Heat Transfer Analysis of Autoclaved Aerated Concrete (AAC) Brick box type Solar Cooker with Side Loading

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ABSTRACT

It is very difficult to calculate and analyze the thermal behavior of the side walls of different materials attached to each other. The study of composite materials thermal behavior is useful for the determination of heat transfer rate. These composite materials which can be implemented to many applications such as thermal Insulators, multiwall thermal protection systems, etc. In this study the thermal behavior of composites materials side wall of box type solar cooker is analyzed. The experimental test is carried out for finding heat loss coefficient of autoclave aerated concrete (AAC) brick box type solar cooker.

Keyword: - *Box type solar cooker, Autoclaved aerated concrete (AAC), heat transfer rate, heat loss coefficient, Thermal performance.*

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1. INTRODUCTION

Solar energy is one of the forms of energy obtained by receiving heat and light from the Sun rays. It is renewable and green source of energy. This green source of energy is used for solar equipments. Technology has provided a number of ways to use this resource. Solar energy is available in large quantities and has been used as a source of heat. A 'solar cooker' is a device which uses the energy of direct sunlight to heat for cooking purpose but some of the heat is loss in box type solar cooker to atmosphere through a composite side wall. An autoclave aerated concrete (AAC) box type solar cooker is mainly a rectangular box. A box made of autoclave aerated concrete block which is an insulating material. Side wall of box type solar cooker made up of composite wall which is a combine conventional material with new materials with different thermal properties to result in improved performance. Heat transfer is the study of thermal energy transport within a medium or among neighboring media by molecular interaction, fluid motion, and electro-magnetic waves, resulting from a spatial variation in temperature. This variation in temperature is governed by the principle of energy conservation, which when applied to a control volume or a control mass, states that the sum of the flow of energy and heat across the system, the work done on the system, and the energy stored and converted within the system, is zero.

Composite systems have considerable practical utility which are made of two or more layers of different materials. The AAC box type solar cooker side walls have layer of bricks, a layer of Rockwool insulation and absorber plate. The treatment of conductive heat flow for such structures may consider as an extension of the single wall structures. In such composite structures each layer has a different value of resistance, the overall cumulative effect of these resistances are also analyzed. Usually the resistances of the free surfaces also have to be accounted for as additional resistances in series in calculations. This is due to the fact that the actual surface temperatures, which are different than the ambient values are not known. It is generally assumed that heat flow is steady and one dimensional, there are no heat sources in the structure and that the resistance due to interface contact is negligible. The mechanism of heat transfer across the interface contact is therefore complicated. So it is necessary to design and fabricate a composite system in order to study the temperature distribution across the width of wall and also estimate the thermal resistances, convective heat transfer coefficient and over all heat transfer coefficient of the system.

Autoclaved aerated concrete (AAC) blocks are light weight, insulating and eco-friendly. These blocks consist of 80% air by volume. These blocks are made using Portland cement, quartz (silica), water and aeration agent. The mixture of these constituents is poured in mould. These blocks formed as a result of reaction of Aluminium on a proportionate blend of lime, cement and fly ash, the hydrogen gas that escapes creates millions of tiny air cells give it a strong structure.

Nomenclature:-

A: - surface area where the heat transfer takes place, m^2
$T_{\infty 1}$:- temperature of the inside cooking space, k.
$T_{\infty 2}$:- temperature of the surrounding fluid, k
T_1:- temperature of the absorber plate surface, k.
T_2:- temperature between absorber plate and rockwool surface, k.
T_3:- temperature between rockwool and AAC brick surface, k.
T_4:- temperature of the AAC brick outside surface, k.
h:-heat transfer coefficient w/m^2k
Q: - heat transfer rate, watt
dt/dx:- the temperature gradient.
K_1:- the thermal conductivity of absorber plate, W/mk
K_2 :- the thermal conductivity of rockwool, W/mk
K_3:- the thermal conductivity of AAC bricks, W/mk
l_1:- thickness of absorber plate, mm
l_2:- thickness of rockwool, mm
l_3:- thickness of AAC brick, mm

