THERMAL PERFORMANCES OF WATER AND HEAT INSULATION MATERIALS FOR WALLS: A CASE STUDY IN NICOSIA, NORTH CYPRUS

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ABSTRACT

The present work has investigated the performances of heat insulations in different wall systems in Turkish Republic of Northern Cyprus (TRNC) by revealing their problems and suggesting solutions. The effects of the solar radiation on the performances of the stone wool and the Y-tong brick wall were examined experimentally. The heat radiation, heat convection and heat conduction for both model rooms in TRNC were determined. The study was concentrated to determine the comparison between the two model rooms facing south: Wall insulated and Y-tong wall. First, the effects of solar radiation on the south face of the walls were tested, and secondly the effect of solar radiation to the wall insulated and Y-tong wall was tested. The effect of climatic conditions during winter was also examined. The wall with heat insulation contained a material of hollow brick, stone wool and gypsum plaster whereas Y-tong wall made of Y-tong and cement concrete.

Seven T-type thermocouples were used with a data logger system to record the temperature data in every 10 minutes. The total heat energy of the wall was determined. The results obtained from the average daily variation of total heat gain and heat loss showed that the Y-tong wall saved energy more than the wall insulated, in addition, Y-tong wall was good at day time and wall insulated was better for night time. The experimental work was performed at the Mechanical Engineering Solar Laboratory Building in Near East University, Nicosia.

Keywords: Heat insulation; solar radiation; south face; Y-tong wall; wall insulated; water insulation

ÖZET

Burada, Kuzey Kıbrıs Türk Cumhuriyeti’ndeki (KKTC) binalarda ısı yalıtımına yönelik problemleri irdelemek ve çözümler önermek üzere bir çalışma yürütülmüştür. Bu kapsamda, taş yünü ve Y-tong tuğla duvar performansları üzerinde deneysel olarak Güneş ışınlarının etkisi test edilmiştir. Model çalışma da, Yakın Doğu Üniversitesi Makina Mühendisliği Güneş Enerjesi Laboratuvarında hazırlanan iki örnek oda için ısı radyasyonu, ısı konveksiyonu ve ısı iletimi belirlenmiştir. Güney yönlü iki odalı bir model üzerinde yalıtımlı duvar ile Y-tong duvar karşılaştırılmalı olarak incelenmiştir. Güneş ışınmasının güney yönlü duvarlar üzerindeki etkileri araştırılmıştır.Yalıtımlı duvarda kullanılan delikli tuğla, taş yünü ve alçı sıva malzemelerinden imal edilmiştir. Y-tong duvar ise Y-tong ve çimento betondan örülmüştü.

Deneyler sırasında model duvarlar içerisinde yedi farklı konumde yerleştirilen T-tipi ısı çiftleri vasıtası ile her on dakikada alınan sıcaklık ölçümleri bir veri aktarıcı ile bilgisayarda depolanmıştır. Bu verilerden her bir duvar sisteminde depolanan toplam enerji hesaplanmıştır. Elde edilen sonuçlardan Y-tong duvarda daha fazla enerji tasarrufu elde edildiği anlaşılmıştır.

Anahtar Kelimeler: Isı yalıtımı; güneş radyasyonu; güney yüzü; Y-tong duvar; yalıtımlı duvar

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AAC: Aerated Autoclaved Concrete

OSB: Oriented Standard Board

MDF: Medium Dimension Fiber

TRNC: Turkish Republic Of North Cyprus

NEU: Near East University

CHAPTER 1
INTRODUCTION

The sun is the most powerful sources of the world energy that drives the organic and physical processes in the global such as oceans and on free land where its fuels plant growth that makes all types of food, and in the atmosphere it heats air which drives the global weather. The amount of energy coming from the sun gradually changes each and every day.

Over many centuries in the Earth-Sun orbital relationship can change the sun distribution of energy around the Earth surface. It has been suggested that changes in sun-energy output may affect the climate both directly and indirectly, by changing the amount of sun energy heating of the Earth surface, and by effecting the cloud forming processes (De Jager & Usoskin , 2006).

The greenhouse effect is the process by which radiation from a planet's atmosphere warms the earth's external to a temperature beyond what it would be in the absence of its atmosphere. If an earth's atmosphere surrounds radioactively energetic gases (i.e., greenhouse gases) the atmosphere radiates energy in each directions. Some amount of this radiation is concentrating towards the surface of the world to warming it (Claussen et al., 2001).

Weather and climate changes play an important role in the global. The goal is to promote humans healthy and supportable life distributing with different categories of climatic change. Climate is an arrangement of weather change collecting on a specific area for a specified interval of time, climate is often set on the weather position averaged for at least 30 years. So, climate is usually determined as the weather averaged over time (Monre, 2008).

Weather describes a short time of period, e.g. daily or weekly, such as variation humidity, air temperature and pressure, wind speed and direction, cloud formation, precipitation (Ramamasy & Pathumthani, 2007).

In northern countries, engineers have been obliged to battle with change in temperatures, change in speed of winds, different humidity, and many other adverse weather conditions. For restful life people require construction with a perfect indoor weather (German, 2012).

In summer, much more radiation falls on the vertical surface than on the south face. This is because the sun is much lower in the sky, so that the angle of incidence favors the vertical surface. The incident radiation on the south face in the morning and the evening is much greater than that on the north, east, and west face during the middle of the day in Cyprus. South facing surfaces effects a particular problems in Cyprus since the maximum intensity of solar radiation received by south walls coincides with the hottest part of the day (Bureau of Indian Standards, 1987).

Nowadays, it is difficult to construct walls from brick or stone with a thickness is close to one meter, because it will cost a lot of money and in our days people check the light and cheap material and small thickness for this reason using the recent thermal insulation for building is the best way to store heat in winter time and cold in summer time (German, 2012).

It will be simple to construct "thin" walls, if we accept such material, which is so available as stone, as brick. In recent constructions, engineers never utilize one and only sort of material in building envelope, because one actual can avoid air leakage, other one protect from weather conditions and another one can bearing loads. But only one layer, which contains of thermal insulation material, can protect heat transfer effect. The main layer of heat insulation can fall heat loses and provide building more energy efficiency, so the principal question is to select adequate thermal insulation material which will help to satisfy requirements of building codes at the lowest cost (German, 2012).

CHAPTER 2
LITERATURE REVIEW

2.1 Definition of Insulation

Thermal insulation characterize by decrease of heat transfer (The transmit of thermal energy between objects of various temperature) between item in warm contact or in territory radiative impact (Bergman et al., 2011). Also, insulation is characterized as those materials and blends which retard the flow of heat, energy by progressing one or more of the following functions:

- Store energy by decreasing heat loss or gain.
- Lead surface temperature for faculty preservation and solace.
- Facilitate temperature control of process.
- Convert water condensation and vapor flow an on cold surfaces.
- Expansion working proficiency of warming/ventilating/cooling, pipes, steam, process and power system found in trade and mechanical establishments.
- Counteract or lessen harm to hardware from presentation to flame or destructive climates.
- Help mechanical frameworks in meeting criteria in nourishment and corrective plants.
- Reduce emissions of pollutants to the atmosphere.

2.1.1 Thermal properties of insulation

The properties of insulation materials must be considered during design by the manufacturing catalogues (Midwest Insulation Contractors Association).

Thermal possessions are the essentially concern in selecting insulations:

- **Temperature limits:** Higher and lower temperatures which the material must retain all its properties.
- **Thermal conductance “C”:** The rate of heat flow for the actual thickness material.
- **Thermal conductivity “K”:** The speed of heat flow for unit thickness of a material.
- **Emissivity “ε”:** It is a measure of a material's capacity to retain and emanate energy; emissivity is a numerical esteem and does not have units.

- **Thermal resistance “R”:** R-value is a measurement of a material's resistance to heat flow. Insulation materials have little tiny pockets of restricted air that oppose the exchange of heat through.
- **Thermal transmittance “U”:** The general conductance of heat move through a “framework” (Des Jarlais & André, 2013).

2.1.2 Heat transfer

Heat constantly shifts from a warmer area to a colder area. During the winter, heat is transferred from the interior of a heated building to the exterior. In the summer, heat can be transferred from the exterior to the interior during the day and may move in the other direction at night when it is cooler outside.

2.1.3 Heat conduction

Conduction happens in a material when the molecules are excited by a heat source on one side of the material. These molecules transmit energy (heat) to the cold side of the material. Conduction occurs primarily through the foundation and framing members in buildings .Poor conductors of heat are placed between materials as insulators (Kern, 1950).

2.1.4 Heat transfer through plane walls or layers in series

Heat conducted through several walls or layers in thermal contact can be expressed as:

$$Q = \frac{\Delta T}{\frac{L1}{k1*A} * \frac{L2}{k2*A} * \frac{L3}{k3*A} * \frac{L4}{k4*A} * \frac{L5}{k5*A}} \qquad (2.1)$$

where:

Q= Heat transfer (W, J/s, Btu hr)

ΔT= Temperature gradient - difference - in the material (K or ^{o}C, ^{o}F)

K= Thermal conductivity of the insulation material (W/m K or W/m ^{o}C)

A= Heat transfer area (m^2, ft^2)

L= Material thickness (m, ft)

2.1.5 Heat convection

The convection is the transfer of heat from one part of a fluid (gas or liquid) to another part at a lower temperature by mixing of fluid particles. Heat transfer by convection takes place at the surfaces of walls, floors and roofs. Because of the temperature difference between the fluid and the contact surface, there is a density variation in the fluid, resulting in buoyancy. This results in heat exchange between the fluid and the surface and is known as free convection. However, if the motion of the fluid is due to external forces (such as wind), it is known as forced convection. These two processes could occur simultaneously. The rate of heat transfer (Q convection) by convection from a surface of area A, can be written as:

$$Q_{\text{convection}} = h\,A\,(T_s - T_f) \qquad (2.2)$$

Where

h= Heat transfer coefficient (W/m^2 -K)

T_s = Temperature of the surface (K)

T_f = Temperature of the fluid (K)

The numerical value of the heat transfer coefficient depends on the nature of heat flow, velocity of the fluid, physical properties of the fluid and the surface orientation (Schlichting, 1968).

2.1.6 External forced convection

Transition from laminar to turbulent occurs at the critical Reynolds number is:

$$Re\ x, cr = \frac{\rho v x, cr}{\mu} = 5 * 10^5 \qquad (2.3)$$

$$Re\ = \frac{Inertial\ Forces}{Viscous\ Forces}$$

Where:

Re: Reynolds number

X cr: Critical number (travelled length of the fluid)

$\boldsymbol{\rho}$: Density kg/m^3

V: Velocity m/s

μ: Dynamic viscosity kg/m^3

The average of the Nusselt number relations for flow over a flat plate as follows:

Laminar:

$$Nu = \frac{hl}{k} = 0.664Re_L^{0.5} Pr^{1/3} \qquad Re_L < 5*10^5 \qquad (2.4)$$

Turbulent:

$$Nu = \frac{hl}{k} = 0.0.037Re_L^{0.5} Pr^{1/3} \qquad 0.6 \leq Pr \leq 60 \qquad (2.5)$$

$$5*10^5 \leq Re_L \leq 10^7 \qquad (2.6)$$

Combined:

$$Nu = \frac{hl}{k} = (0.0.037Re_L^{0.5} - 871)\, Pr^{1/3} \qquad 0.6 \leq Pr \leq 60 \qquad (2.7)$$

$$5*10^5 \leq Re_L \leq 10^7 \qquad (2.8)$$

where:

Pr: Prandtl number

h: Heat coefficient

L: Thickness of material (m)

$Re_{L:}$ Reynolds number for laminar

Nu: Nusselt number (ratio of convective to conductive heat transfer across the boundary)

2.1.7 Heat radiation

Radiation is the heat transfer from a body by virtue of its temperature; it increases as temperature of the body increases. It does not require any material medium for propagation. When two or more bodies at different temperatures exchange heat by radiation, heat will be emitted, absorbed and reflected by each body.

In the case of buildings; external surfaces such as walls are always exposed to the atmosphere. So the radiation exchange ($Q_{radiation}$) between the exposed parts of the building and the atmosphere is an important factor and is given by:

$$Q_{radiation} = A \varepsilon \sigma (T_s^4 - T_{sky}^4) \quad (2.9)$$

where

A =Area of the building exposed surface (m^2)

E =Emissivity of the building exposed surface

T_s =Temperature of the building exposed surface (K)

T_{sky} =Sky temperature (K)

T_{sky} represents the temperature of an equivalent atmosphere. It considers the fact that the atmosphere is not at a uniform temperature, and that the atmosphere radiates only in certain wavelengths. There are many correlations suggested for expressing sky temperature in terms of ambient air temperature (Kern, 2006).

Total heat transferred to the room (Q_{total}) determined by adding the heat radiation (Q_{rad}), heat convection outside (Q conv-out), heat conduction (Q_{cond}) and heat convection inside ($Q_{conv-in}$). When the total heat is less than zero the room is losing heat.

$$Q_T = Q_{rad} + Q_{conv\ in\text{-}out} + Q_{cond} \quad (2.10)$$

2.2 Wall Insulation

Properly sealed, moisture-protected, and insulated walls help increase comfort, reduce noise, and save on energy costs. However, walls are the most complex component of the building envelope to insulate air sail, and control moisture. Previous work done in the past show that it is seen that the insulated wall significantly reduces peak load and load fluctuations at inside surf ace, compared with uninsulated wall. In this case, it is seen that the isolation of the brick and concrete is more significant than that of wall with Y-tong (Ozel & Pihtili, 2012)

The keys for an active wall are:

- Airtight constructional air leaks sealed in the wall during construction and to prior insulation installation

- Moisture / rain drainage system, continuous air barrier, and vapor barrier located on the appropriate side of the wall
- Complete insulation coverage: Advanced framing to maximize insulation coverage and reduce thermal bridging, no gaps or compressed insulation, and continuous insulated sheathing (Anchor Building Solutions, 2015).

Figure 2.1: Wall insulated internally (U.S Department Energy, 2015)

2.2.1 Truss walls insulation

Stud walls as shown in Figure 4.3 are usually insulated by installing flexible batt insulation between studs. Polyethylene sheets with sealed joints installed over the studson the warm side act as both the air and vapour barrier.

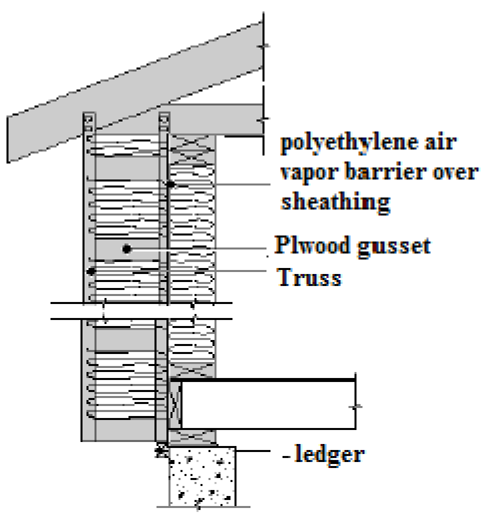


Figure 2.2: Truss wall (U.S Department Energy, 2015)

2.2.2 Stud walls

Stud walls as shown in Figure 2.3 are usually insulated by installing flexible batt insulation between studs. Polyethylene panes with vacuum-packed joints installed over the studs on the warm side act as both the air and vapour barrier.

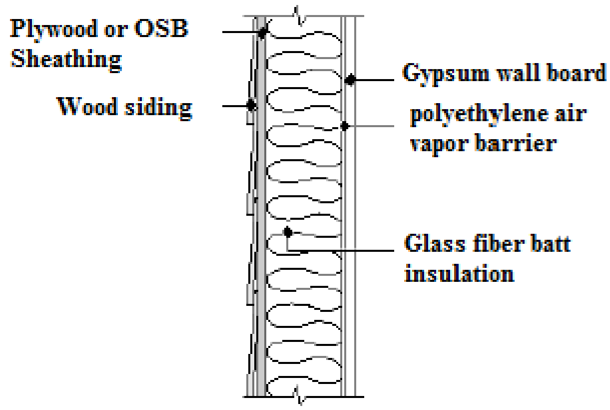


Figure 2.3: Stud walls (U.S Department Energy, 2015)

A common way to increase the insulating value of a stud wall is to use external thermal sheathing. The structural sheathing is replaced with rigid or semi-rigid insulation panels as it's shown in Figure 4.4. The panels can be nailed to the stud wall using special nails with large plastic washers.

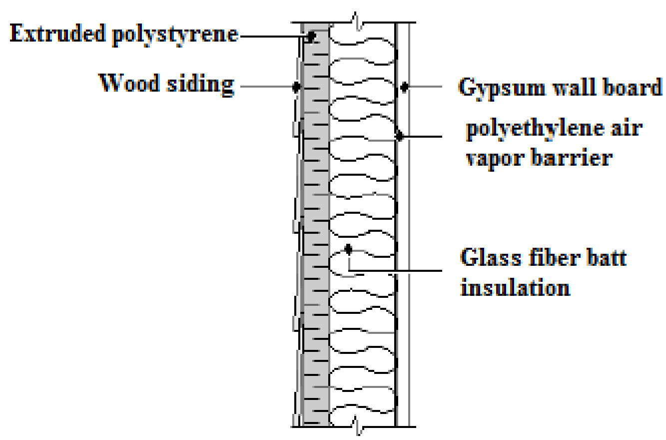


Figure 2.4: Stud walls with exterior thermal sheathing (U.S Department Energy, 2015)

Wood-frame walls can be constructed with strapping on the interior of the studs to create a space for additional insulation, as it's shown in Figure 4.5.

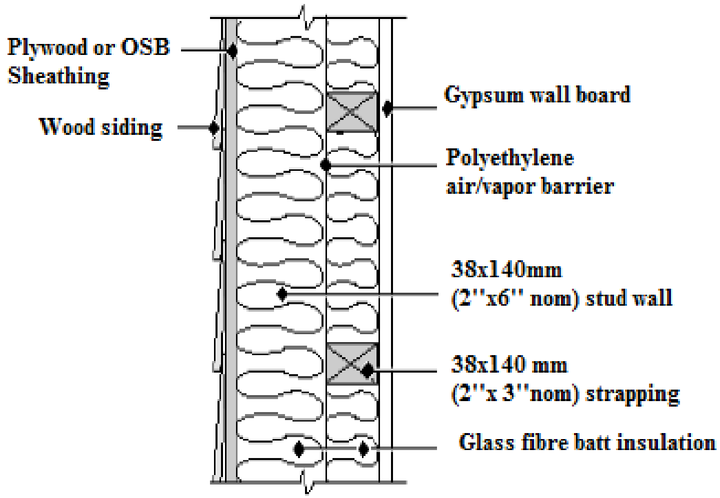


Figure 2.5: Stud walls with interior strapping (U.S Department Energy, 2015)

2.2.3 Cavity wall insulation

In the cavity walls filling the gap between the two walls of a house with an insulating material massively decreases the amount of heat which escapes through the walls.Representations of cavity walls are shown in Figure 2.6. It will help to create a more even temperature in the house, help to prevent condensation on the walls and ceilings and can also reduce the amount of heat building up inside the house during summer hot spells (Heat, 2015).

Figure 2.6: Typical brick formation for cavity walls (Heat, 2015)

2.2.4 Solid wall insulation

There are two types of solid wall insulation, external and internal. Solid walls lose even more heat than cavity walls; the only way to reduce this heat loss is to insulate them on the inside or the outside. There are two types of solid wall insulation, external andinternal. Solid walls lose even more heat than cavity walls; the only way to reduce this heat loss is to insulate them on the inside or the outside. up inside the building during summer hot spells (floor insulation) Typical solid wall insulation is shown in Figure 2.7.

Figure 2.7: Typical brick formation for solid walls (U.S Department Energy, 2015)

2.2.5 Crawlspace wall insulation

Although no crawlspace is used in the houses of North Cyprus, an illustration of the application is shown in Figure 4.8.

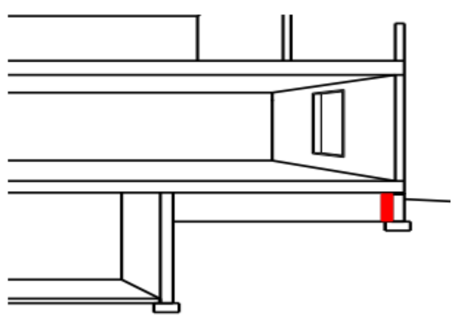


Figure 2.8: Application area of crawlspace wall insulation (U.S Department Energy, 2015)

2.2.6 Basement walls

When insulating a conditioned (heated or cooled) basement, only the walls need to be insulated. The basement ceiling may be insulated for noise control between floors (U.S. Department of Energy.2015).Figure 4.9 shows the application area of basement wall. Figure 4.10 shows an exterior application .

