficiency of buildings with regards to the use of energy, thereby contributing to the indoor comfort of the building www.wienerberger.in/wall/porotherm-thermo-brick.

Thermal insulation of bricks with different materials has a challenge especially in regions where temperature go down to about 10°C and below to freezing stage. In tropic region of the world where atmospheric temperature ranges between 22 and 35 °C, clay bricks can be thermally insulated. In other regions of the world, unfortunately, the addition of insulation will change the thermal and moisture balance of any wall assembly and, in some cases, can initiate moisture problems such as freeze-thaw damage (Straube and Schumacher 2007) in masonry units by decreasing the drying capacity while simultaneously reducing the temperature of the inner wythes. The very real increased risk of freeze-thaw damage has caused many designers and owners to avoid the addition of interior insulation. This is a major loss of energy saving potential and often renders a building less comfortable and usable than it would be if insulated (Mensinga *et. al.*, 2010). Therefore, when planning a retrofit strategy, an engineer or architect can pursue a strategy in which the predicted in-service moisture load will be less than the critical degree of saturation of the material. Older load-bearing clay brick masonry buildings are common throughout North America and are considered good candidates for renovation and conversion: they are often in desirable urban location, have strong structures, are often aesthetically pleasing with architectural significance, and have useful window areas and floor plans. Given the current and expected future energy costs and demands for carbon emission reductions, insulation retrofits are a highly desirable as part of any modern retrofit of this type of building stock (Mensinga *et. al*., 2010).

The tropical city needs an appropriate concept of heat balance of thermal environment. Buildings with heavyweight material in this area absorb and trap heat and make the environment hotter. Based on the building material and orientation analysis, the tropical areas need an appropriate wall panel for east west wall of buildings. The concept consists of several points, such as; 1. The eastwest wall material should be low in heat capacity and high in thermal insulation. Low heat capacity wall panel allows a little amount of heat absorption, while high thermal insulation allows a little amount of heat transferred through the material. 2. The east-west wall material should have good direct reflection or screening solar radiation to reduce direct heat gain (Wonorahardjo *et. al.,* 2008).

In addition, The vast natural land depletion is contributed by agricultural land cultivation and agrobased industry's expansion too, to support the survival needs of the human race. The production and manufacturing processes inadvertently generate large quantities of natural wastes, such as fibres, pulps and grains, which are disposed of in landfill and open burning. Besides, the accumulation of unmanaged or improperly managed wastes has raised significant environmental and sustainable concerns. An on-going effort to counter this vicious cycle is by interception: to recycle and incorporate these natural wastes in the construction industry, especially in the manufacturing of building materials. A particularly potential area for the reuse of these wastes is brick-making. Adding natural fibres in clay bricks has been reported to improve the compressive strength and flexibility. Apart from that, the baking of composite bricks with natural fibres and grains leaves a porous structure which consequently enhances thermal and acoustic insulation of the finished products (Chee-Ming, 2011).

In this study, we have used several materials as supposed insulating materials such as processed glass, paper, poly vinyl chloride (pvc), palm kernel shell, wood dust in their particulate forms. Polyetheyne fibers in their continuous forms and different percentages by volume of fiber 0, 0.5, 1, 1.5, 2 and 2.5 % were also used. These were embedded in layers to produce insulated bricks. Insulating capacities of the materials were investigated and the insulating effect by the materials were estimated and compared. The research is channelled towards saving energy in house cooling, promoting a clean environment and usage of cheaper and reliable materials for building.

Materials and Experimental Techniques

Materials

The main material used in this work is clay used in manufacturing the ordinary bricks for building houses. Clay is aluminum silicates, being composed of allumia (Al_2O_3) and silica (SiO_2) that contain chemically bound water. They have a broad range of physical characteristics, chemical compositions and structures. The insulating materials used for the alternate-layers particulate insulated composite bricks are glass, paper, polyvinyl chloride (PVC), palm kernel shell, wood dust in particle forms. The second set of composite bricks were made using polyethylene polymer continuous fibers arranged also in alternating layers in the clay to form composite bricks. The insulating materials were chosen because of their ease of handling and supposed low thermal conductivity. Other equipments used are the rectangular shaped flat heater, a variac, a thermometer and furnace.