2. METHODOLOGY

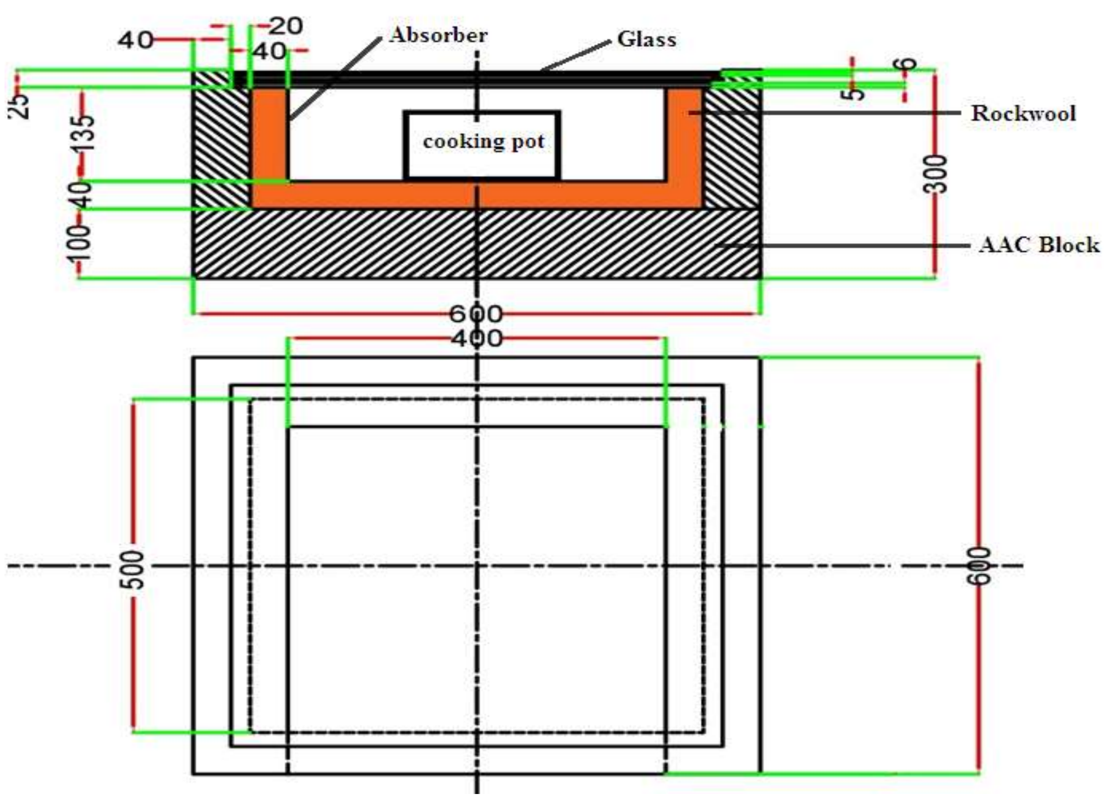

Fig -1(a): ***Sectional Front View and Top View of AAC Box type Solar Cooker.***

In this study an Autoclaved aerated concrete box type solar cooker is constructed with AAC blocks, side walls of the cooker is made up of composite materials such composite structures each layer has a different value of resistance and different thermal properties to result in improved performance. A composite slab consist of three different materials which are absorber; Rockwool and AAC Brick for one composite are having size of 100 mm thick. Thermocouples are placed between interfaces of the slabs, to read the temperature at the surface. The inside surface of box is painted by mat black colour. Solar box cooker with single reflectors was designed, constructed and tested.

Consider three plane walls in contact (called a composite wall) as shown below. The individual walls are labeled 1,2and 3 as are each the thermal conductivity K and thickness L. Assume the wall boundaries convect heat to the environment on both sides. Each side may have different convection coefficients h and environmental temperature T_∞.