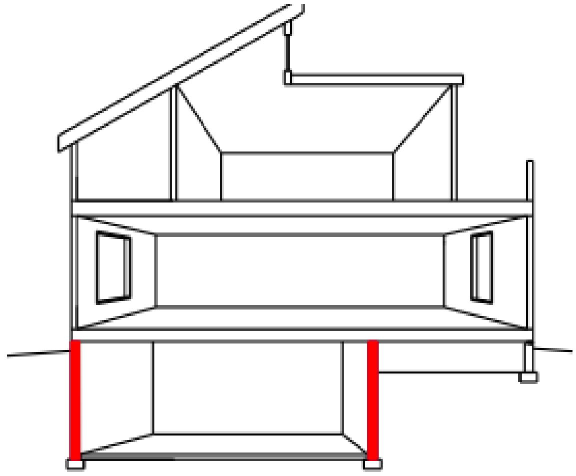


Figure 2.9: Application areas of basement wall

Figure 2.10: Insulating basement walls externally (U.S Department Energy.2015)

2.3 Choosing Insulation

Insulation products come in two main categories bulk and reflective. These are sometimes combined into a composite material. There are many different products available,To compare the insulating ability of the products available look at their R-value, which measuresresistance to heat flow. The higher the R-value the higher the level of insulation. Productswith the same R-value will provide the same insulating performance if installed as specified.Bulk insulation mainly resists the transfer of conducted and convected heat, relying onpockets of trapped air within its structure. Its thermal resistance is essentially the sameregardless of the direction of heat flow through it.Bulk insulation includes materials such as glass wool, wool, cellulose fibre, polyester and polystyrene. All products come with one material R-value for a given thickness (Max & Caitlin, 2013).

2.4 Where to Install Insulation

External walls should be insulated to reduce radiant, conducted and convicted heat transfer. Wall insulation can be installed:

- Within cavities
- Within stud frames
- On the outside of stud frames
- On the inside or outside of solid walls.

Depending on the particular situation, some forms of insulation can double as a vapor or moisture barrier (Max & Maitlin, 2013).

2.5 Heat Insulation Materials Used

2.5.1 Stone wool

Stone wool fibers which had been used for isolation of buildings for decades have been used more and more also in high-temperature applications, especially since the health hazards associated with asbestos products loomed. The high-temperature behavior of stone wool has already been investigated by others (Kirkegaard et al., 2005).

Table 2.1: Thickness and thermal insulation of stone wool (Kimmco, 2012)

Thicknes (mm)	**Thermal Resistance (m^2 k/w) at 25 º C Mean Temp. for the following densities in kg/m^2**							
	48	64	80	100	120	144	160	200
25	0.694	0.714	0.714	0.735	0.735	0.735	0.694	0.676
50	1.389	1.429	1.429	1.471	1.471	1.471	1.389	1.351
75	2.083	2.143	2.143	2.206	2.206	2.206	2.083	-
100	2.778	2.857	2.857	2.941	2.941	2.941	-	-
125	3.472	3.571	3.571	3.676	3.676	-	-	-
150	4.167	4.286	4.286	-	-	-	-	-
200	5.55	-	-	-	-	-	-	-

2.5.3 Specifications

1. Rock Wool Board, Pipe, Blanket.
2. Fireproof, Heat Insulation.
3. Sound and Shock absorption,
4. Waterproof.
5. CE, SG S, ISO (Kimmco, 2012).

Figure 2.11: Stone wool and glass wool batts (Kimmco, 2012)

2.6 Y-tong

Y-tong is a well-known international brand name which stands for aerated concrete products. The products have unlimited constructional possibilities and good building physical properties. Their main advantages are:

- Excellent insulating characteristics – External walls of Y-TONG extra with a thickness of 30 cm meet construction requirements and do not need any additional heat insulation.
- Non-flammable – in case of fire the Y-TONG walls do not deform and get destroyed, they do not let the heat and prevent the fire from passing into neighboring rooms. With Y-TONG one can obtain the highest possible fire resistance class easily even with smaller wall thicknesses.
- Light weight;
- Easily to work with ;
- Precise dimensions;
- Ecological – Y-TONG blocks are produced completely of natural raw materials – sand, lime, cement, gypsum and water;
- Vapor diffusion – Y-TONG walls "breathe".

The masonry blocks Y-TONG are produced with a length of 60 cm and a height of 25 cm. These dimensions are the same for all blocks. Only their thickness varies – within the range from 5 to 35 cm. The blocks with a thickness of 5, 7.5 and 10 cm are used for lining existing or newly built walls for increasing their heat insulation capacity. The blocks with a thickness from 10 to 25 cm are suitable for making partition walls within the dwellings or among the separate dwelling units. Blocks with higher density are produced specially for internal walls in order to increase their noise insulation capacity. The dimensions of 20, 25, 30 and 35 cm are used for façade enclosure of the buildings, dimensions of 20 and 25 cm are appropriate for non-heated or seasonally used buildings. External walls with Y-TONG extra 30 cm meet the requirements of the current regulations regarding the heat insulation for sites with residential, public or industrial purpose, which are used throughout the year. The AAC blocks Y-TONG are produced of completely natural raw materials sand, lime, cement, gypsum and water. These natural raw materials are practically inexhaustible in nature. Their production does not disturb the ecological balance and they undergo processing within a closed production cycle with moderate energy consumption (Ytong, 2012).

2.7 Stone Brick

Brick is a solid unit of building having standard size and weight. Its history traces back thousand years (almost 7500BCE). Clay bricks made of fired clay. The composition of clay varies over a wide range. Usually clays are composed mainly of silica (grains of sand), alumina, lime, iron, manganese, sulfur, and phosphates, with different proportions. Clay bricks have an average density of 125 pcf. Bricks are manufactured by grinding or crushing the clay in mills and mixing it with water to make it plastic. The plastic clay is then molded, textured, dried, and finally fired, Bricks are manufactured in different colors, such as dark red, dark brown, or dull brown, depending on the fire temperature during manufacturing. The firing temperature for brick manufacturing varies from 900°C to 1200°C (1650°F to 2200°F) (Jamal, 2014).

2.7.1 Use of brick

Since the clay bricks or burnt bricks are strong, hard, durable, resistive to abrasion and fire, therefore, they are used as a structural material in different structures: Buildings, bridges, foundation, arches, pavement (footpath, streets).

2.7.2 Advantages of bricks

- Economical (raw material is easily available)
- Hard and durable
- Compressive strength is good enough for ordinary construction
- Different orientations and sizes give different surface textures
- Very low maintenance cost is required
- Demolishing of brick structures is very easy, less time consuming and hence economic
- Reusable and recyclable
- Highly fire resistant produces less environmental pollution during manufacturing process

2.7.3 Disadvantages of bricks

- Time consuming construction
- Cannot be used in high seismic zones
- Since bricks absorb water easily, therefore it causes fluorescence when not exposed to air
- Very less tensile strength
- Rough surfaces of bricks may cause mold growth if not properly cleaned (Jamal, 2014).

2.8 BH10 30 Hollow Heat Insulation Brick

2.8.1 Specifications

1. Product code: BH10 30
2. Description: Horizontal perforated non-load bearing wall
3. Dimension: L 300x W 100 x H 200 (mm)

Table 2.2: Specification of hollow clay brick

Product Code	BH 1030
Description	Horizontal Perforated Non-load Bearing Wall
Manufacturing Method	Extrusion
Unit Weight	5.0 (kg)
Quantity/m^2	16 pieces
Compressive Strength	>30 N /mm^2
Water Absorption	>9%
Reaction Fire	Class A1
Dimension	L 300 x W 100 x H 200 (mm)

2.8.3 Main advantages:

- 60% less weight than a solid concrete block
- Compressive strength >3.5 N/mm^2
- Density of approx. 694 to 783 kg/m^3
- Large size & low weight
- Excellent thermal insulation
- Water absorption ~15% .

2.9 Climate

Climate is the characteristic condition of the atmosphere near the earth's surface at a certain place on earth. It is the long-term weather of that area (at least 30 years). This includes the region's general pattern of weather conditions, seasons and weather extremes like hurricanes, droughts, or rainy periods. Two of the most important factors determining an area's climate are air temperature and precipitation. The sun's rays hit the equator at a direct angle between 23 ° N and 23 ° S latitude. Radiation that reaches the atmosphere here is at its most intense. In all other cases, the rays arrive at an angle to the surface and are less intense. The closer a place is to the poles, the smaller the angle and therefore the less intense the radiation (Ready, 2008).

The climate system is based on the location of hot and cold air-mass regions and the atmospheric circulation created by trade winds. Trade winds at north of the equator blow from the northeast. At south of the equator, they blow from the southeast. The trade winds of the two hemispheres meet near the equator, causing the air to rise. As the rising air cools, clouds and rain develop. The resulting bands of cloudy and rainy weather near the equator create tropical conditions (Ready, 2008).

Westerly's blow from the southwest on the northern hemisphere and from the northwest in the southern hemisphere. Westerly's steer storms from west to east across middle latitudes.

Both westerly's and trade winds blow away from the 30 ° latitude belt. Over large areas Centered at 30 ° latitude, surface winds are light. Air slowly descends to replace the air that blows away. Any moisture the air contains evaporates in the intense heat. The tropical deserts, such as the Sahara of Africa and the Sonoran of Mexico, exist under these regions.

The Earth rotates about its axis, which is tilted at 23.5 degrees. This tilt and the sun's radiation result in the earth's seasons. The sun emits rays that hit the earth's surface at different angles. These rays transmit the highest level of energy when they strike the earth at a right angle. Temperatures in these areas tend to be the hottest places on earth.

Other locations, where the sun's rays hit at lesser angles, tend to be cooler. As the earth rotates on its tilted axis around the sun, different parts of the Earth receive higher and lower levels of radiant energy. This creates seasons (Ranjan et al., 2006).

2.10 Köppen Climate Classification Systems

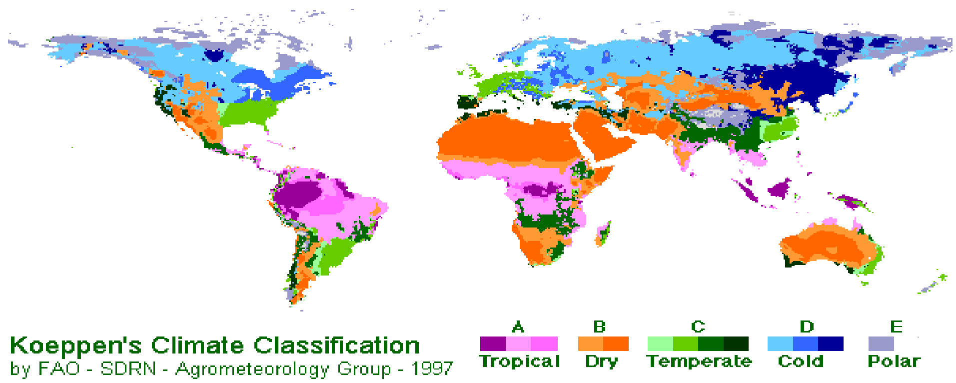


Figure 2.12: Koeppen's Climate Classification (Arthur et al., 1984)

The Köppen climate classification system is the most widely used for classifying the world's climates. Most classification systems used today are based on the one introduced in 1900 by the Russian-German climatologist Wladimir Köppen.

To further denote variations in climate, a third letter was added to the code:

a - Hot summers where the warmest month is over 22°C (72°F). These can be found in C and D climates.

b - Warm summer with the warmest month below 22°C (72°F). These can also be found in C and D climates.

c - Cool, short summer with less than four months over 10°C (50°F) in the C and D Climates.

d - Very cold winters with the coldest month below -38°C (-36°F) in the D climate only.

h - Dry-hot with a mean annual temperature over 18°C (64°F) in B climates only.

k - Dry-cold with a mean annual temperature less than 18°C (64°F) in B climates only.

Global Range: Southwestern United States and northern Mexico; Argentina; North Africa; South Africa; central part of Australia (Peel et al., 2007).

2.11 Climate of Cyprus

Cyprus is located in the north eastern of the east Mediterranean Basin and is the third largest island in the Mediterranean after Sicily and Sardinia. It is 71 kilometers south of Turkey, 98 kilometers west of Syria and 384 kilometers north of Egypt.

The climate of the Northern Cyprus island is of an extreme Mediterranean type with very hot dry summers and relatively cold winters. Most of the rainfall is concentrated between December and January. The sea temperature in North Cyprus never falls below 16°C (January and February); in August it can rise to 28 °C. Spring and autumn in Northern Cyprus are short with occasional heavy storms.

The North Cyprus enjoys over 300 days of sunshine and from mid-May to mid-September the sun shines on a daily average of around 11 hours. Summer temperatures in Northern Cyprus are high in the lowlands, even near the Mediterranean Sea, and reach the highest readings in the Masuria.

Daily temperature in North Cyprus in July and August is about 29°C on the central plain, able to culminate at the average maximum of 38°C in these months. A mean January temperature is 10°C on the central plain and 5°C on the higher parts of the Northern Cyprus Kyrenia mountains. The sky is cloudless with a low humidity. During the wet winter months Cyprus is a green island. Frost and snow are almost unknown in Northern Cyprus. The higher mountain areas are cooler and moister than the rest of the North Cyprus Island (Korinia, 2015). Figure 2.15 shows the average annual radiation over the island. It can be seen that Cyprus takes place at high solar energy region over the world (Kalogirou, 2003).

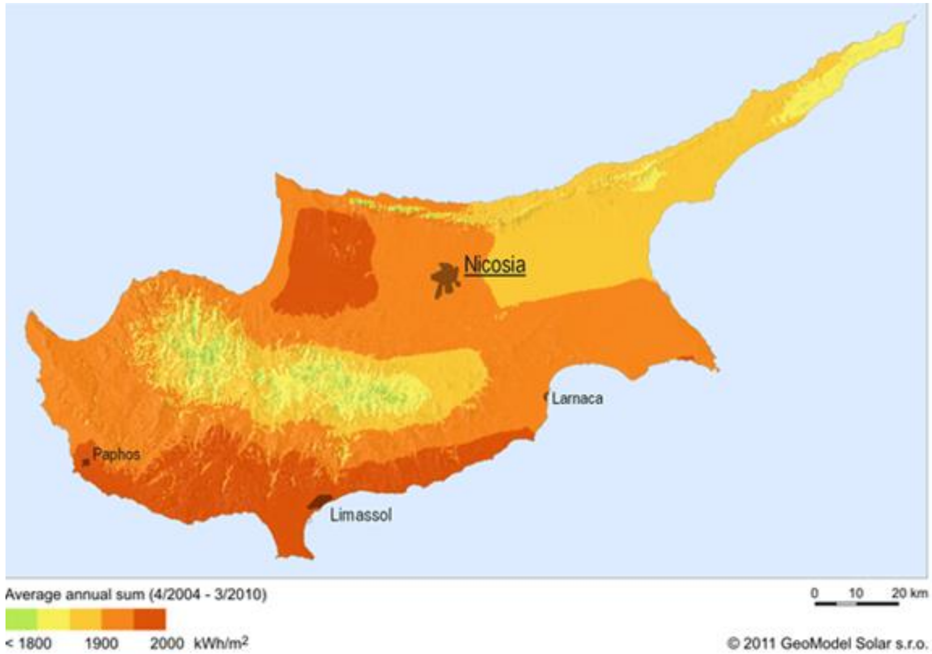


Figure 2.13: Solar Energy map of Cyprus (Kalogirou, 2003)

The Table 2.3 below shown, is the monthly average maximum and minimum temperature, also the average of rain days and snow days in Nicosia based on 8 years of historical weather readings.

Table 2.3: The average monthly climate indicators in Nicosia based on 8 years of historical weather readings (Balaras et al., 2007)

NICOSIA 35 15 N, 33 40 E, 161 meters (528 feet) above sea level.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. Temperature (C^0)	12	12	15	20	26	30	32	32	28	24	17	13
Avg. Max Temperature (C^0)	14	15	18	23	29	33	36	36	32	27	20	16
Avg. Min Temperature (C^0)	5	5	6	10	15	19	21	21	18	15	10	6
Avg. Rain Days	5	3	3	1	1	0	0	0	0	1	3	3
Avg. Snow Days	0	0	0	0	0	0	0	0	0	0	0	0

Table 2.4 below shown, is characterized the general information of Turkish Republic of Northern Cyprus (capital, area, climate, location, geographic coordinate, coastline, terrain, elevation extremes).

Table 2.4: General information of Turkish Republic of Northern Cyprus (United Nations, 2013)

Name:	Turkish Republic of Northern Cyprus
Capital:	Nicosia
Area:	Total:9250 km^2 (of which 3355 km^2) North Cyprus 3355 km^2
Climate:	Temperature, Mediterranean with hot, dry summers and cool winters
Location:	Middle East, island in the Mediterranean Sea, south of Turkey
Geographic Coordinates	35 N, 33N
Coastline:	648 Km
Terrain :	Central plain with mountains to north and south; Scattered but significant plains along southern coast
Elevation extremes:	Lowest point Mediterranean sea 0 m, highest point: Olympus 1.951 m

CHAPTER 3
METHODOLOGY

3.1 The Experimental Procedure

The experiment study identifies with the impacts heat insulation materials for walls in TRNC. The study consists two stages: the first stage tests effect of solar for south face to walls and second stage tests effect the solar of the wall insulated and the Ytong wall insulation. The study was continuously done between the months of November, December and January.

The study was tested at the south face, because the south face takes more sun powered radiation than the others facades. The experiment was tested at the Mechanical Engineering Solar Laboratory Building in NEU, Lefkoşa. This study was depended of two model rooms, room L1 was faced at south face without insulation material and the second room L2 with heat insulation material at south face. Rooms L1 and L2 was based over a wood material and the floor wooden materials.

Room L1 consists for four side facing: North, East, West and South. The experiment study for south face, The three walls contains same materials (Nord, East, west) insulation for heat stone wool, block of concrete, and plaster gypsum (outside and inside of the Three walls). South face contains cement concrete (inside and outside of wall) and in the middle Y-tong.

Room L2 consists for four side facing: North, East, West and South. The experiment study for south face, the three walls contains same materials (North, East, west) insulation for heat stone wool, block of concrete, and plaster gypsum (outside and inside of the walls). South face contains plaster gypsum (outside and inside of the wall), insulation for heat stone wool and at the middle blocks of hollow brick clay.

For roofs of two models room L1 and L2 have same procedure. First of all wood OSB (oriented standard board) was placed over the rooms structured , after OSB the glass wool batts was insulated, and over the glass wool insulation of water (yalteks) was insulated, the tiles was lay one after the others.

Figure 3.1: Laboratory Set-ups (L-1 and L-2) at Near East University Building

Figure 3.2: Room L1 (3D)

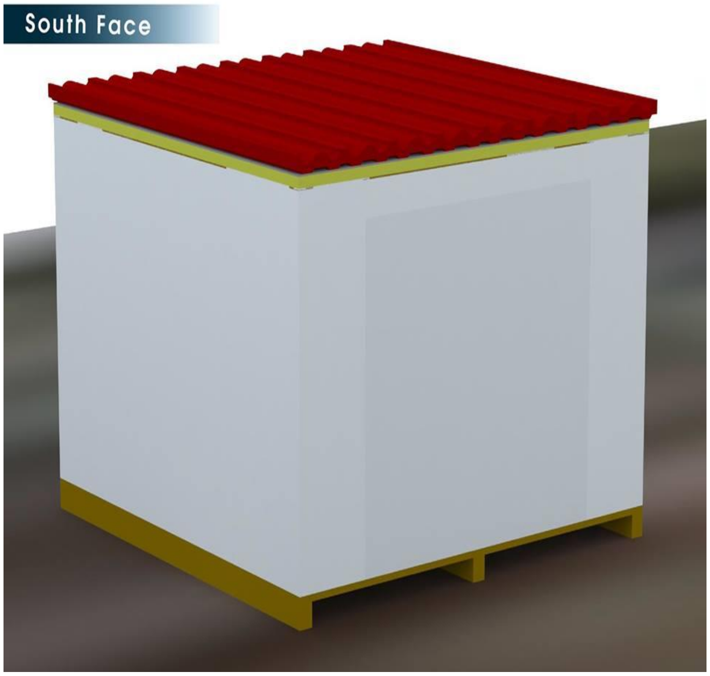


Figure 3.3: Room L2 (3D)

3.2 Construction Stage:

The base was constructed of a wooden materials with a four standing legs and a wooden board MDF (medium density fiberboard).