Experimental Techniques

Clay processed

The first step is called Mining or Winning the clay. After digging the ground to extract the clay, it was matched to powder and was sieved to remove the stones and get soft fine clay free from stones. The second step is the Preparation of the clay. The clay was poured in a bowl, a little amount of water was added to it to serve as a binder to obtain the proper consistency for molding. The clay used was a red clay extracted and tested by adding a little water to know the plasticity, after confirming this, it was sieved to get a soft fine texture.

Insulating Materials Processed.

The wood dust was obtained from the wood log, sieved to remove the dirt and make it neater. The glass was crushed in a mortal, sieved to make it to be in a powdered form. The paper was soaked overnight, smashed, sun dried and later ground to get the smallest particles. The palm kernel shell was picked, washed to remove dirt, dried and was later grinded to make the powdered form. The PVC was cut from the PVC pipe, the pipe was crushed and the powder remaining was packed. The third step is moulding. After the clay has been prepared into lump, then we now roll and it is been dash forcefully into the mode. A mode is the wooden box 9.1 cm x 6.9 cm x 4.3 cm, that gives the bricks its shape. The clay was then pressed into the mode with hand. The excess clay was scraped to make it flat. After that 60cm^3 of the clay would be remove and will be replaced by the insulator, that is 60cm^3 of (glass, paper, wood dust, PVC, and palm kernel shell) would be added to the make the insulated bricks. Then we now pour back the remaining clay and we remould it in the box by laminating it with a nylon that the mould will not stick to the box and we force the lump of clay and insulators into the box layer by layer in the order of clay-insulator-clay–insulator-clay. And the insulated brick was moulded. The moulded bricks is been compressed for two days in the box to give it a nice shape and to drain the water. The bricks were removed from the box after two days and were left to dry at a room temperature for about seven day to facilitate uniform drying and top preventing warping. After about two week the bricks were hard and ready to be fired in the furnace. We simply heat the insulated bricks by placing them in the furnace for one hour at a temperature of 300 °C at long run the brick became harder and the colour changed to brown.

Measurement of Heat Transfer

The measurement of conductivity of heat through the materials is carried out and described under a phenomenon of heat transfer in materials which is quite possible due to temperature changes existing in the material. These was carried out with the use of the heater, by placing the heater on one side recording the temperature at that point of the heater as outside temperature (T_1) and also recording the temperature from the other side of the bricks inner temperature (T_2), the change in temperature (ΔT) could be measured by the difference between the temperature T_1 and T_2 which serves as a proof for the conductivity heat in the bricks the temperature is measured using a digital thermometer in which it measures even the smallest change in temperature, and was lagged to prevent heat loss during the experiment. The heater used was kept at a maximum temperature of about 68^0c.the voltage required is regulated with the use of a variable transformer voltage regulator (variac) for the heater which reduced the voltage to 40 volts.

Results and Analysis

The Change in Temperature $\Delta T = (T_1 – T_2)$ °C with time is shown in Figure 1 for particulate insulated composite bricks. The temperature of the first face T_1 is about 68°C and the temperature on the opposite side of the brick is T_2. It is observed that the change in temperature ΔT decreases as T_2 increases with time. This is true for all particulate composite bricks and even the reference clay-only brick. However, the rate of change in face temperature with time differs from one insulating material to the other. Considering the rate of change after 90 and 120 minutes, it is seen that the change in face temperature ΔT for wood dust, paper, clay only, PVC, palm kernel and glass are 27.9, 27.5, 26.6, 19.0, 24.0 and 25.5 °C respectively and 26.2, 26.3, 24, 17.9, 22.9 and 22.8 respectively. It is seen that the face change in temperature after 90 and 120 minutes are higher for wood dust and paper than that of clay only but lower for PVC, palm kernel and glass. A high face change in temperature (ΔT) indicates a drop in temperature T_2. Comparing the ΔT values for only clay brick with that of insulated ones therefore shows that wood dust and paper insulators will cause a cooling effect if used in building bricks. This is because the T_2 after 90 and 120 minutes for wood dust and paper are lower compared with T_2 for clay only. It implies that using particulate wood dust and paper will give cooling effect if used as thermal insulating materials for bricks in tropical region. Figure 3 represents the change in temperature (°C) with time (Secs.) for fiber-clay composite bricks, with 0, 0.5, 1, 1.5, 2 and 2.5 % of fiber by volume. It is observed that temperature difference ΔT, decreases with time for all the samples but the rate of change in temperature varies with the percentage of fiber in each sample. The rate of change in temperature increases with fiber content in the bricks. The change in temperature after 1200 seconds are 34.2 (0% Fiber), 35.4 (0.5% Fiber), 35.5 (1% Fiber), 35.7