Consider a solid composite material wall placed between two environments of different temperatures. Let T_1 be the temperature at x=0 and T_2 be the temperature at x=L, and suppose $T_1 > T_2$ heat flow from hot region to cold region. According to the second law of thermodynamics, heat will flow from the hot region to the cold one in an attempt to analyze the temperature difference. The thermal conductivity of the composite wall material is also very much necessary in determining the overall heat transfer through the medium.

3. HEAT TRANSFER PROCESS:

3.1. Convection:-

The heat transfer coefficient or film coefficient, or film effectiveness, in thermodynamics and in mechanics is the proportionality constant between the heat flux and the thermodynamic driving force for the flow of heat (i.e., the temperature difference, ΔT).The overall heat transfer rate for combined modes is usually expressed in terms of an overall conductance or heat transfer coefficient, U. In that case, the heat transfer rate is:

$$Q= hA (T_2-T_1)$$

3.2. Conduction: -

Conduction is the heat transfer from one end to the other end, it is important for calculating about the heat transfer rate. For one dimension conduction heat transfer in a plain wall, the amount of heat energy being transferred per unit time is proportional to the normal temperature gradient and the cross-sectional area A, this can be expressed as

$$Q= -kA (dt/dx)$$

3.3. Combined heat transfer through composite side wall of box type solar cooker:-

Consider the heat flow through composite wall made of several materials of different thermal conductivity and thickness. An example is a wall of AAC box type solar cooker, constructed of different layers of materials of different insulating properties. All the materials arranged in series in the direction of heat transfer, as shown in below figure. The thickness of the wall is L_1, L_2 and L_3 and thermal conductivity of the walls are K_1, K_2 and K_3 respectively. A side wall of AAC box type solar cooker has constructed of aluminum absorber (K_1=237W/m K), 0.64mm thick, the second layer 40mm thick Rockwool (K_2=0.04 W/m K), the third layer 60mm thick AAC brick (K_3=0.16W/m K). The heat transfer coefficient at interior and exterior of wall fluid layers are 8 W/m^{2}K and 14 W/m^{2}K respectively.

$$\mathbf{Q}= \frac{(\boldsymbol{\Delta T})_{overall}}{\boldsymbol{\varepsilon} \mathbf{R_{th}}}$$

$$\text{Where, } (\boldsymbol{\Delta}\mathbf{T})_{\mathbf{overall}} = (\mathbf{T\infty_1} - \mathbf{T\infty_2})$$

$$\boldsymbol{\varepsilon}\mathbf{R_{th}} = R1 + R2 + R3 + R4 + R5$$

$$Q=\left[\frac{(\Delta T)}{R1+R2+R3+R4+R5}\right]$$

$$\varepsilon R_{th}=\frac{1}{h_{1A}}+\frac{l_1}{K_{1A}}+\frac{l_2}{K_{2A}}+\frac{l_3}{K_{3A}}+\frac{1}{h_{2A}}$$

$$Q=\left[\frac{(\Delta T)}{\frac{1}{h_{1A}}+\frac{l_1}{K_{1A}}+\frac{l_2}{K_{2A}}+\frac{l_3}{K_{3A}}+\frac{1}{h_{2A}}}\right]$$