Three walls (nord ,east and west) was built by laying hollow block concrete after the lay the stone wool was insulated and was plastered with plaster of gypsum.

The three walls of the two models rooms L1 and L2 was constructed with the same procedure only the south face of the both two rooms was built with different materials and procedure. The first model room L1 of south face was constructed by lay of block Ytong and it plastered concrete of cement (outside and inside).

The second model room of south face was built by lay of hollow clay brick after the laying the stone wool was installed and plastered with gypsum plaster.

All top of the walls was finished with stone wool and was plastered by plaster of gypsum.

Two models room was used the same roofing materials and design structure. The roof was constructed with following materials Firstly OSB wood, insulation for heating glass wool batts, insulation for water (yalteks), and lastly roofing tiles. All materials was installed respectively.

In two models room had a small plate of wooding material (tables) was screwed on the east face of the walls inside the rooms and the testo (data logger) was placed on the table for the collection of data.

The place where the cables pass through into the room is between the roofs and the top end of wall and the place was sealed using glass wool.

3.2.1. The materials used in walls of two models room

The constituents of the material used in wall as following:

- Plaster thickness 10 mm
- Hollow concrete block 400 mm*150 mm*200 mm
- Hollow brick block 300 mm*100 mm*200 mm
- Block of Ytong 600mm*300 mm*100 mm
- Insulation for heat stone wool 600 mm*1200 mm*50 mm.

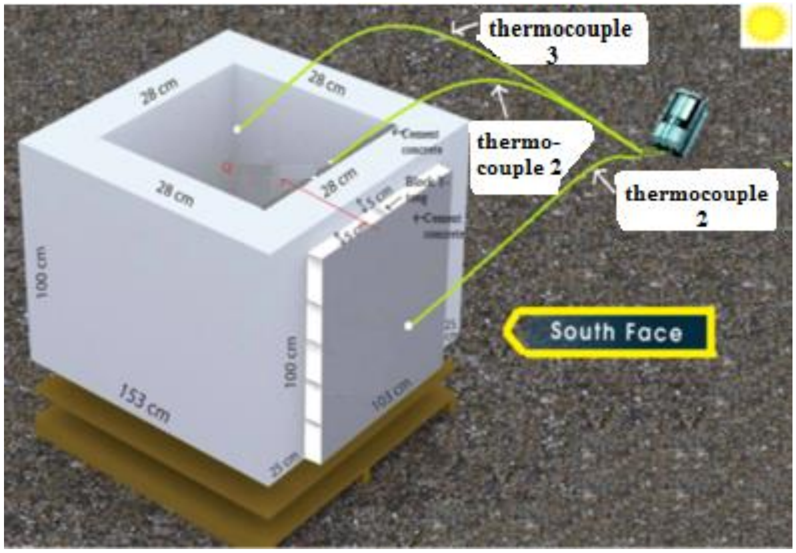


Figure 3.4: Room L1, size and dimensions (3D)

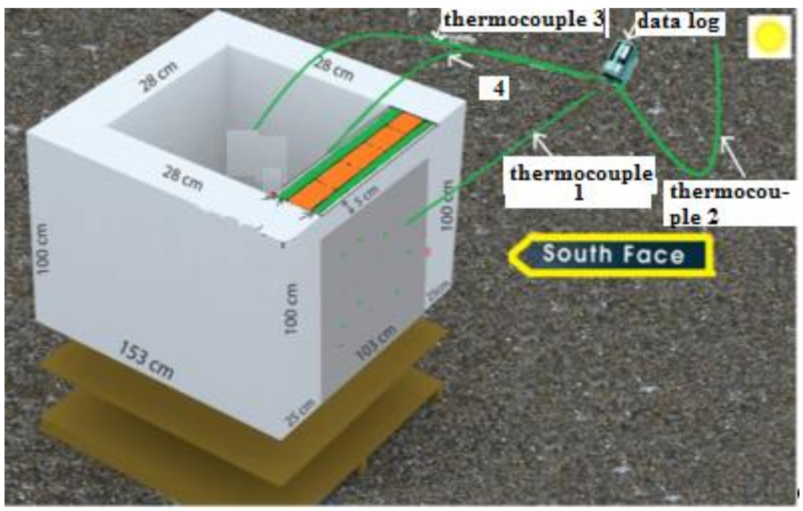


Figure 3.5: Room L2, size and dimension (3D)

3.2.2 The material used on roofs

The constituents of the material used on roofs as following:

- Wood OSB (oriented standard fiberboard) 1500 mm*1500 mm*20 mm
- Glass wool batts height 50 mm
- Yalteks water insulation material The height of yalteks is 5 mm
- Roof tiles has 40 mm height

3.2.3 The materials used on the floor

The constituents of the material used on the floor as following:

- Wood MDF (Medium dimension fiber) 1500 mm*1500 mm*2 mm
- Wood deck base 1500 mm*1500 mm.

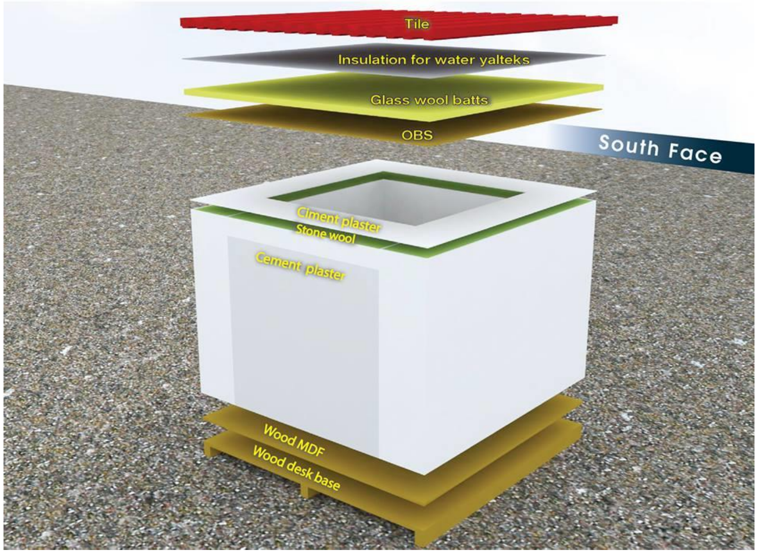


Figure 3.6: L-2 Roof and Floor Layers

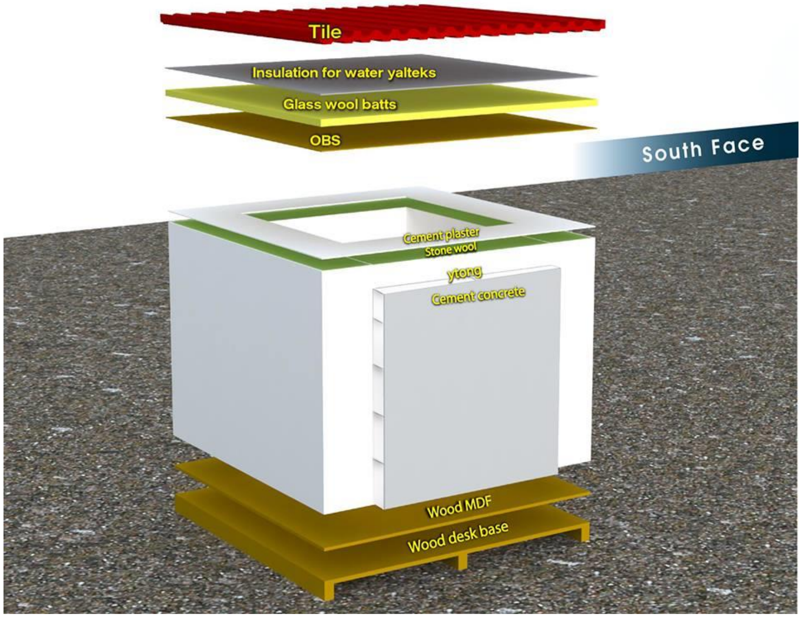
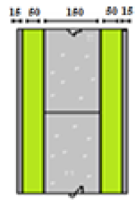
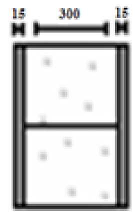
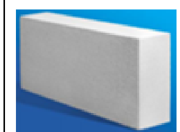
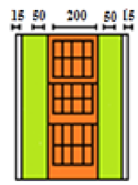
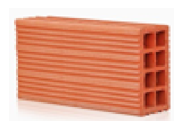


Figure 3.7: L-1 Roof and Floor Layers

Table 3.1: Categorization of conventional wall types.

Wall reference	Construction material	Detail	U – value	Thickmes (mm)	Image of material
Walls facades, Nord, East, West Of Rooms L1 &L2 **LECA block**	• Plaster cement (15 mm) • Stone wool (50 mm) • LECA Block (150 mm)		1.34	270 mm	
Wall South Of Room L1 **Ytong**	• Send & cement mortal (15 mm) • Ytong (300 mm)		0.37	320mm	
Wall South Face Of Room L2 **Hollow brick**	• Plaster cement (15 mm) • Stone wool (50 mm) • Hollow brick (200 mm)		1.3	320 mm	

3.3 Water Insulation Material Used

In most climates, insulation is included in the roof system to improve comfort and to minimize energy use. In addition, roof insulation may decrease the range of thermal expansion of the structure. For low slope roof systems, the best location is usually above the structural deck. For conventional membrane roof systems, the insulation is under the membrane. For protected membrane roof systems, the insulation is above the membrane. Except in protected membrane roof systems, rigid roof insulation usually provides in low slope systems both the insulation for the building and a substrate to which the roofing membrane is applied. Therefore roof insulation must be compatible with and provide adequate support for, the membrane and other rooftop materials and permit limited rooftop traffic, such as for roof inspection and maintenance.

Table 3.2 shown, is characterized the Yakteks Poliser 200-C when it had a high performance modified bituminous waterproofing Membrane reinforced with Glass Fiber tissue. Bitumen is modified with APP (Atactic Poly-Propylene) which provides an excellent elasticity.

Table 3.2: Yalteks water insulation features (Watson & Crosbie, 2004)

CHARACTERISTICS	STANDARDS	UNIT	VALUES
Bituminous Sheet	ASTM D6509/97		APP Modified
Thickness	EN 1849-1	mm	> 1.9
Roll Length	UNI 8202/03 TS 11758-1	m	15
Roll Width	UNI 8202/04 TS 11758-1	kg./ m²	> 2.4
Surface	-	-	Polyethylene or Fine sand
Cold Flexibility	EN 1109	°C	- 10
Heat Flow	DIN 52123 TS 11758-1	°C	120
Water Impermeability	P r EN 1928	-	Absolute
Fire Resist (Flammability)	P r EN ISO 11925-2	°C	250

Figure 3.8: Yalteks water insulation (Watson & Crosbie, 2004)

3.4 Wood OSB:

Oriented strand board (OSB), otherwise called sterling board, sterling OSB, chip board, as penile, and insightfully in British English, is a sort of designed timber like molecule board shaped by including cements and after that compacting covers of wood strands (drops) in particular introductions. It was designed by Armin Elmendorf, California US in 1963 OSB Patent. OSB may possibly have a harsh and mottled surface amid the single pieces of nearby 2.5 × 15 cm (1" × 6"), lying unequally separately and arrives in an assortment of sorts and thicknesses

OSB is a material amid high mechanical possessions that make it especially appropriate for burden bearing implementation in development. The farthest widely recognized utilizes are as sheathing in dividers, ground surface, and rooftop flooring. For outside divider applications, boards are accessible with a brilliant hindrance cover pre-covered to the other cross; this facilitates establishment and expansions vitality execution of the construction covering. OSB likewise realizes some utilization in furnishing creation. Changes in accordance with the assembling procedure can grant contrasts in width, board dimension, quality, and inflexibility. OSB boards have no interior crevices or vacuums, and are water resistance, despite the fact that they do need extra films to accomplish waterproofness and are not prescribed for outside utilize. The completed item has properties like plywood, however is identical and inexpensive. When tried to disappointment, OSB has a more prominent burden bearing limit than processed timber panels. It has supplanted plywood in numerous situations, particularly of the Northern American basic board shop. However OSB doesn't consume a consistent grain as a characteristic timber, it has a hub along which its quality is most prominent. This can be seen by watching the arrangement on the surface wood chips. All wood-established plain utilize boards can be disconnects and introduced without any difficulty and sorts of gear utilized with strong wood (Han et al., 2012).

Table 3.3: General properties of OSB used in the study (Han et al., 2012)

Physical and mechanical Specification characteristics	**Standard**	**Specification**
Formaldehyde content	EN 120	in conformity with E1 (8 mg/100g) and the ordinance on the prohibition of chemicals
Combustibility (classification)	DIN 4102 T1	B 2 (normal incendiary)
Density	DIN 52 361	600 kg/m3
Moisture content	EN 322	9 +– 3 %
Swelling in thickness	DIN 52 364	≤10 %
Thickness tolerance 1)	EN 300	+ – 0,8 mm unsanded surface
Tolerance of length and	EN 300	+ – 3 mm
Squareness (Diagonal Difference) 1)	EN 300	2 mm for each 1000 mm in length
Thermal conductivity	DIN 4108 T2	0.13 W/m K
Dimensional change length/width	change of relative humidity from 30 to 85 % at 20 ^{0}C	0.30 %
Vapor diffusion resistance factor	DIN 52615	15 mm 18 mm 22 mm
Binders/glue	surface layer	modified melamine resin

Figure 3.9 shown is OSB panels contains of covered mats. Outer or surface covers are collected of strands allied in the lengthy panel bearing; inner-layers contains of section or haphazardly-aligned strands. These with mats are then exposed to dense heat and pressure to develop a "principal" panel and are clop to dimension.

Figure 3.9: OSB (Oriented Standard Boards) 3D picture (Han et al., 2012)

3.5 Roof Tiles

A tile is a fabricated bit of hard-wearing material, such as, artistic, rock, metallic, or even glass, for the greatest part utilized for layering roofs, floors, walls, or different objects. (Marilyn, 1998)

Roof tiles are planned mostly to keep out rainstorm, and are customarily produced using locally accessible materials, such as, terracotta or slate. Current materials like concrete and plastic are likewise utilized and some mud tiles have a waterproof coating. Roof tiles are "hung" from the structure of a rooftop by altering them with nails. The tiles are generally hung in parallel columns, with every line covering the line beneath it to bar water and to cover the nails that hold the line underneath. There are additionally rooftop tiles for extraordinary positions, especially where the planes of the few pitches meet. They incorporate edge, hip and valley tiles. These can either be had relations with and pointed in bond mortar or mechanically altered. So also to roof tiling, has been utilized to give a defensive climate envelope to the sides of timber casing structures. These are held tight strips nailed to divider timbers, with tiles uniquely shaped to cover corners and frames. Frequently these tiles are molded at the presented end to give an improving impact.

Another type of this is the supposed numerical tile, which was held tight slats, nailed and afterward grouted (William & Elizabeth,. 1981).

3.6 The Arrangement of Thermocouples

While the walls material layers were being finished by the laborers thermocouple were put on each of the layers of materials to measure the temperature. The thermocouple are organized by this numbers at below. The temperatures of each material were taken at every 10 minutes. We picked outdoor and solar radiation temperatures from the meteorology office in Lefkoşa. There were four thermocouples for each room of walls. Both of walls south faces wall material temperatures were measured by the thermocouple.

3.6.1 Room L-1 connections

L1 Thermocouple arrangement;

- No:1 Inside on the surface wall (inside of hall 5 mm)
- No:2 Outside on the surface wall (inside of hall 5 mm)
- No:3 Inside of model room
- No: 4 outside temperature.

3.6.2 Room L-2 connections

L2 Thermocouple arrangement;

- No:1 Inside on the surface wall (inside of hall 5 mm)
- No:2 Outside on the surface wall (inside of hall 5 mm)
- No: 3 Inside of model room.

In the Experimental study the thermocouple were mounted at different points of the walls and the temperatures were recorded continuously every ten minutes.

3.7 Data Logger

3.7.1 Description of the system components

The system provides complete simplicity, extreme versatility and absolute expandability by Figure 2.12 below.

Figure 3.10: The modular system Testo 350 contains of 3 main components (Testo, 2003)

3.7.2 The control unit

The Control Unit displays all flue gas measurements, up to 6 parameters simultaneously per page, as well as all instrument diagnosis and operating information. The Analyzer Box is controlled by the Control Unit and can be programmed as well. With the Control Unit you can operate the Analyzer Box remotely up to (6', 16' and 65' standard and more with optional powered cables). The Control Unit has memory up to 250.000 readings and an integrated printer for customized printouts. You operate the instrument with the 2 x 4 user-defined function keys, the keypad and, optionally, by touch-screen display. In addition, a multi probe input and an integrated Δ pressure probe are located in the Control Unit.

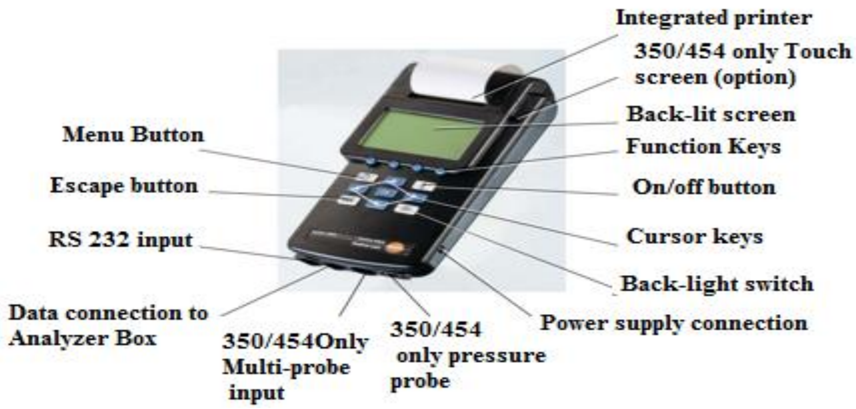


Figure 3.11: The control unit 350/454 (Testo, 2003)

3.7.3 The display

The Figure 2.14 shown is the Control Unit displays all flue gas measurements up to 6 parameters simultaneously on one screen.

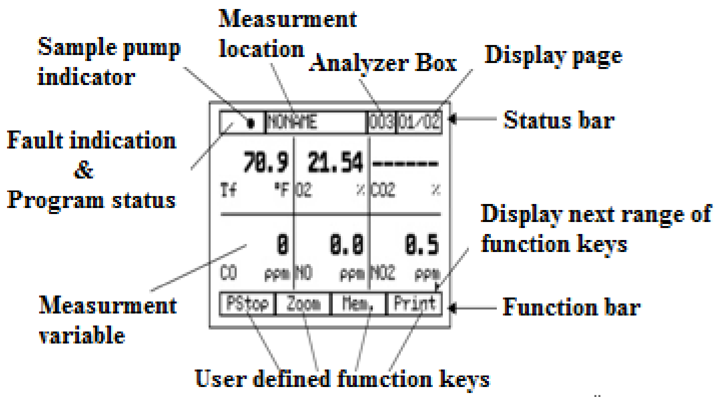


Figure 3.12: The display of control unit screen (Testo, 2003)

3.7.4 Control unit 350/454 charge status

Control Unit 350S contains non-rechargeable batteries. When the analyzer box is plugged into AC, the display will show the charge in the analyzer box.a fully charged. Analyzer Box is approximately 10 volts (Testo, 2003).

3.7.5 Ni Cr-Ni probe

Table 3.4: Features of NiCr-Ni Probe (Testo, 2003)

Air probes	Illustration	Measure range	Accuracy	T99s	Conn.	Part.no
Thermocouple made of fiber-glass insulated Thermal pipe ,Pack of 5 ,insulation twin,conductors,flat oval .opposed and covered with fiber-glass,both conductor are wrapped together with fiber-glass	 2000 mm  Φ :0.8mm	Φ :0.8mm -200...+400 ºC	Class A	5 S	Please order adapter 06001693	06441109

CHAPTER 4

RESULTS AND DISCUSSION

The results of theoretical calculations, radiation, temperature, wind velocity data obtained from meteorological office (Nicosia, 2015) (Appendix A, A1, B, B1, C, C1). The experiments performed in solar laboratory of Near East University (NEU) will be presented and discussed in this chapter.