(1.5%Fiber), 36.6 (2% Fiber) and 37.2 (2.5% Fiber). This shows that, there is increase in change in temperature with increase in the percentage fiber content as shown in figure 4. It is an ndication that the temperature on the opposite side of the composite brick is reducing with increase in percentage fiber content resulting in cooling effect.

Conclusion

Different particulate materials such as glass, paper, polyvinyl chloride (PVC), palm kernel shell, wood dust and continuous aligned polyethylene fibers were used as supposed thermal resistors in developing the insulated bricks for houses in tropical region. The face change in temperature {Outside temperature (T_1) – Inner Temperature (T_2)} across the brick insulated with particulate materials after 90 and 120 minutes are higher for wood dust and paper than that with no-material but lower for PVC, palm kernel and glass. A higher face change in temperature than that of no insulating material bricks indicates a cooling effect. It has a benefiting economic advantage in conserving energy used for cooling. The same cooling effect was observed when continuous and aligned polyethylene fibers were used to make fiber – clay composite bricks. Change in temperature $\Delta T°C$ was found to increase with increasing quantity of polyethylene fibers embedded in the samples. This shows that thermal conductivity decreases due to decrease in T_2 with quantity of fiber. The use of clay also provides a material with features needed to achieve a clean environment and it is a reliable material in terms of fire resistant, durable and cheap.

References

Arsenovic M., Lalic Z. and Radojevic Z. (2010). Clay Brick Walls Thermal Properties. International Journal of Modern Manufacturing Technologies. Vol. II, No. 1, pp. 15-18.

Chee-Ming C. (2011). Effect of Natural Fibre Inclusion in Clay Bricks: Physico-Mechanical Properties. International Journal of Civil and Enviromental Engineering. Vol. 3, No. 1, pp. 51-57.

Indian Green Building Council. Stay Cool with the Fruits of Technology and Save Energy. Wienerberger Building Value: POROTHERM Thermo Brick Ultimate in Energy Efficiency. www.wienerberger.in/wall/porotherm-therrmo-brick.

Inglis C. and Downton P. Material in Use: Clay Brick. Energy Smart Housing Manual, Victorian Government Cho61. Pp. 166-168.

Kidger P. Nothing Compares to Clay Brick in a Wall: Lightweight Walled Alternate Building Systems No Match to Double Skin Clay Construction.

Mensinga P., Straube J. and Schumacher C. (2010). Assessing the Freeze-Thaw Resistance of Clay Brick for Interior Insulation Retrofit Projects.

Othman A.M. (2010). Experimental Investigations of the Effect of some Insulating Materials on the Compressive Strength, Water Absorption and Thermal Conductivity of Building Bricks. Jordan Journal of Mechanical and Industrial Engineering. Vol. 4, No. 4, pp. 443-450.

Ties and Bricks of Europe (2005). The Clay Life Cycle. Stay with Clay: Building in Use. www.staywithclay.com/default-en.asp.

Wonorahardjo S., Edward B., Olivia D. and Tedja S. (2008). Wall Panel and Material for Tropical Area Case Study: The City of Bandung, Indonesia. Paper Number: 3897834.