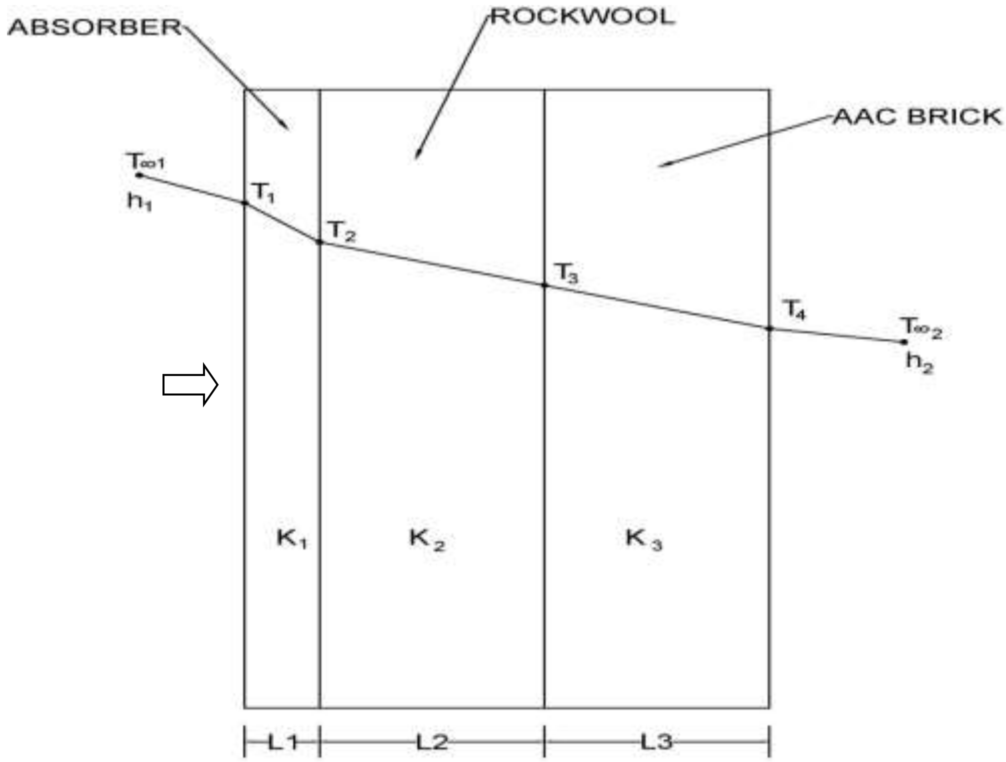

Fig -2 (a): **c**/s of ***composite side wall of AAC Box type Solar Cooker.***

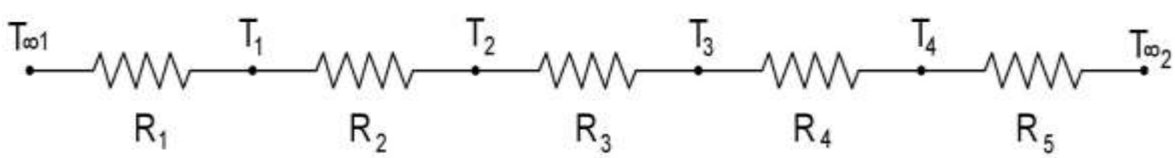

Fig -2 (b): ***Electrical analogy of composite side wall of AAC Box type Solar Cooker.***

Heat transfer rate in each layer in composite wall can be as

$$Q=\left[\frac{(T\infty_1-T_1)}{\frac{1}{h_{1A}}}\right]=\left[\frac{(T_1-T_2)}{\frac{l_1}{K_{1A}}}\right]=\left[\frac{(T_2-T_3)}{\frac{l_2}{K_{2A}}}\right]=\left[\frac{(T_3-T_4)}{\frac{l_3}{K_{3A}}}\right]=\left[\frac{(T_4-T\infty_2)}{\frac{1}{h_{2A}}}\right]$$