4.1 Average Radiation Data for Nicosia 2015

Daily variation of solar radiation on horizontal surface in Nicosia, 2015 obtained from meteorological office of TRNC is given in Appendix A. Figure 4.1 shows the variation of daily total solar radiation throughout the year. The average of daily total solar radiations for each month is also shown in Figure 5. The daily solar radiation changes from about 10 MJ/m^2 during winter and up to 28 MJ/m^2 during summer.

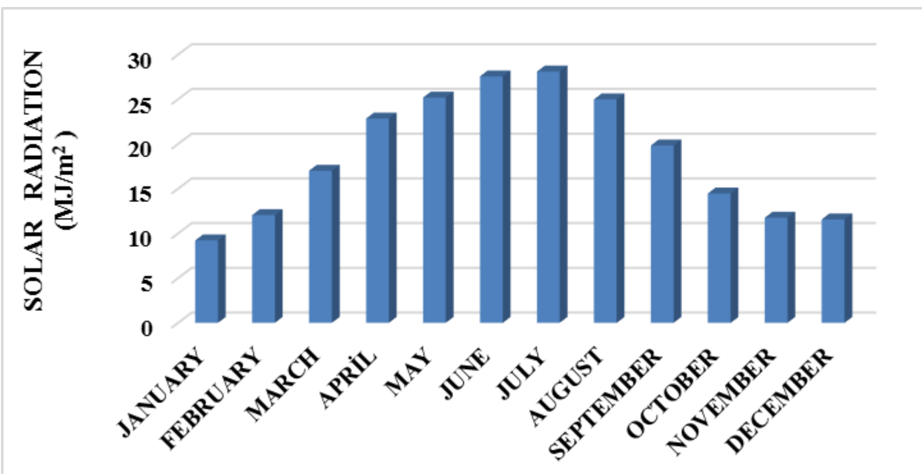


Figure 4.1: Daily variation of solar radiation in Nicosia, 2015

Daily variation of Solar radiation on horizontal surface in Nicosia, 2015 obtained from meteorological office of TRNC is given in Appendix B. Figure 4.1 shows the variation of daily total solar radiation during November and December. So the month November has solar radiation more than December, the reason was month November had temperature more than month December. The weather in November as expected is changing as the season moves well into autumn and towards winter. Towards the end of November, the rainy season begins. November has more than an average of 7 rainy days.m[2]

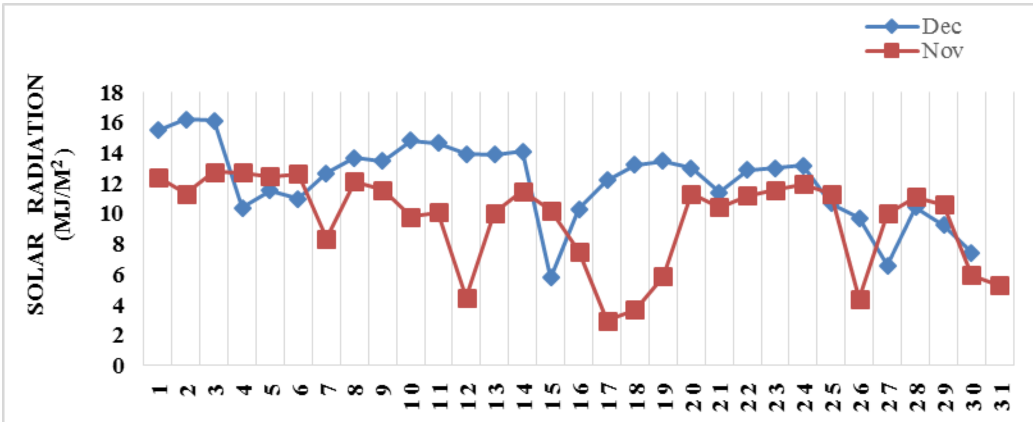


Figure 4.2: Daily variation of solar radiation in Nicosia, December and November 2015

4.2 Average Temperature Data for Nicosia 2015

Monthly variation of Temperature in Nicosia, 2015 obtained from meteorological office of TRNC (appendix B). Figure 4.2 shows the variation of daily temperature throughout the year. The average of daily temperature for each month is also shown in Figure 4.3. The daily temperature changes from about 10 ^{o}C during winter and up to 29 ^{o}C during summer.

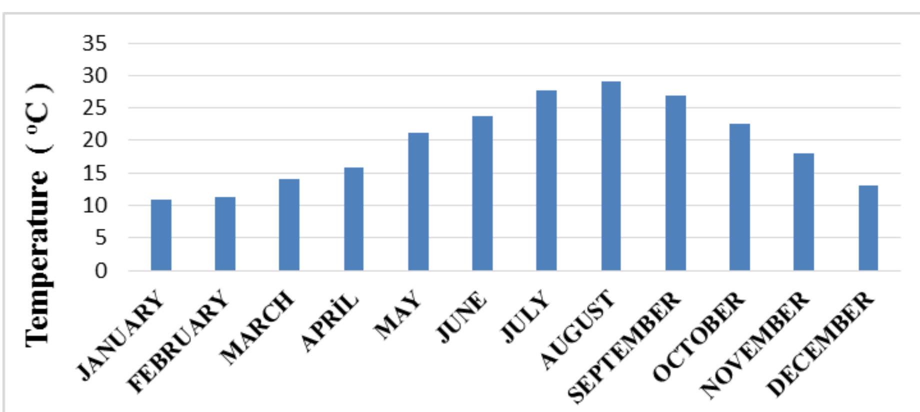


Figure 4.3: Daily variation of temperature in Nicosia, 2015

Daily variation of temperature in Nicosia, 2015 obtained from meteorological office of TRNC is given in Appendix B1. Figure 4.4 shows the variation of daily temperature during November and December. We noted that November had temperature more than December, the reason was month November had radiation more than month December. The weather in November as expected is changing as the season moves well into autumn and towards winter. Towards the end of November, the rainy season begins. November has more than an average of seven rainy days.

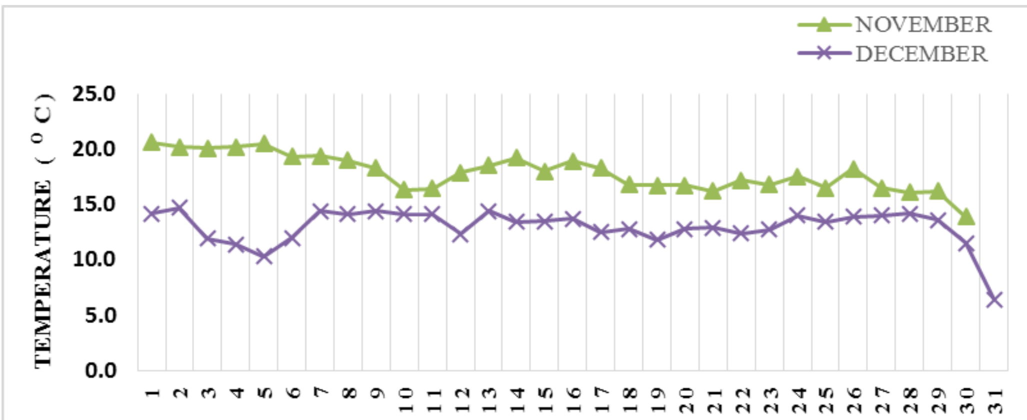


Figure 4.4: Daily variation of temperature in Nicosia, November and December 2015

4.3 Average Air Velocity Data for Nicosia (Nov, Dec, 20015)

Daily variation in velocity m/s for the Nicosia during November and December 2015 shown in Figure 4.5 below (Appendix C).

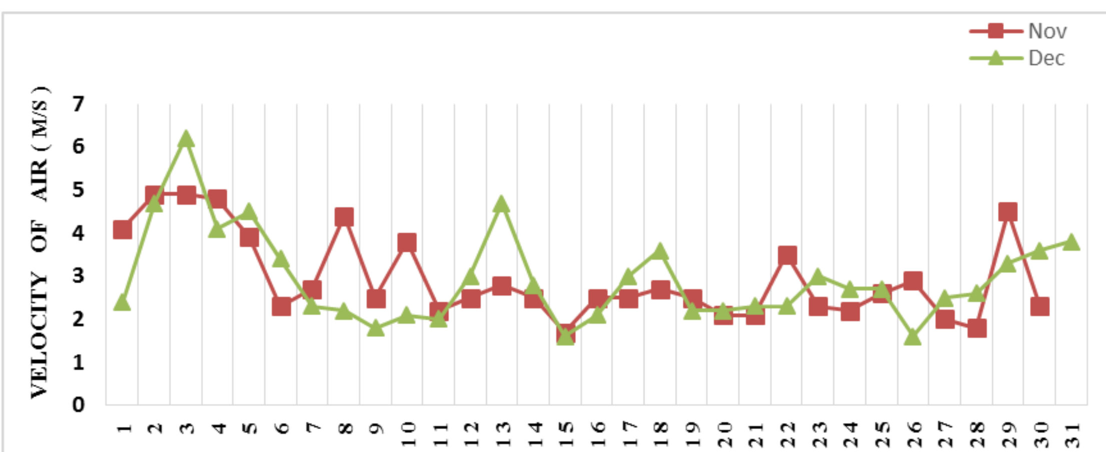


Figure 4.5: Daily variation of velocity in Nicosia, (Nov, and Dec, 2015)

4.4 The Results of Solar Laboratory Tests

4.4.1 On-site (insulated wall)

Total heat transferred to the room (Q_{total}) determined by adding the heat radiation (Q_{rad}), heat convection outside ($Q_{conv-out}$), heat conduction (Q_{cond}), heat convection inside ($Q_{conv-in}$).

Four T-type thermocouples where used during the experiments to measure the temperatures. The heat is at maximum during the day and at minimum during the night.

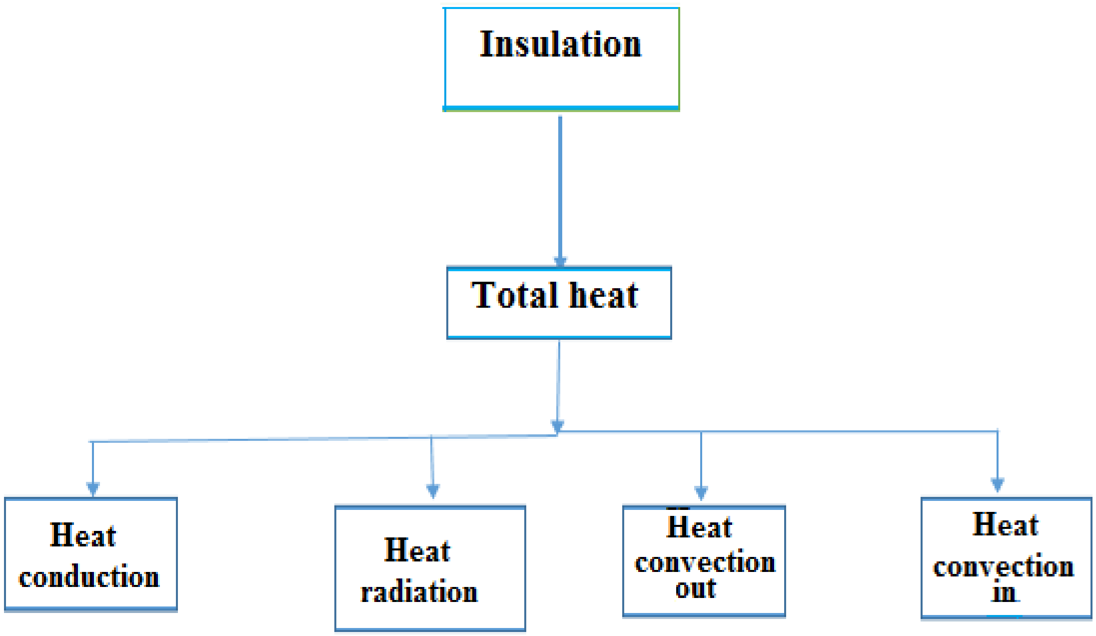


Figure 4.6: Distribution of heat on the wall insulated

4.4.2 Average heat conduction

Daily average heat conduction throughout the insulated wall was calculated as given and presented in Figure 4.7 below. The process of heat conduction depends on four basic factors: the temperature gradient, the cross section of the materials involved, their path length, and the properties of those materials. At the maximum point heat conductivity was high temperature, increase energy, and molecules contact between materials. Whereas at minimum was heat conduction was at lowest point as a result of minimal or absence of energy between materials.

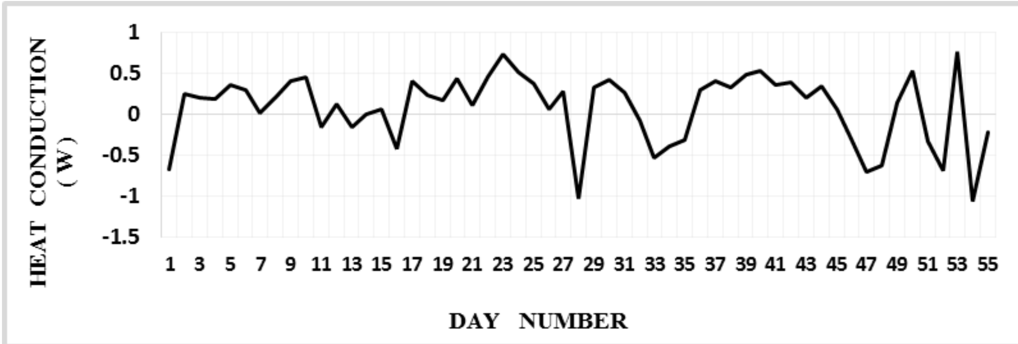


Figure 4.7: Daily variation of average heat conduction of wall insulated

4.4.3 Average heat radiation (Q_{Rad})

The solar radiation taken by the meteorological office and the temperatures taken by the thermocouples during the same day represented by calculated to give the average heat radiation Q_{rad} which can affect in the heat gain of the room where the wall is directed to the south, daily Q_{Rad} was calculated and presented in Figure 4.8 below. This shows that the highest heat radiation was at the fifth day of the experimentation with heat radiation of 38 w. It indicated the maximum temperature reached than, on fifty third day the temperature was the lowest minimum point with heat radiation at -20 W.

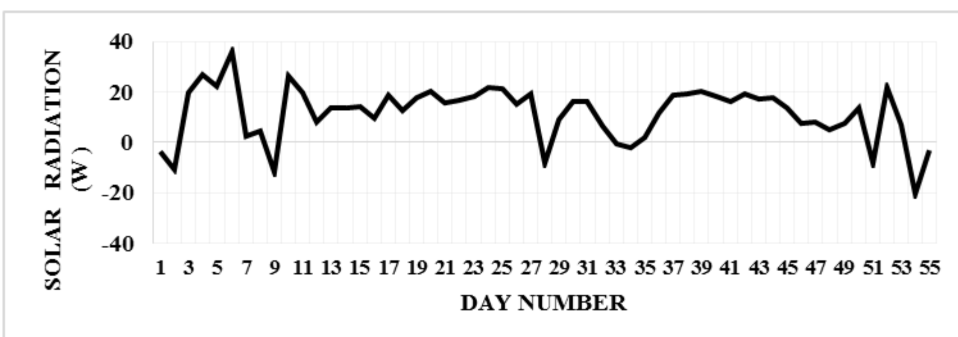


Figure 4.8: Daily variation of average heat radiation of wall insulated

4.4.4 Average heat convection ($Q_{Con-out}$, Q_{con-in})

During the day the room was facing two convection processes one from outside the room by the wind and the other is inside the room where there is only sill air. Daily variation in $Q_{con-out}$ and Q_{con-in} where calculated and presented in Figure 4.9 and Figure 4.10 respectively.

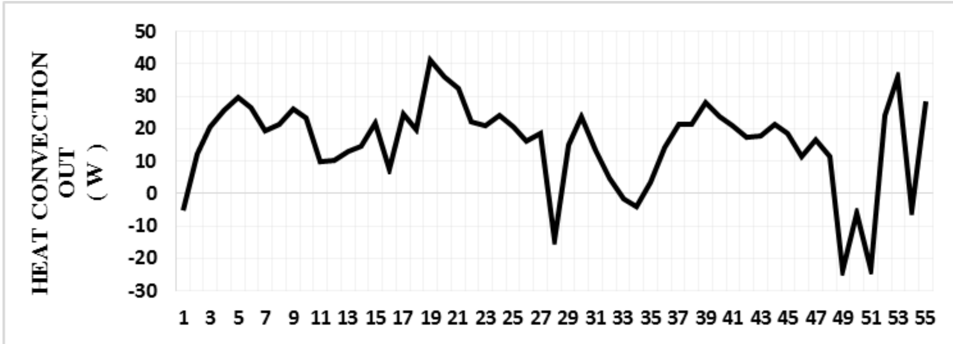


Figure 4.9: Daily variation of outer average heat convection ($Q_{Con\text{-}out}$, insulated)

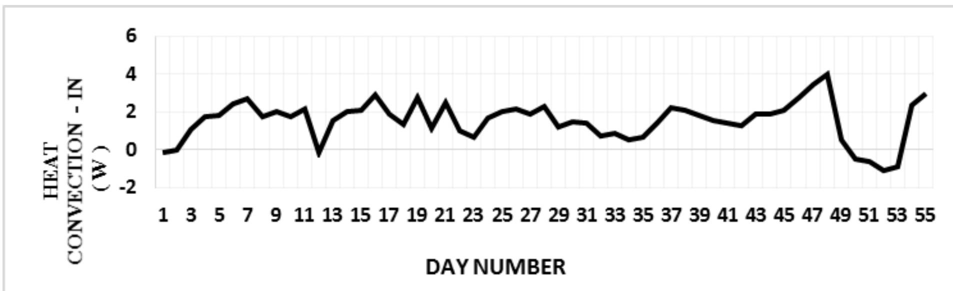


Figure 4.10: Daily variation of inner average heat convection ($Q_{Conv\text{-}in}$,insulated)

4.4.5 Total average heat (Q_T)

Total heat was calculated by adding the 4 different heat types (Q_{Rad}, $Q_{con\text{-}out}$, $Q_{cond,}$ $Q_{con\text{-}in}$) of the room where Q_T was represented in Figure 4.11 below.

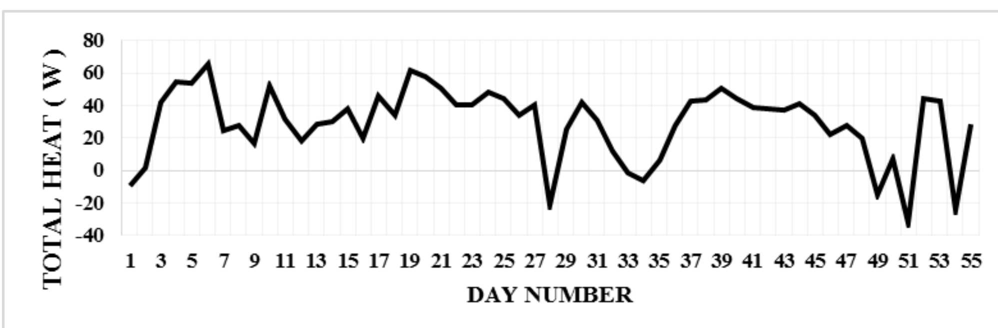


Figure 4.11: Daily variation of total heat of wall insulated

4.5 Maximum heat conduction

Daily maximum heat conduction throughout the insulated wall was calculated and presented in Figure 4.12 below. During the day time the heat conduction gains more energy through material that has more molecular effect across layers. And this proved that that heat conduction is affected by temperature difference.

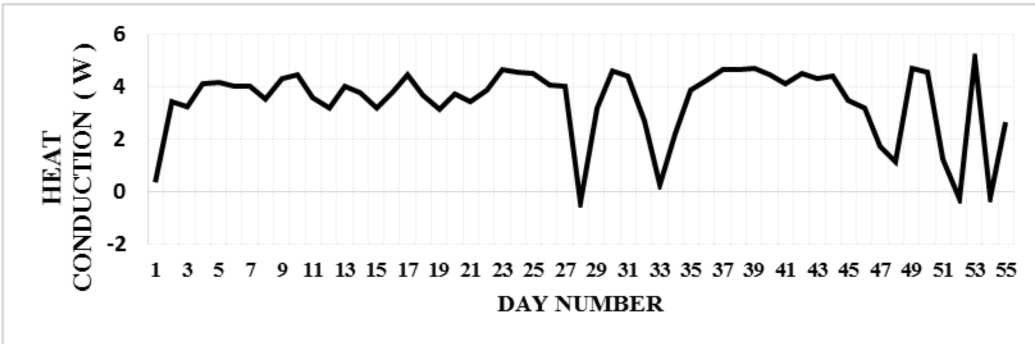


Figure 4.12: Daily variation of maximum heat conduction of wall insulated

4.5.1 Maximum heat radiation (Q_{Rad})

Daily maximum Q_{Rad} was calculated and presented in Figure 4.13 below.

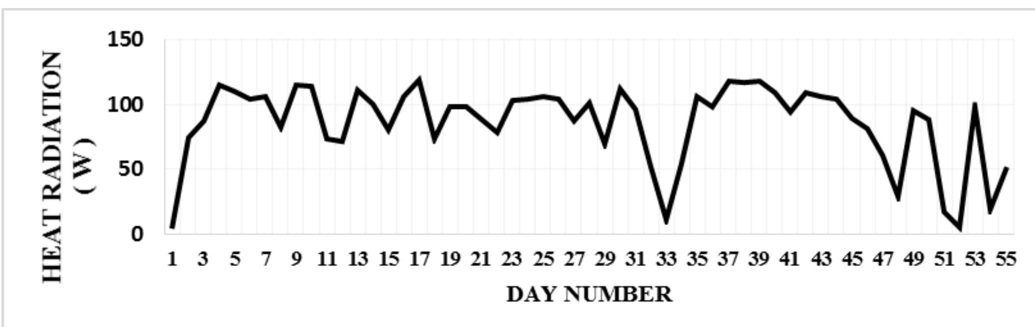


Figure 4.13: Daily variation of maximum heat radiation of wall insulated

4.5.2 Maximum heat convection ($Q_{Con-out}$, Q_{con-in})

Daily variation in $Q_{con-out}$ and Q_{con-in} where calculated and presented in Figure 4.14 and Figure 4.15 respectively.

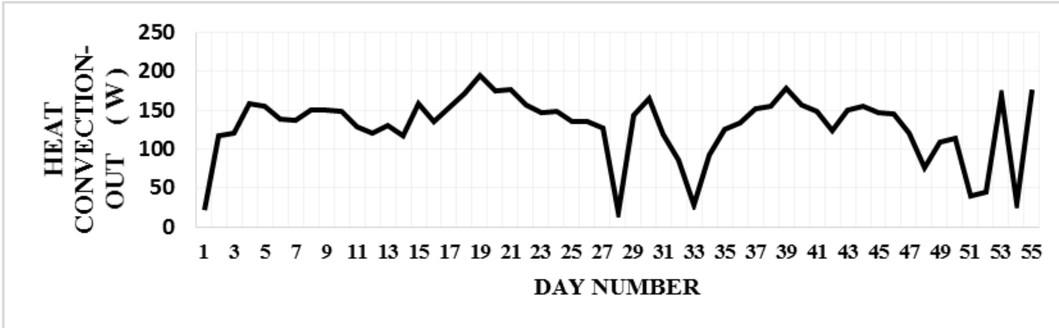


Figure 4.14: Daily variation of max Heat convection ($Q_{\text{conv-out}}$) of wall insulated

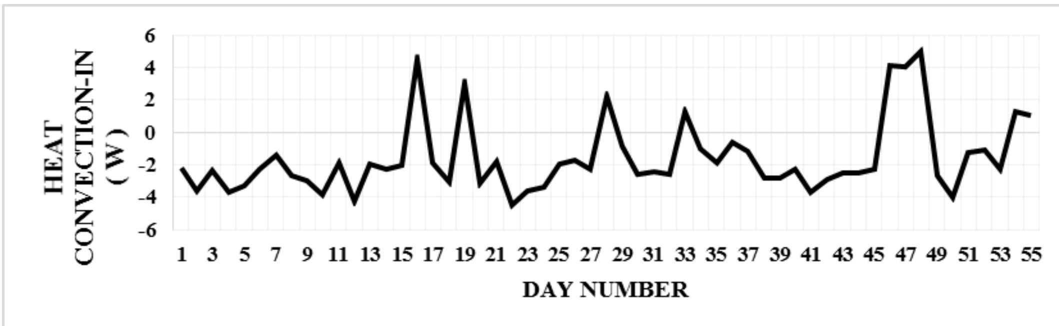


Figure 4.15: Daily variation of maximum heat convection ($Q_{\text{conv-in}}$) of wall insulated

4.5.3 Total Maximum heat (Q_T)

Total heat was calculated by adding the 4 different heat types (Q_{Rad}, $Q_{con\text{-}out}$, Q_{cond}, $Q_{con\text{-}in}$) of the room where Q_T was represented in Figure 4.16 below.

- Total Heat (Q_T):

$$Q_T = Q_{Rad} + Q_{Conv-out} + Q_{Cond} + Q_{Conv-in}$$

- Heat radiation:

$$Q_{\text{radiation}} = A\,\varepsilon\,\sigma\,(T_{s(out)}^4 - T_{sky}^4)$$

- Heat convection (inside-room)

$Q_{\text{convection}} = h\,A\,(T_{s(in)} - T_\infty)$ When we have still air h=8.3 (W/m^2-K)

- Heat conduction

$$Q_{cond} = \frac{\Delta T}{\frac{L1}{k1*A}+\frac{L2}{k2*A}+\frac{L3}{k3*A}+\frac{L4}{k4*A}+\frac{L5}{k5*A}}$$

- Heat convection (outside-room)

$$Re\,x,cr = \frac{\rho v x,cr}{\mu} = 5*10^5$$

$$Nu = \frac{hl}{k} = 0.664 Re_L^{\,0.5}\,Pr^{1/3}$$

$Q_{conv} = h\,A\,(T_{s(in)} - T_{\infty})$

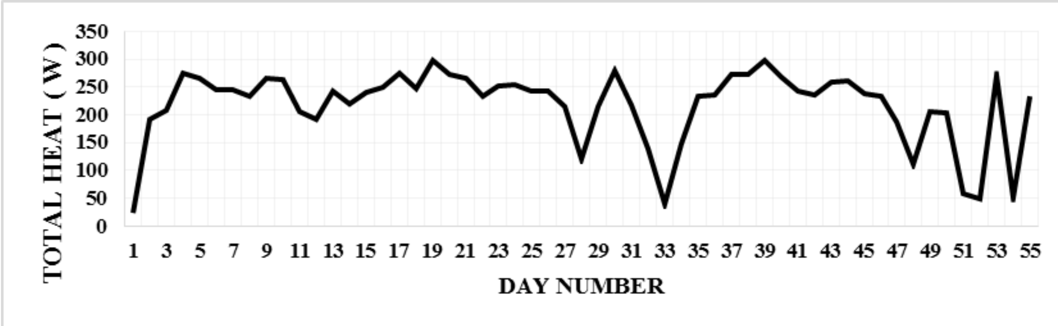


Figure 4.16: Daily variation of total maximum heat of wall insulated

4.5.4 Minimum heat conduction

Daily maximum heat conduction throughout the insulated wall was calculated and presented in Figure 4.17 below.

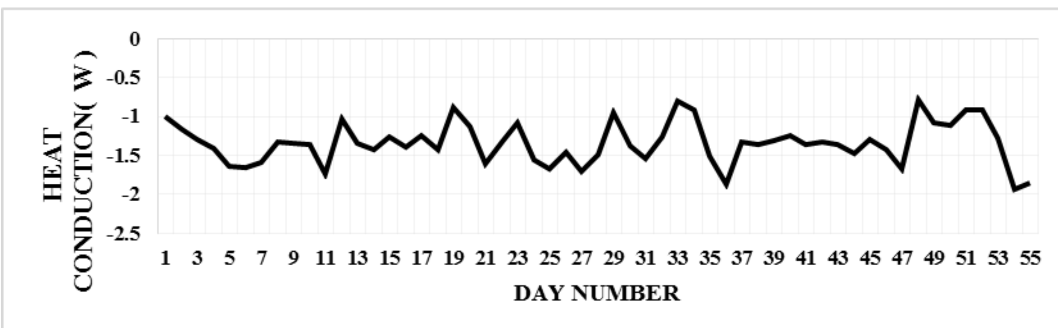


Figure 4.17: Daily variation of minimum heat conduction of wall insulated

4.5.5 Minimum heat convection ($Q_{Con\text{-}out}$, $Q_{con\text{-}in}$)

Daily variation in $Q_{con\text{-}out}$ and $Q_{con\text{-}in}$ where calculated and presented in Figure 4.18 and Figure 4.19 respectively.

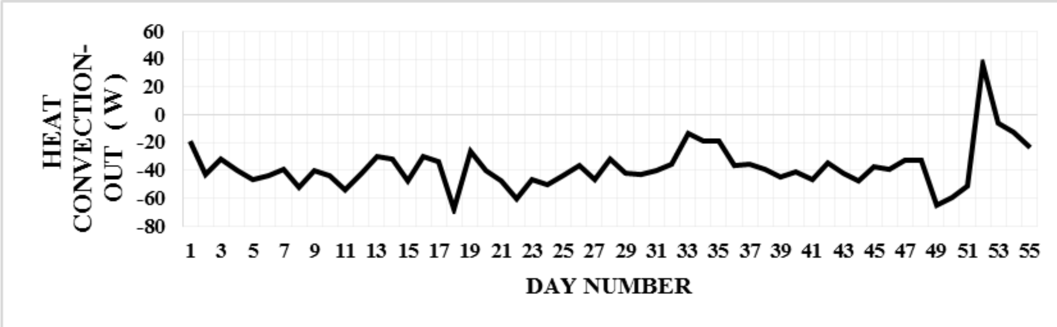


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Figure 4.18: Daily variation of minimum outer heat convection ($Q_{conv-out}$) of wall insulated

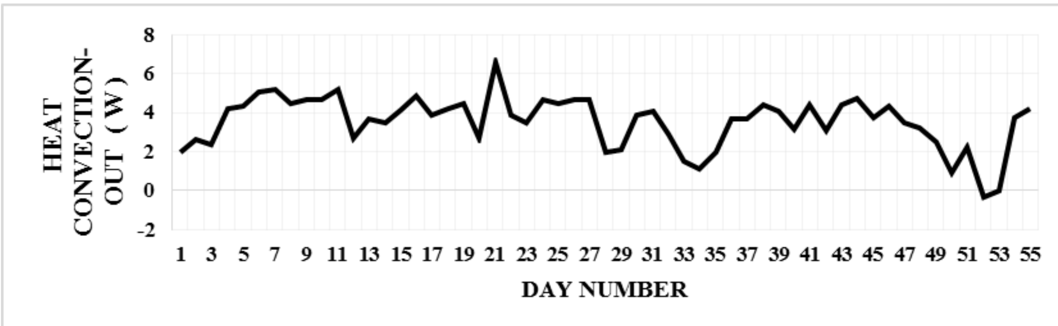

Figure 4.19: Daily variation of minimum inner heat convection of wall insulated

4.5.6 Minimum total heat

Total heat was calculated by adding the 3 different heat types ($Q_{conv-out}$, Q_{cond}, $Q_{conv-in}$) of the room where Q_T was represented in Figure 4.20 below.

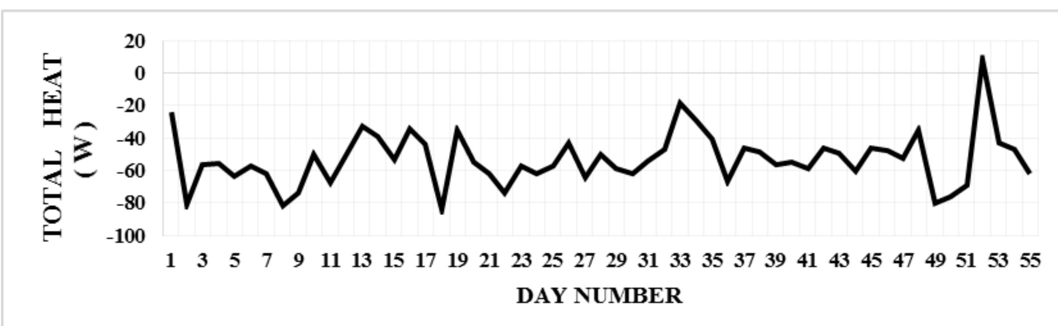

Figure 4.20: Daily variation of minimum total heat of wall insulated

4.6 On-site (Y-tong wall)

Three T-type of thermocouple used in on-site during the experiment to measures the temperature.

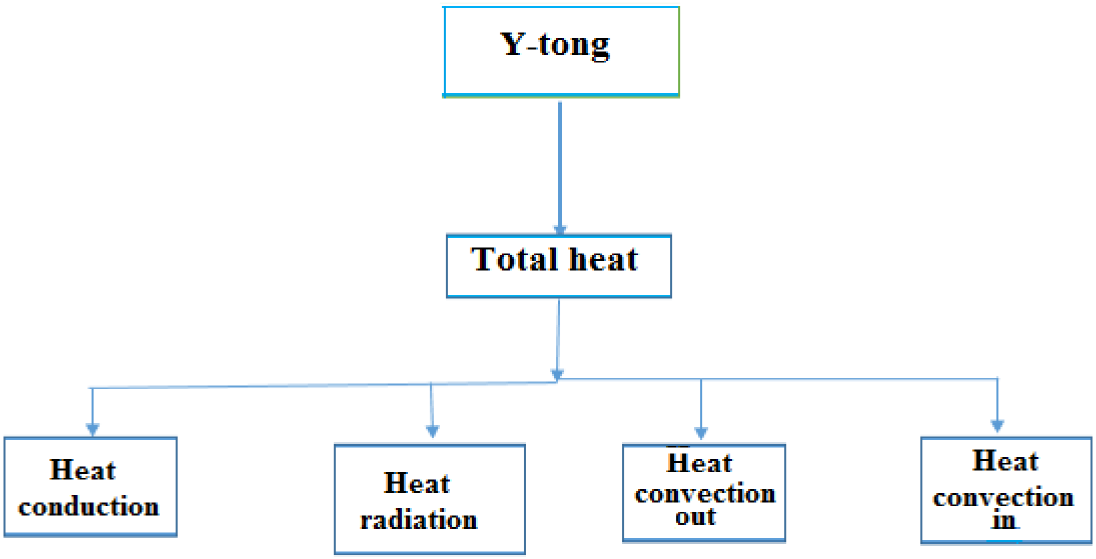

Figure 4.21: Distribution of heat on the Y-tong wall

4.6.1 Average heat conduction

Daily heat conduction throughout the ytong wall was calculated and presented in Figure 4.22 below.

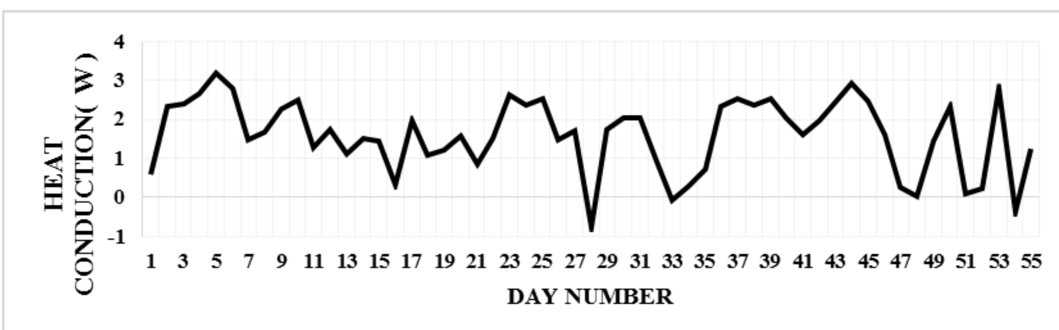

Figure 4.22: Daily variation of heat conduction of Y-tong wall

4.6.2 Average heat radiation

The solar radiation taken by the meteorological office and the temperatures taken by the thermocouples during the same day represented by calculated to give the heat radiation Q_{rad} which can affect in the heat gain of the room where the wall is directed to the south, daily Q_{Rad} was calculated and presented in Figure 4.23 below.

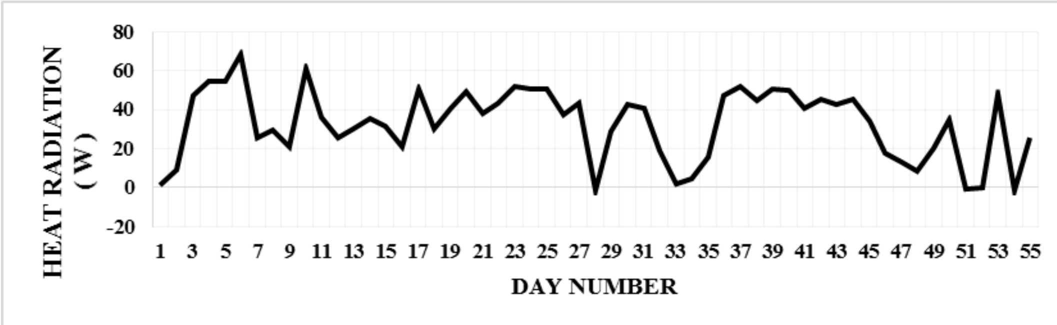

Figure 4.23: Daily variation of average of heat radiation of Y-tong wall

4.6.3 Average heat convection ($Q_{Con-out}$, Q_{con-in})

During the day the room was facing two convection processes one from outside the room by the wind and the other is inside the room where there is only sill air. Daily variation in $Q_{con-out}$ and Q_{con-in} where calculated and presented in Figure 4.24 and Figure 4.25 respectively.

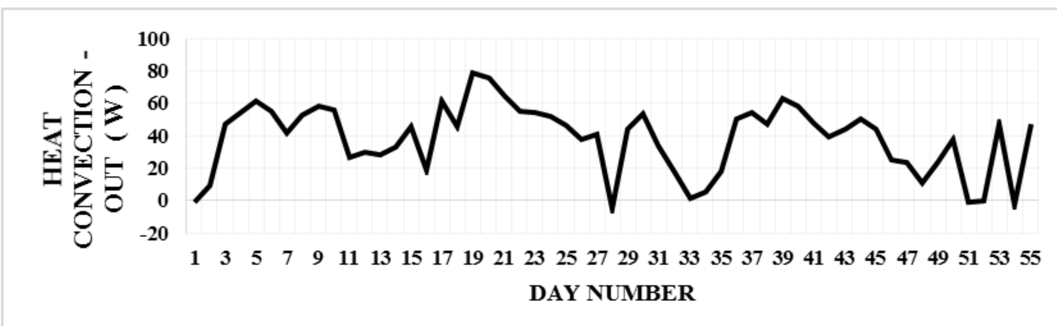

Figure 4.24: Daily variation of heat convection of Y-tong wall ($Q_{Con-out}$)

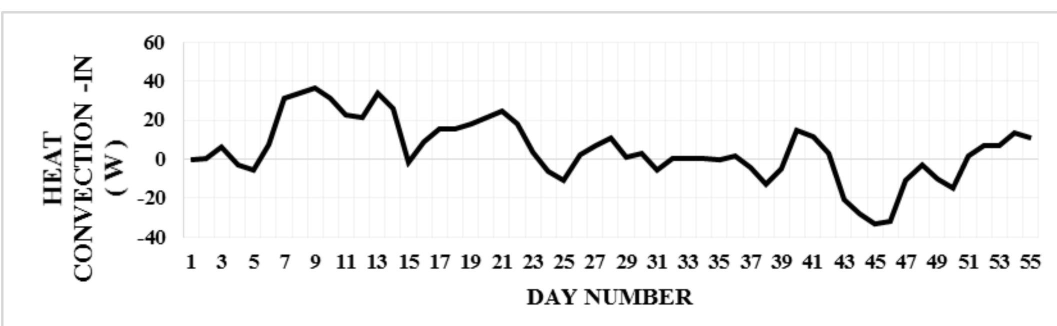

Figure 4.25: Daily variation of heat convection of Y-tong wall (Q_{con-in})

4.6.4 Average of total heat of Ytong wall

Total heat was calculated by adding the 4 different heat types (Q_{Rad}, $Q_{con-out}$, $Q_{cond,}$ Q_{con-in}) of the room where Q_T was represented in Figure 4.26 below.