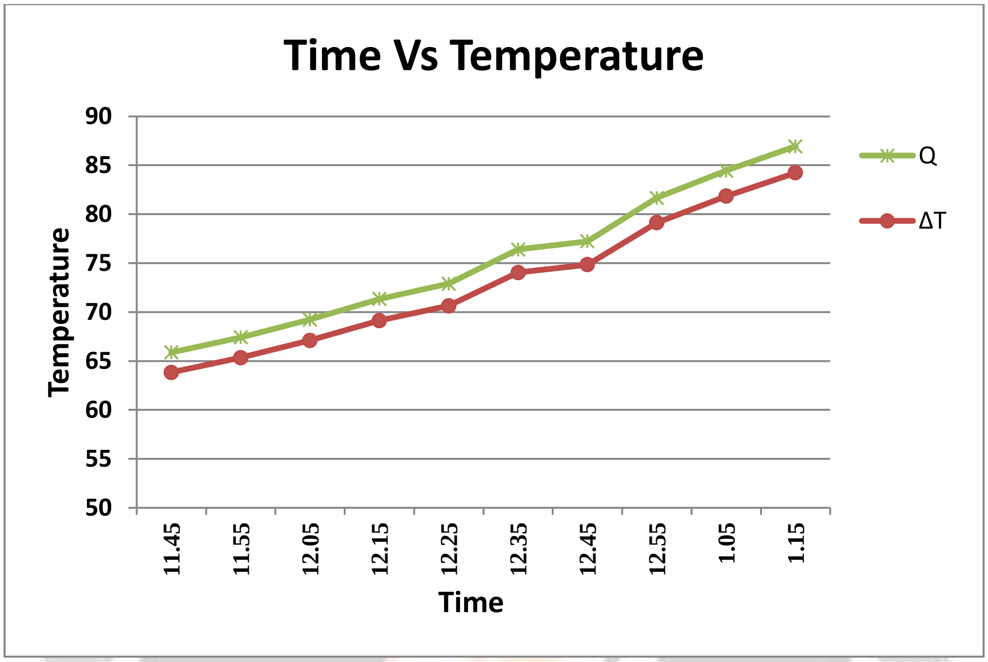

Chart -1: Variation of temperature with time

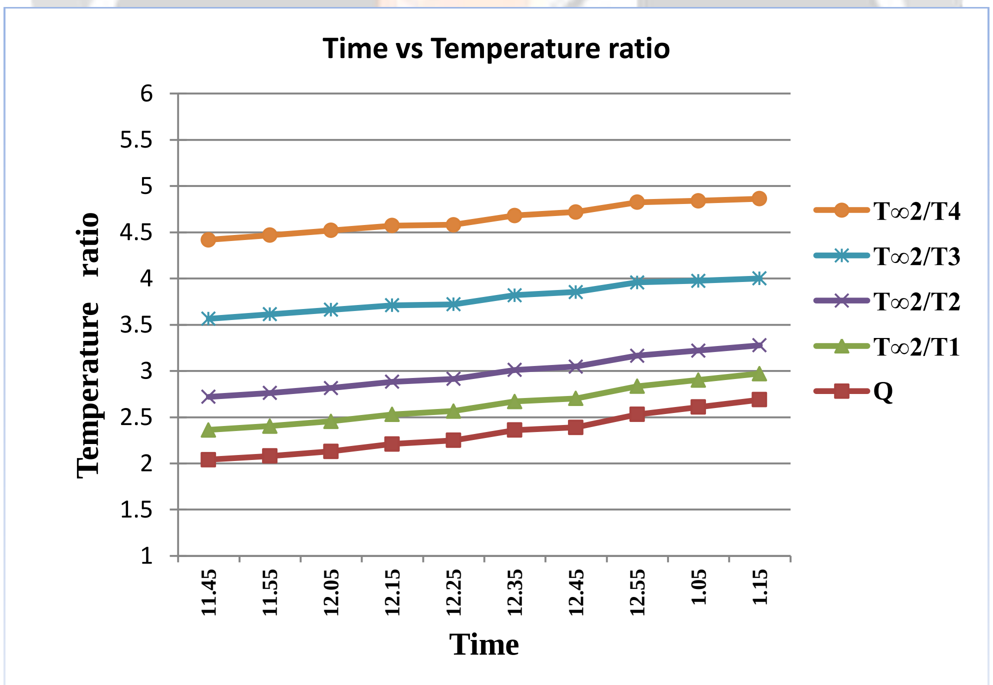

Chart -1: Variation of temperature ratio with time

4. CONCLUSION

It is observed that in commercial solar cooker, for side wall and bottom insulation, Rockwool is loosely filled in between the absorber and outside of sheet metal cover. In such process of Rockwool filling some air pockets may be present, which reduces the insulating quality of this cooker. In present solar cooker side wall and bottom is made up from AAC bricks, which reduces the chances of having air pockets and it leads to decrease overall heat loss as compared to commercial solar cooker.

5. REFERENCES

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