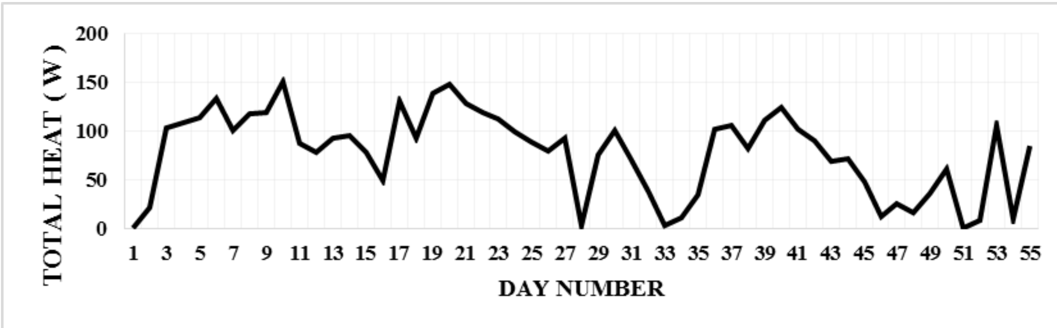

Figure 4.26: Daily variation of average of total heat of Y-tong wall

4.6.5 Maximum heat conduction

Daily maximum heat conduction throughout the insulated wall was calculated and presented in Figure 4.27 below.

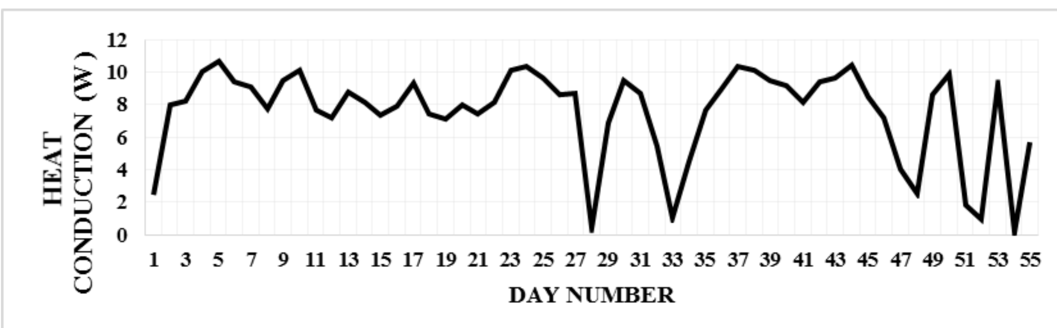

Figure 4.27: Daily variation of maximum heat conduction of Y-tong wall

4.6.6 Maximum heat radiation

Daily Q $_{Rad}$ was calculated and presented in Figure 4.28 below.

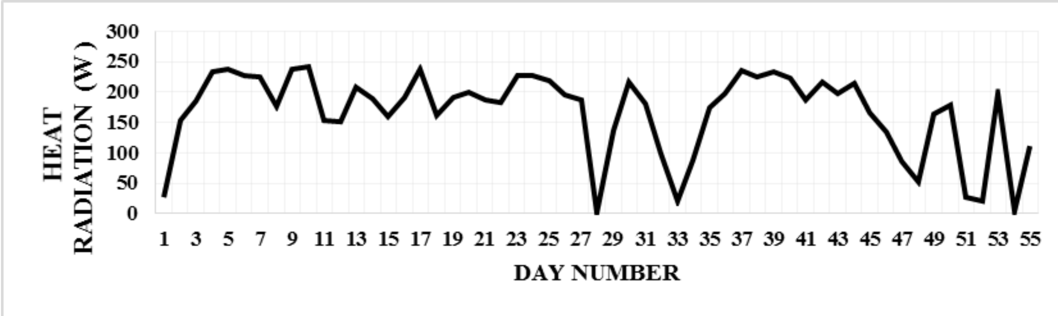

Figure 4.28: Daily variation of heat average radiation

4.6.7 Maximum heat convection ($Q_{Con\text{-}out}$, $Q_{con\text{-}in}$)

Daily variation in $Q_{con\text{-}out}$ and $Q_{con\text{-}in}$ where calculated and presented in Figure 4.29 and Figure 4.30 respectively.

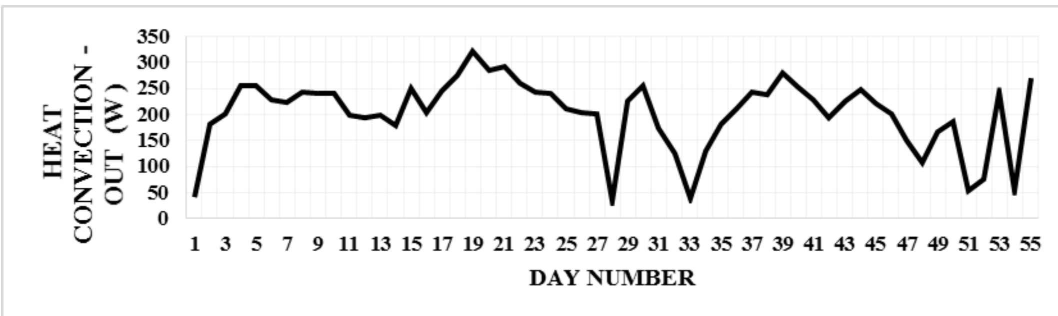

Figure 4.29: Daily variation of maximum heat convection outside of Y-tong

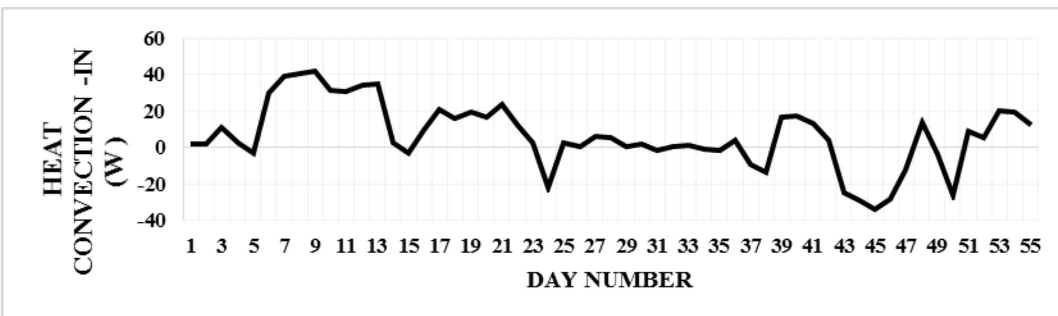

Figure 4.30: Daily variation of maximum heat convection inside of Y-tong

4.6.8 Maximum total heat

Total heat was calculated by adding the 4 different heat types ($Q_{conv\text{-}out}$, Q_{rad}, Q_{cond}, $Q_{conv\text{-}in}$) of the room where Q_T was represented in Figure 4.31 below.

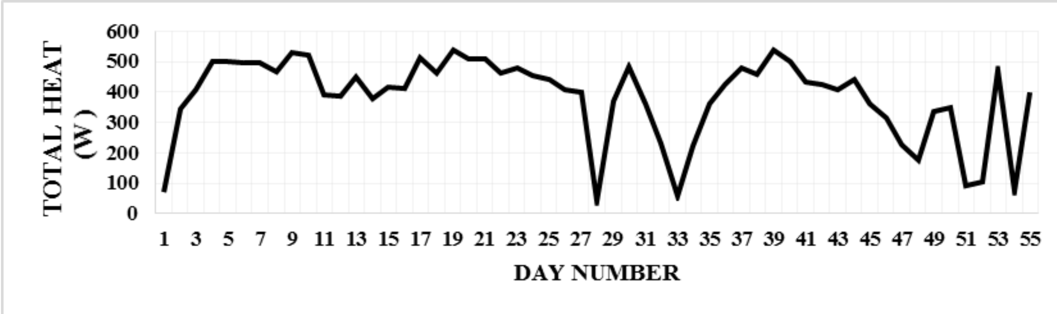

Figure 4.31: Daily variation of maximum total heat of Y-tong wall

4.6.9 Minimum heat conduction

Daily minimum heat conduction throughout the insulated wall was calculated and presented in Figure 4.32 below.

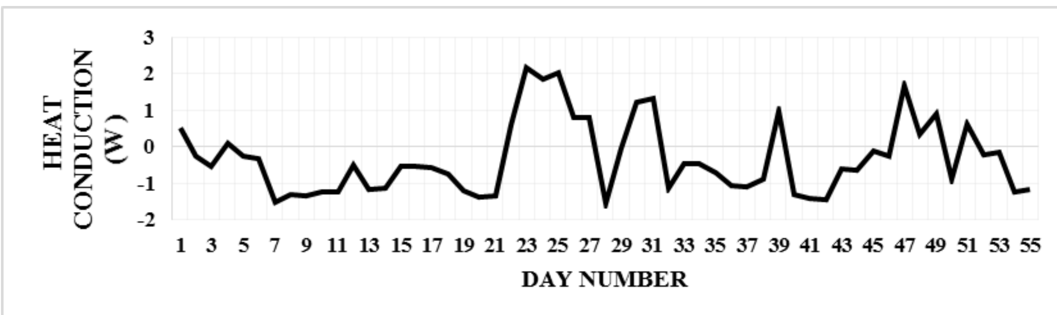

Figure 4.32: Daily variation of minimum heat conduction of Y-tong wall

4.6.10 Minimum heat convection ($Q_{Con\text{-}out}$, $Q_{con\text{-}in}$)

Daily variation in $Q_{con\text{-}out}$ and $Q_{con\text{-}in}$ where calculated and presented in Figure 4.33 and Figure 4.34 respectively.

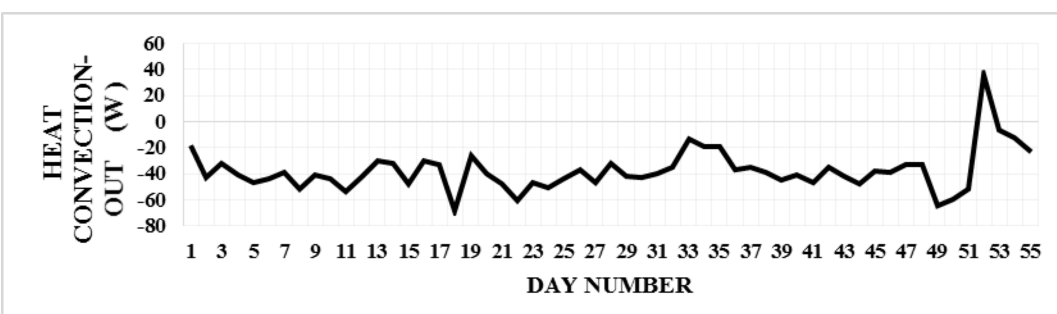

Figure 4.33: Daily variation minimum of outer surface heat convection ($Q_{conv\text{-}out}$) of Y-tong wall

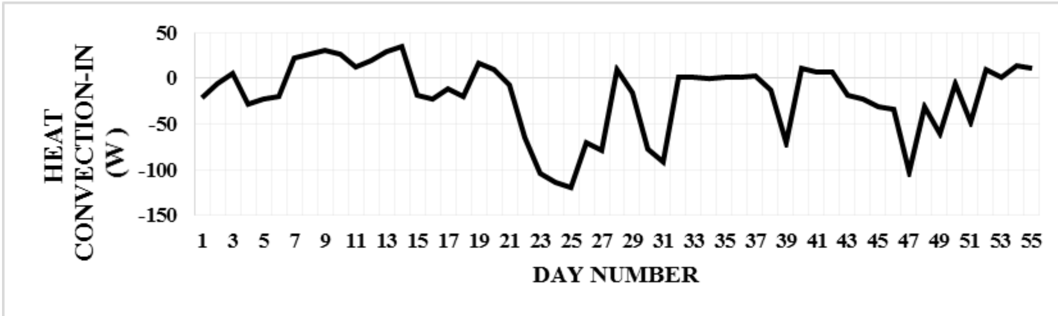

Figure 4.34: Daily variation minimum of inner surface heat convection ($Q_{\text{Conv-in}}$) of Y-tong wall

4.6.11 Minimum total heat

Total heat was calculated by adding the 3 different heat types ($Q_{\text{Conv-out}}$, Q_{Cond}, $Q_{\text{Conv-in}}$) of the room where Q_T was represented in Figure 4.35 below.

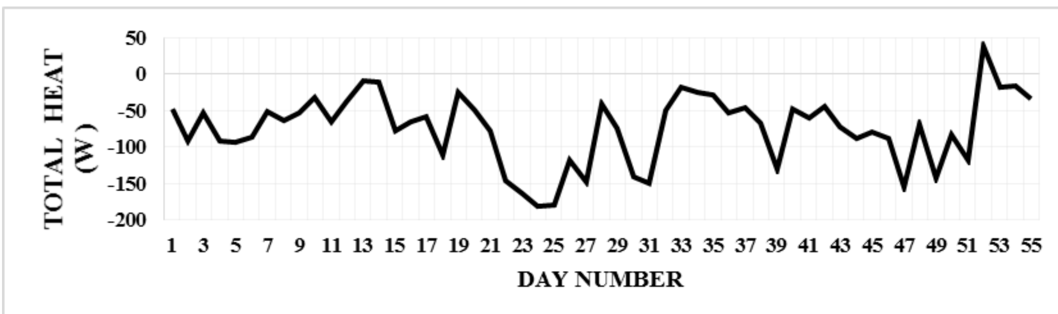

Figure 4.35: Daily variation of minimum total heat of Y-tong wall

4.7 Maximum Heat Radiation Ytong Wall vs Heat Insulation Wall

The figure 4.36 shown, is the relationship of maximum heat radiation between Y-tong wall and heat insulation wall during the days. The maximum means during the day time. We noted the Y-tong wall has heat radiation greater than of wall insulated. That means Y-tong wall takes more solar radiation. The reason was that their insulation value and their impact on energy consumed varies, Y-tong bricks has a more preferred thermal quality when compared to heat insulated wall during the period of intense heat or solar radiation. Whereas Y-tong material had thermal conductivity greater than heat insulation and stone wool has heat coefficient more than Y-tong material. The properties of stone wool has high resistance to pressure, higher fire resistance, high melting temperature, over 1000°C, low tensile strength, lower elasticity of the material, maximum working temperature 750°C, greater density of the product from 30 to 200kg/m^3 . And the properties Y-tong material has low density, high tensile strength, fire resistance less than stone wool ,melting temperature over 700 °C.

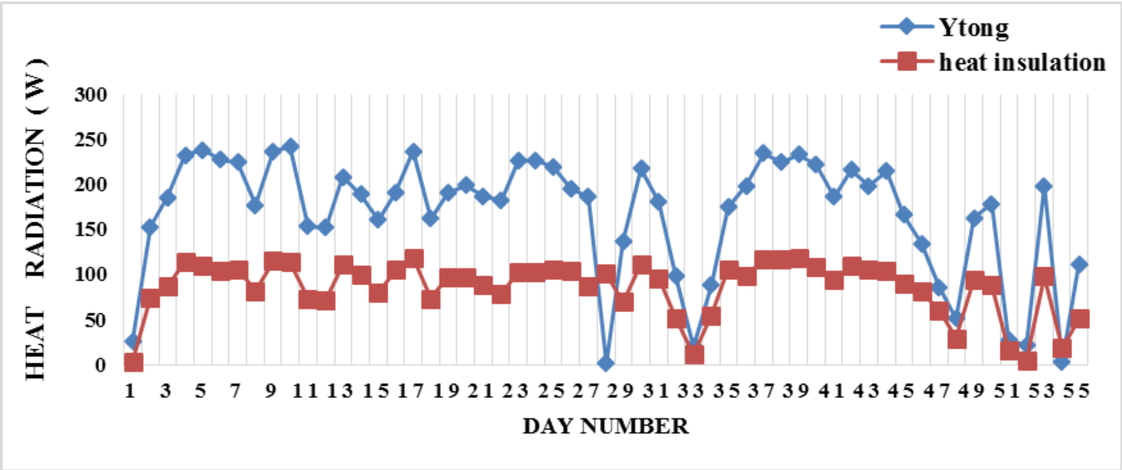

Figure 4.36: A comparison of the maximum heat radiation between Y-tong wall and heat insulation wall

4.8 Maximum Heat Conduction Y-tong Wall vs Heat Insulation Wall

The Figure 4.37 shown, is the relationship of maximum heat conduction between Y-tong wall and heat insulation wall during the days. The Y-tong wall has heat conduction greater than heat insulated wall. That is heat moves through a material at a specific rate. It is understood that Y-tong material absolved heat from the outside to the inside surface quickly and the heat insulation material absolved heat slowly. The reason was the Y-tong wall conducted more, when compared to stone wool as a result the heat conduction decreased with multi-materials and also it was depend on the thermal conductivity for each layer. Therefore heat conduction of Y-tong moves quickly across materials more than stone wool. As the result of this, it was noted that heat conduction is affected by temperature difference. The difference temperature of Y-tong has a greater of stone wool and two walls has different heat thermal conductivity.

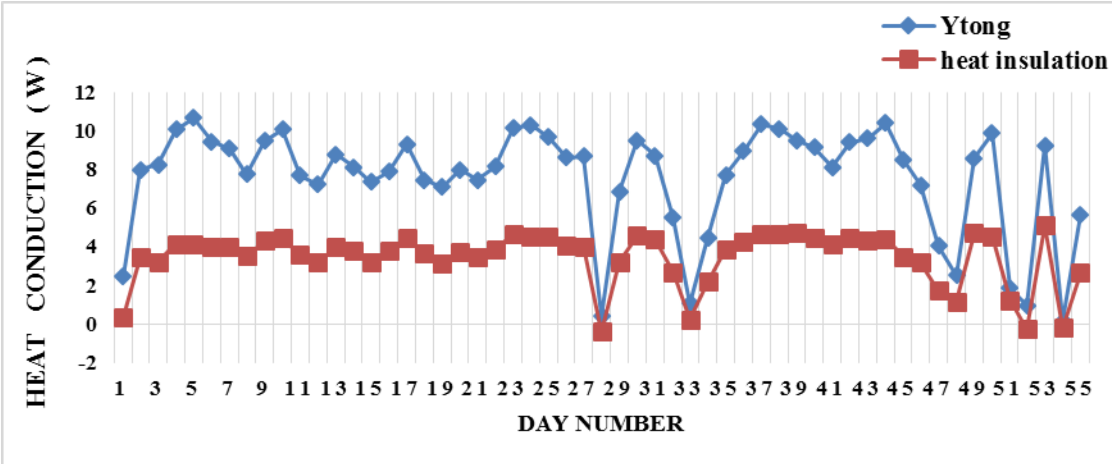

Figure 4.37: A comparison of the maximum heat conduction of Y-tong wall and wall insulated

4.9 Maximum Heat Convection ($Q_{\text{Con-out}}$, $Q_{\text{con-in}}$) Y-tong Wall vs Heat Insulation Wall

The Figure 4.38 and figure 4.39 shown, is the relationship between heat convection of outer and inner surface of Y-tong wall and heat insulation wall during the specified days. The Y-tong wall (outside) has heat convection ($Q_{\text{conv-out}}$) greater than of wall insulated at day time. This means that's fluid and wind velocity has effect on the outer wall surface. Meanwhile heat convection ($Q_{\text{con-in}}$) of Y-tong changed within the specified days, but heat insulated wall has heat convection ($Q_{\text{con-in}}$) approximately constant, the reason was the difference in temperature inside the room and inner wall surface. Heat coefficient transfer rate at the vertical wall is constant on inner surface because there is still air inside, h = 8.3w/k.m^2 (Appendix D). As the results the magnitude of convective heat flow upon from the area of contact with the solid wall, this thermal flow was characterized by the overall temperature difference between the two compared model. Therefore, this implies that heat convection was depended on the temperature different, heat convection, heat coefficient, thermal conductivity, and thickness of materials. Whereas heat and mass transfer by convection, focuses on heat and mass flows at walls; that is why fluid flow near a solid wall (boundary layer flow) is so important.

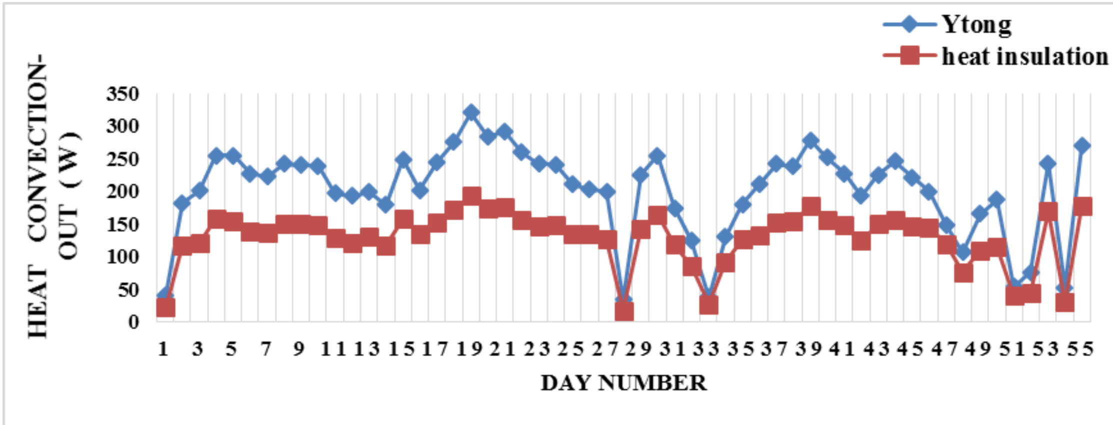

Figure 4.38: A comparison of maximum heat convection of outer surface between Y-tong and wall insulated

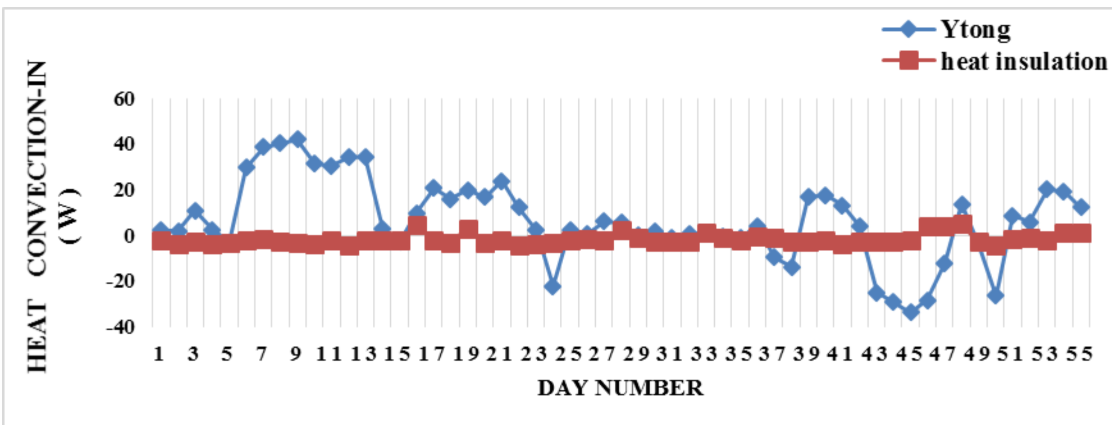

Figure 4.39: A comparison of heat convection of inner surface between Y-tong and wall insulated

4.10 Maximum Total Heat Y-tong wall vs Heat Insulation Wall

The Figure 4.40 shown below, is the relationship of total heat between Y-tong wall and heat insulation wall during the days. From the graph we noted that the total heat of Y-tong wall is greater than of total heat of heat insulated wall. From the graph below ,the reason behind max (day time) total heat of Y-tong material when compared to heat insulated wall,was in accordance with the thermal properties of y-tong material which are, high resistance to pressure, high tensile strength, and the content of extended fibers, which offer thermal insulation acoustic insulation and vapor permeability.

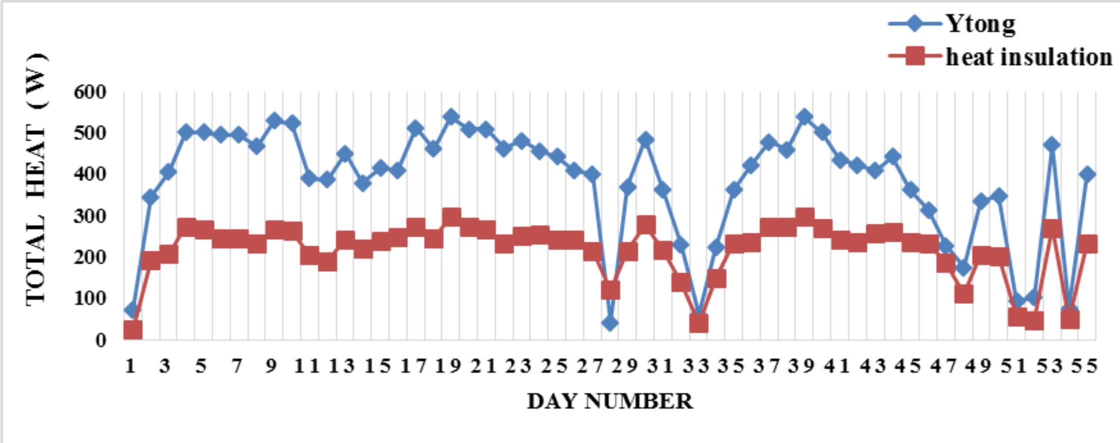

Figure 4.40: A comparison of the maximum total heat between Y-tong wall and wall insulated

4.11 Minimum Heat Conduction Y-tong Wall vs Heat Insulation Wall

The Figure 4.41 shown below is the relationship of total heat between Y-tong wall and heat insulated wall during the specified days. The result indicated in the graph proved that at the night time heat conduction of Y-tong wall is greater than heat conduction of heat insulated wall within the stipulated days. This is because of the thermal properties of both material combination, at the minimum level (heat is during the night time), there is a slight variation of heat conduction for heat insulated wall material, it has a better time lag to decremental factor ratio as compared to Y-tong wall , that is sparsely varied.

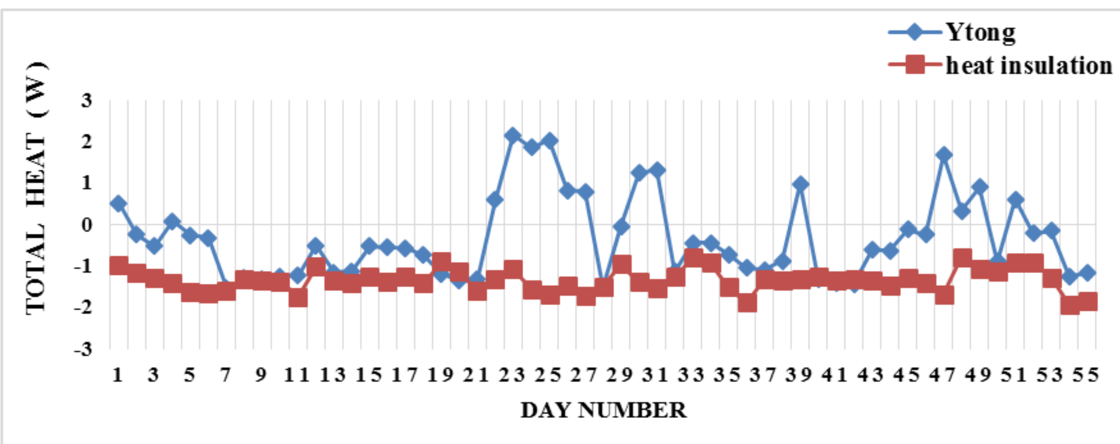

Figure 4.41: A comparison of the minimum heat conduction of Y-tong wall and wall insulated

4.12 Minimum Heat Convection ($Q_{Con\text{-}out}$, $Q_{con\text{-}in}$) Y-tong Wall vs Heat Insulation Wall

The Figure 4.42 and figure 4.43 shown, below are the relationship of minimum heat convection of outer and inner surface between Y-tong wall and heat insulated wall within the days. Y-tong wall and heat insulated wall have the same heat convection ($Q_{Con\text{-}out}$) outside on the surface during the night because there is usually no radiation during the night time. Heat convection ($Q_{con\text{-}in}$) at inner surface of heat insulated wall during the night remains approximately constant but the Y-tong wall varies during the night. The reason was that, the temperature of out surface wall of both room had approximately same ambient temperature during the night time .Since the velocity ,heat coefficient and temperature difference was at the level.

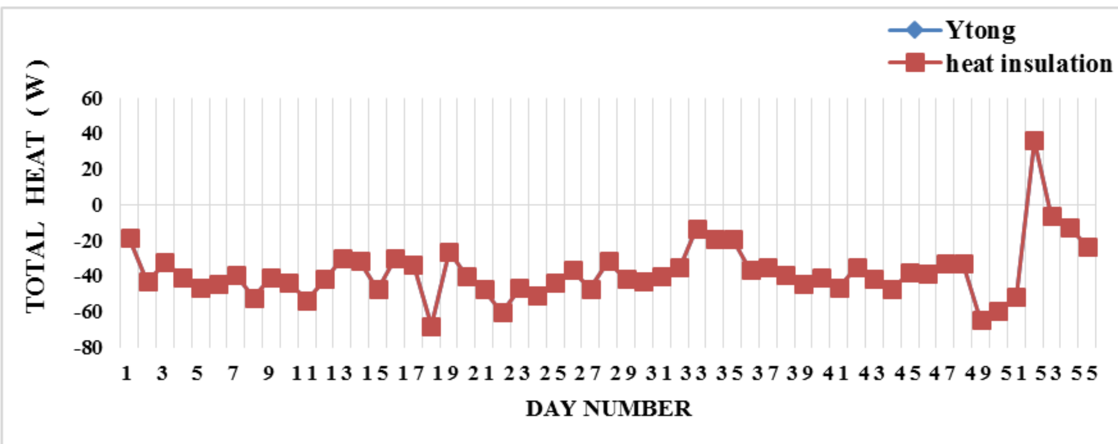

Figure 4.42: A comparison of the minimum heat convection ($Q_{Con\text{-}out}$) Y-tong wall and heat insulation wall

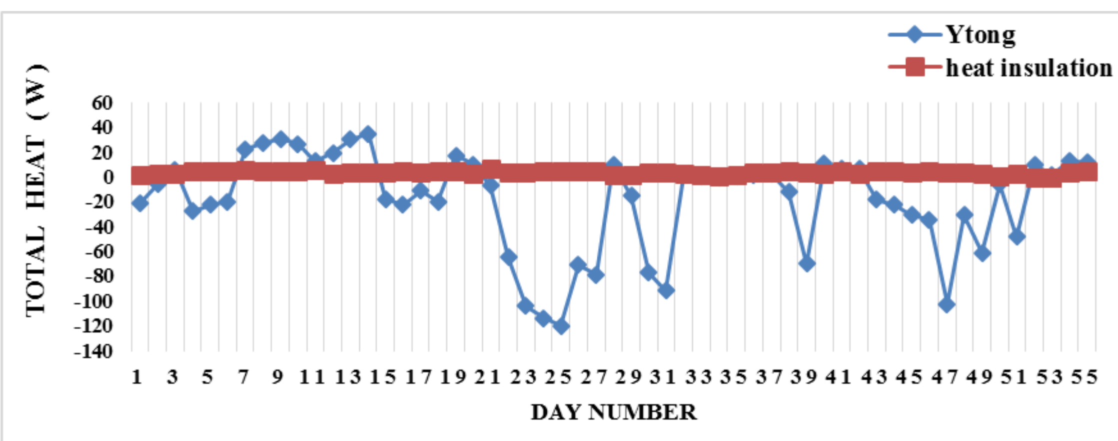

Figure 4.43: A comparison of minimum heat convection ($Q_{Con\text{-}out}$) of Y-tong wall and wall insulated

4.13 Total Heat Loss and Total Heat Gain During Day and Night Time

The Figure 4.44 shown below, is the summary of the results from the graph above, and it gives a clear explanations for heat loss and heat gain for Y-tong wall and heat insulated wall. Y-tong wall has heat gain more than the heat insulated wall at the maximum time (during the day) but it also has more heat loss then the insulated wall at minimum time (at night time). This because Y-tong material has a better insulation properties during the day time compared to stone wool. Whereas during the night stone wool had a minimal heat loss led to its superior time lag.

Considering the descriptive structure of both walls which is detailed below, the Y-tong which is aerated concrete rely deeply in its buildings properties, the main raw materials are quartz, sand, Portland cement, lime and water. The materials is put into autoclaves with approximately 190 ^{o}C and 12 bar pressure, during this procedure the essential for Y-tong block, spherical, closed air pores are created and it can also be called isotropic building material with high construction speed , fire resistance, thermal insulation and comfort, acoustic insulation, lightweight construction material, ecological and durability. Whereas for the stone wool which is also known as mineral cotton, is generated from fiber materials that are formed by spinning or drawing cotton minerals (synthetic minerals such as slag and ceramics) it also offer thermal insulation, filtration, soundproofing and hydroponic growth medium. The heat resistance of stone wool is at a temperature between 700- 850 ^{o} C. We can see that Y-tong material has a better insulation properties

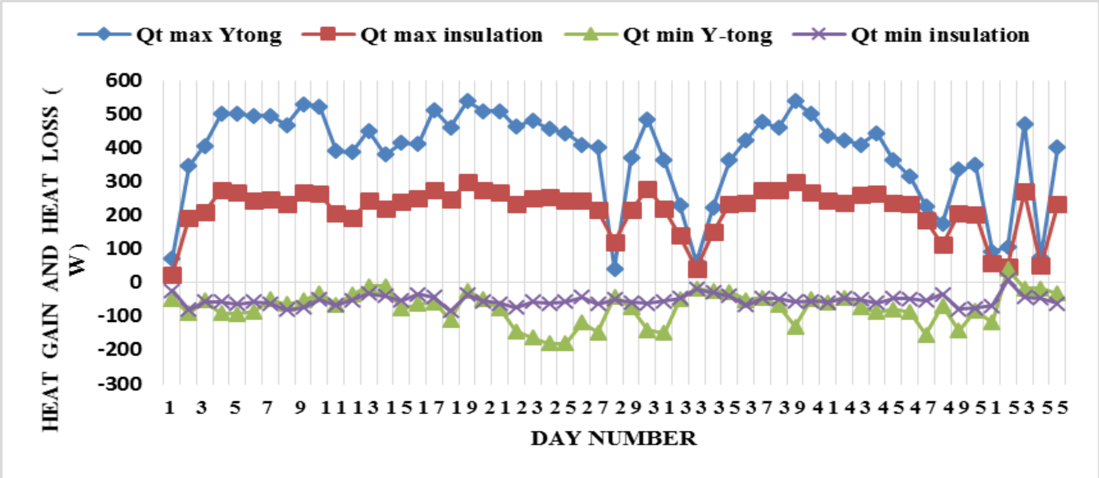

Figure 4.44: Daily variation of total heat loss and heat gain

4.14 Average of Total Heat Loss and Total Heat Gain

Figure 4.45 demonstrates the average total heat loss and heat gain per day .Y-tong wall gains heat more than the heat insulation it carries out. This is due to the fact that Y-tong saves more energy than stone wool does during the day. Having reviewed an analysis of the laboratory experiment, the thermal proporties of the Y-tong material are better compared to the stone wool and heat insulated materials in terms of heat flux. Comparing the two models, L1 (Y-tong wall) had higher heat radiation than insulated model (L2). This indicated that Ytong brick wall absorbed more thermal radiation with a greater heat conduction, fluid and wind velocity on each of the outer surface of the wall . Meanwhile, the heat convection of Y-tong changed within the specified days. A review of illustrious work has been conducted on this subject which indicated that time lag and decrement factor are of great importance. The building walls are integrated parts of the envelope of building as they protect the inner space from extreme weather conditions and damp down large fluctuations in temperature.The gap in this present research suggests different options in terms of the most suitable material selection for the research location. Asan (1998 and 2000) carried out analysis using finite difference method for the investigation of insulation thickness and its optimum portion in wall for maximum decrement factor. Ozel (2011) determined the thermal performance and optimum thickness of the building wall using an implicit finite difference method. Finite difference analysis was carried out and compared with the result of the experimental findings. The effect of wall configurations on time lag and decrement factor, the interior surface instanteneous heat load and the influence of exterior surface coefficient in the time lag and decrement have been studied.

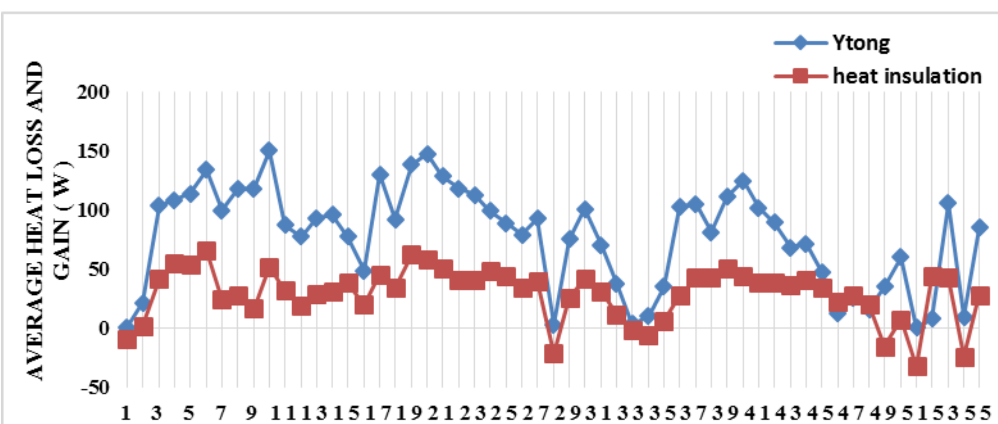

Figure 4.45: Daily variation of average total heat loss and heat gain by day

4.15 Heat Convection ($Q_{conv\text{-}out}$, $Q_{conv\text{-}in}$) Y-tong Wall vs Heat Insulation Wall on 01/01/2016

The Figure 4.46 and Figure 4.47 shown, below are a comparison heat convection of outer and inner surface between Y-tong wall and wall insulated during the time. We noted Y-tong wall and heat insulation have the same heat convection ($Q_{conv\text{-}out}$) outside on the surface during the night the reason was no radiation during the night time. Meanwhile heat convection ($Q_{conv\text{-}in}$) at inner surface of wall insulated rests nearly constant during the night however the Y-tong wall varies at night time.

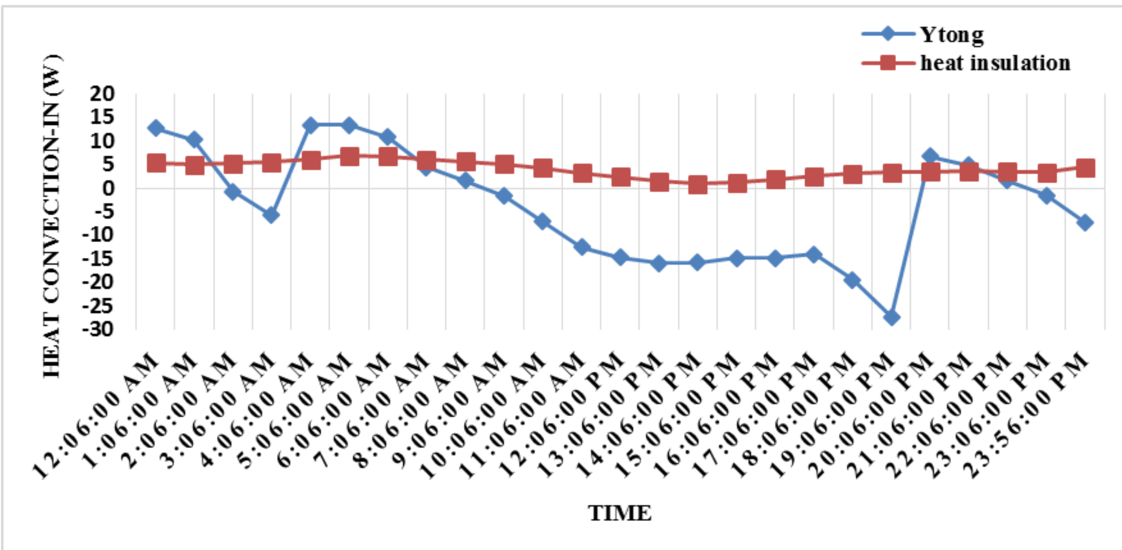

Figure 4.46: Hourly variation of the heat convection in of Y-tong wall and wall insulated

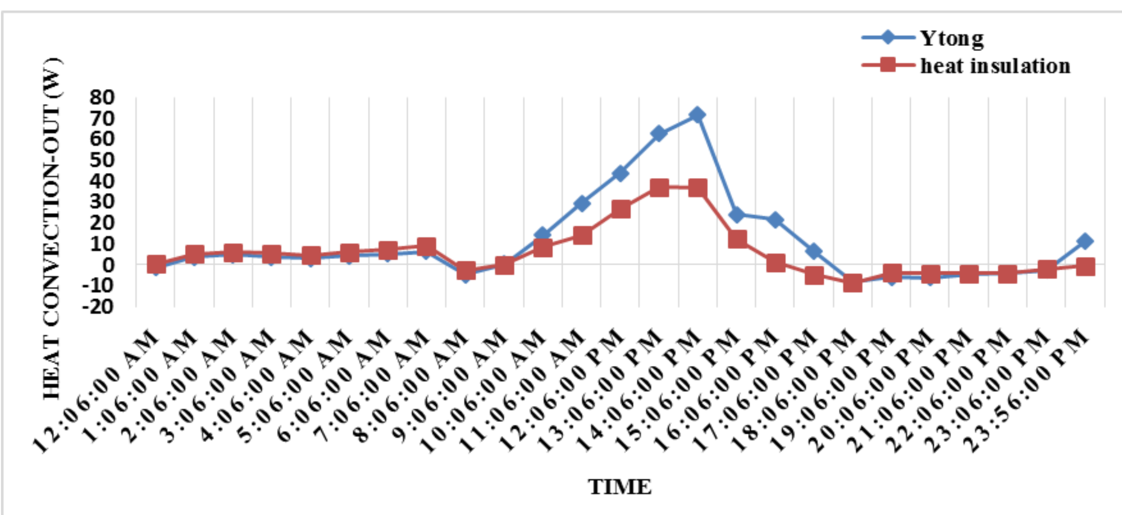

Figure 4.47: Hourly variation of the heat convection out of Y-tong wall and wall insulated

4.16 Heat Radiation Y-tong Wall vs Heat Insulation Wall on 01/01/2016

The Figure 4.48 shown below a comparison of heat radiation between Y-tong wall and heat insulation wall during the time. We noted that y-tong wall has heat radiation greater than of the wall insulated. The reason was material Y-tong absorbed radiation more than stone wool.

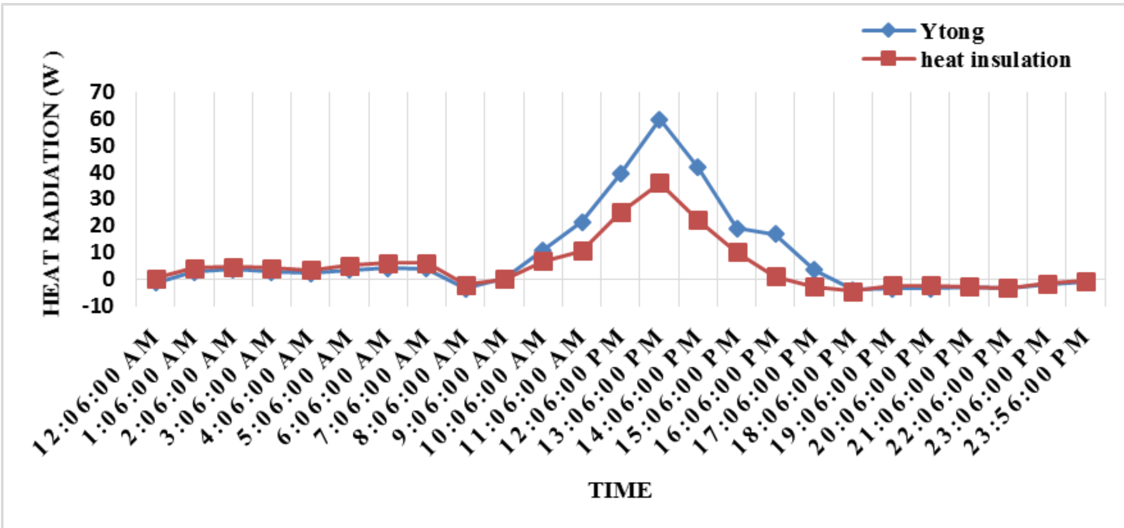

Figure 4.48: Hourly variation of heat radiation of Y-tong wall and wall insulated

4.17 Heat Conduction Y-tong Wall Vs Heat Insulation Wall on 01/01/2016

The Figure 4.49 shown, is a comparison of heat conduction between Y-tong wall and wall insulated during the time .The Y-tong wall had heat conduction greater than wall insulated because the Y-tong conducted more, when compared to stone wool and it depended of the thermal conductivity of material.

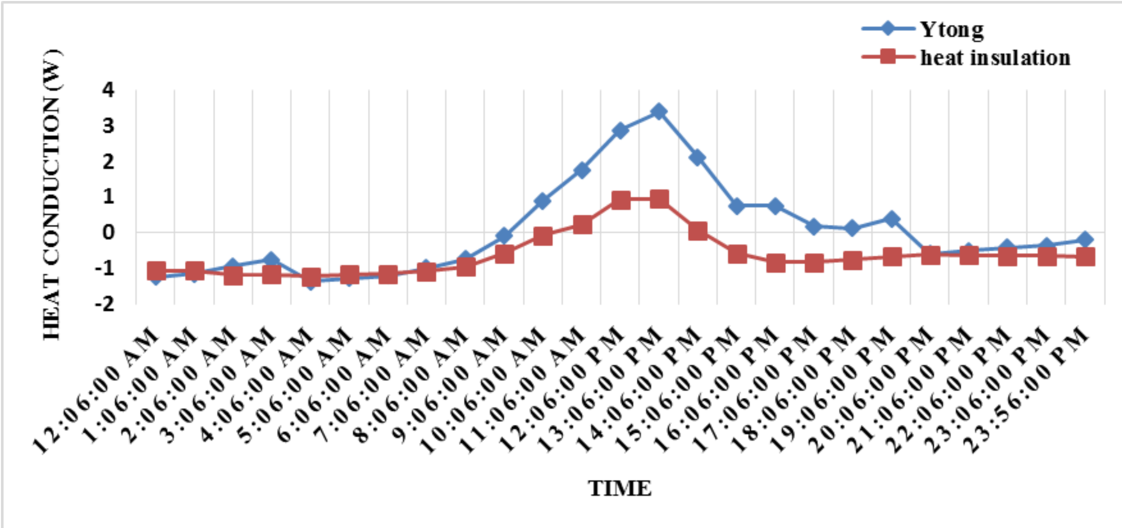

Figure 4.49: Hourly variation of heat conduction of Y-tong wall and wall insulated

4.18 Total Heat Loss and Gain During the Time on 01/01/2016

The Figure 50 shown below is the summary of the results graph above and gives a clear explanations for heat loss and gain of Y-tong wall and wall insulated on 1/1/2016. We noted that Y-tong had heat gain more than heat insulation during the day time and also it had lost more than heat insulation during the night time. The summary of the results from the graph above, and it gives a clear explanations for heat loss and heat gain for Y-tong wall and heat insulated wall. Y-tong wall has heat gain more than the heat insulated wall at the maximum time (during the day) but it also has more heat loss then the insulated wall at minimum time (at night time). This because Y-tong material has a better insulation properties during the day time compared to stone wool. Whereas during the night stone wool had a minimal heat loss led to its superior time lag.

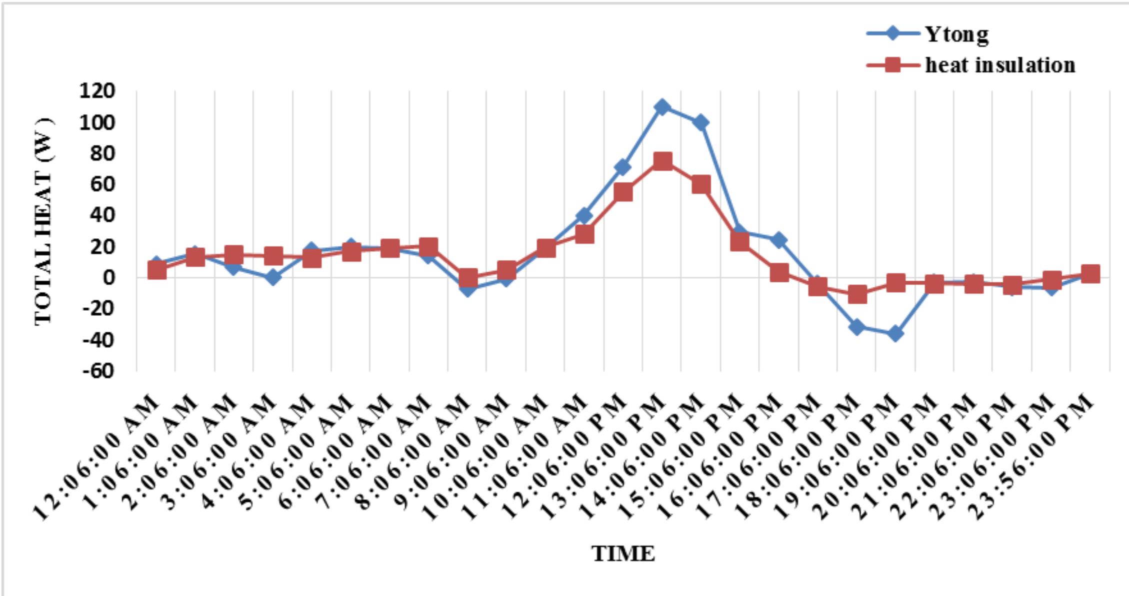

Figure 50: Hourly variation of heat loss and gain of Y-tong wall and wall insulated

CHAPTER 5
CONCLUSION

The increasing demand on energy and decreasing fossil fuel reserves lead us to search an effective way to insulate our houses, schools, hospitals, etc. and to decrease the heat gain and heat loss (winter time). Cyprus has around 340 sunny days per year. The study aimed to find the best type of insulation in Turkish Republic North Cyprus.

The study was conducted in two stages. In the first stage, an insulated room was connected with four T-type thermocouples meteorological daily radiation, wind speed, temperature were studied together to find the heat transferred to the room and from the room, respectively. In the second stage, a Y-tong room was studied using the same variables taken by the on-site experiment.

In the experimental study, a two model building called L1 and L2 were built. At the initial stage, Room L1 consisted of four side facing: North, East, and West which contained the same materials insulation for heat stone wool, block of concrete, and plaster gypsum (outside and inside of the three walls). South face contains cement concrete (inside and outside of wall) and in the middle of Y-tong.

Room L2 consisted of four side facing: North, East, West and South. The (North, East, West) contained insulation for heat stone wool, block of concrete, and plaster gypsum (outside and inside of the walls). South face contains plaster gypsum (outside and inside of the wall), insulation for heat stone wool and at the middle blocks of hollow brick clay.

The results of the experiments have shown that, considering the two model building when exposed to thermal radiation, model L1 Y-tong wall has greater heat radiation than the heat insulated wall. Y-tong wall took more thermal radiation. So, the reason was that their insulation value and their impact on energy consumed vary. Y-tong bricks have a more preferred thermal quality compared to heat insulated wall during the period of intense heat or solar radiation. However, Y-tong material had greater thermal conductivity than heat insulation and stone wool, which has higher heat coefficient than Y-tong material.

Model L1 (Y-tong wall) has greater heat conduction compared to thermal insulated at a specific rate. Also, fluid and wind velocity have an effect on the outer surface of the wall.

Meanwhile, heat convection ($Q_{\text{Con-in}}$) of Y-tong varied within the specified days, but heat convection ($Q_{\text{Con-in}}$) of wall insulated had approximately constant value. This was because the difference in temperature inside the room and in the inner wall surface was changed during the time. Heat coefficient transfer rate at the vertical wall was constant on inner surface because there was still air inside, when h = 8.3w/k.m^2. In addition, it has been noted that the total heat of Y-tong wall was greater than that of total heat of wall insulated at the maximum time. Again, at the day time, heat conduction for Y-tong was greater than the heat conduction of heat insulated wall. Therefore, the process of heat conduction depends on four basic factors: the temperature gradient, the cross section of the materials involved, their path length, and the properties of those materials. At the maximum point, heat conductivity was high temperature, increase energy, and molecules contact between materials. Whereas at minimum was heat conduction was at lowest point as a result of minimal or absence of energy between materials.

As a result of sunset, there is no thermal radiation at the outer surface during the night time, therefore, the two model wall L1 and L2 has same heat convection. Whereas Y-tong wall has a varied heat convection at the inner surface while the heat convection of heat insulated wall at the inner surface remained approximately constant.

The wall insulated is good for night time and Y-tong wall is good for day time during the winter season, in general case the Ytong wall is better than heat insulated wall during the day because the Ytong wall has heat gain more than heat insulation per day. Insulation aims at reducing the speed of this convergence of temperature in order to decrease the need for heating or cooling.

Finally, for the future work we need to choose good insulation which can reduce the heat loss in buildings in cold weather and also it against heat loss during the winter with a economical insulation. In addition, further work is suggested on the comparative study between different wall systems and their efficiency in reducing heat loss and gain at when appropriate, then the introduction of advance insulation materials the use of cork as an insulation material to insulate a building. A work that could show the thermal performance of heat and water insulation for building wall during summer can as well be considered in the long future.

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APPENDICES

APPENDIX A

METEOROLOGICAL DATA (NICOSIA-2015)

Monthly solar radiation average values data (cal/cm^2)

January	221.4
February	289.2
March	408.3
April	548.2
may	604.6
June	661.4
July	674.4
August	599.6
September	476.1
October	347.1
November	282.2
December	277.6

APPENDIX A1

METEOROLOGICAL DATA (NICOSIA-2015)

Daily solar radiation average values data (cal/cm^2)

DAYS	OCTOBER	NOVEMBER	DECEMBER
1	295.0	372.0	297.9
2	290.1	389.0	271.5
3	427.4	386.4	305.6
4	466.4	248.7	305.1
5	462.3	276.9	298.6
6	398.1	263.5	303.1
7	392.3	303.4	200.3
8	368.1	328.5	290.9
9	461.9	323.0	277.9
10	455.0	355.2	234.9
11	384.8	351.1	241.8
12	422.9	334.2	107.9
13	388.0	333.4	241.0
14	405.9	338.0	275.6
15	389.4	139.1	245.3
16	412.6	247.4	180.7
17	421.4	292.5	71.0
18	360.0	317.1	88.5
19	364.3	323.3	141.2
20	419.0	311.8	271.7
21	372.5	273.2	250.0
22	166.8	309.1	268.1
23	180.2	311.8	277.9
24	204.8	316.3	286.7
25	202.2	256.2	271.4
26	257.9	233.1	105.7
27	360.1	157.7	240.5
28	247.1	250.3	265.9
29	148.8	221.4	254.5
30	269.3	178.1	143.5
31	357.4		126.6

APPENDIX B

METEOROLOGICAL DATA (NICOSIA-2015)

Monthly average temperature values data (^{o} C)

January	10.9
February	11.3
March	14.1
April	15.8
may	21.2
June	23.8
July	27.6
August	29
September	26.8
October	22.6
November	17.9
December	13

APPENDIX B1

METEOROLOGICAL DATA (NICOSIA, OCT, NOV, DEC, 2015)

Daily average temperature values data (^{o}C)

DAYS	OCTOBER	NOVEMBER	DECEMBER
1	24.5	20.6	14.2
2	25.0	20.2	14.7
3	25.2	20.1	11.9
4	24.6	20.2	11.4
5	23.5	20.5	10.3
6	22.8	19.3	12.0
7	22.2	19.4	14.4
8	21.4	19.0	14.1
9	22.5	18.3	14.4
10	23.1	16.3	14.1
11	24.1	16.4	14.1
12	24.5	17.9	12.3
13	22.9	18.5	14.4
14	22.2	19.2	13.4
15	22.8	18.0	13.5
16	23.8	18.9	13.7
17	24.2	18.3	12.5
18	23.6	16.8	12.8
19	23.3	16.7	11.8
20	22.5	16.7	12.8
21	22.6	16.2	12.9
22	21.8	17.2	12.4
23	23.3	16.8	12.7
24	21.4	17.5	14.0
25	19.3	16.5	13.4
26	18.7	18.2	13.9
27	20.0	16.5	14.0
28	18.8	16.1	14.2
29	18.7	16.2	13.6
30	19.4	13.9	11.5
31	20.3		6.4

APPENDIX C

METEOROLOGICAL DATA (NICOSIA, OCT, NOV, DEC-2015)

Daily wind velocity average values data (m/s)

Days	Nov	Dec	JAN
1	4.1	2.4	8.0
2	4.9	4.7	10.5
3	4.9	6.2	10.5
4	4.8	4.1	9.5
5	3.9	4.5	13.5
6	2.3	3.4	11.0
7	2.7	2.3	11.0
8	4.4	2.2	10.0
9	2.5	1.8	
10	3.8	2.1	
11	2.2	2	
12	2.5	3	
13	2.8	4.7	
14	2.5	2.8	
15	1.7	1.6	
16	2.5	2.1	
17	2.5	3	
18	2.7	3.6	
19	2.5	2.2	
20	2.1	2.2	
21	2.1	2.3	
22	3.5	2.3	
23	2.3	3	
24	2.2	2.7	
25	2.6	2.7	
26	2.9	1.6	
27	2	2.5	
28	1.8	2.6	
29	4.5	3.3	
30	2.3	3.6	
31		3.8	

APPENDIX D

THE PROPERTIES OF AIR AT 1 ATM AND THE FILM TEMPERATURE

(Calculated in the present study)

Temp (C)	density	thermal conductivity	kinematic viscosity	dynamic viscosit	Pr
0	1.292	0.02364	0.00001338	0.00001729	0.7362
5	1.269	0.02401	0.00001382	0.00001754	0.735
10	1.246	0.02439	0.00001426	0.00001778	0.7336
15	1.225	0.02476	0.0000147	0.00001802	0.7323
20	1.204	0.02514	0.00001516	0.00001825	0.7309
25	1.184	0.02551	0.00001562	0.00001825	0.7296
30	1.164	0.02588	0.00001608	0.00001849	0.7282
35	1.145	0.02625	0.00001655	0.00001872	0.7268
40	1.125	0.026065	0.000017	0.00001895	0.7282

T∞	T surf(ou	Tf	V ∞(Wind Velocity)	ρ	K (thermal conductivit	υ (kinematic viscosity)	Dynamic viscosit	Pr
18	25.56	21.78	1.7	1.1969	0.02527172	1.53238E-05	0.00001825	0.7304
18.9	46.59	32.745	2.5	1.1536	0.02608313	1.6338E-05	1.86163E-05	0.7274
18.3	48.84	33.57	2.5	1.1504	0.02614418	1.64156E-05	1.86542E-05	0.7272
16.8	54.1	35	2.7	1.145	0.02625	0.00001655	0.00001872	0.7268
16.7	55.54	36.12	2.5	1.1405	0.02620856	1.66508E-05	1.87715E-05	0.7271
16.7	54.5	35.6	2.1	1.1426	0.0262278	0.000016604	1.87476E-05	0.727
16.2	53.12	34.66	2.1	1.1463	0.02622484	1.6518E-05	1.87044E-05	0.7269
17.2	48.3	32.75	3.5	1.1536	0.0260835	1.63385E-05	1.86165E-05	0.7274
16.8	54.94	35.87	2.3	1.1415	0.02621781	1.66283E-05	1.876E-05	0.727
17.5	56.52	37.01	2.2	1.137	0.02617563	1.67309E-05	1.88125E-05	0.7274
16.5	45.87	31.185	2.6	1.1595	0.02596769	1.61914E-05	1.85445E-05	0.7279
18.2	45.38	31.79	2.9	1.1572	0.02601246	1.62483E-05	1.85723E-05	0.7277
16.5	50.33	33.415	2	1.151	0.02613271	1.6401E-05	1.86471E-05	0.7272
16.1	48.15	32.125	1.8	1.1559	0.02603725	1.62798E-05	1.85878E-05	0.7276
16.2	44.42	30.31	4.5	1.1628	0.02590294	1.61091E-05	1.85043E-05	0.7281
13.9	45.9	29.9	2.3	1.1644	0.0258726	1.60708E-05	1.84852E-05	0.7282
14.2	52.15	33.175	2.4	1.1519	0.02611495	1.63785E-05	1.86361E-05	0.7273
14.7	45.14	29.92	4.7	1.1643	0.02587408	1.60726E-05	1.84862E-05	0.7282
11.9	42.75	27.325	6.2	1.1747	0.02568205	1.58339E-05	1.83616E-05	0.7289
11.4	45.11	28.255	4.1	1.171	0.02575087	1.59195E-05	1.84062E-05	0.7287
10.3	43.17	26.735	4.5	1.1771	0.02563839	1.57796E-05	1.83333E-05	0.7291
12	45.8	28.9	3.4	1.1684	0.0257986	1.59788E-05	1.84372E-05	0.7285
14.4	52.67	33.535	2.3	1.1506	0.02614159	1.64123E-05	1.86526E-05	0.7272
14.1	53.07	33.585	2.2	1.1504	0.02614529	1.6417E-05	1.86549E-05	0.7272
14.4	52.16	33.28	1.8	1.1515	0.02612272	1.63883E-05	1.86409E-05	0.7273
14.1	47.75	30.925	2.1	1.1605	0.02594845	1.6167E-05	1.85326E-05	0.7279
14.1	48.01	31.055	2	1.16	0.02595807	1.61792E-05	1.85385E-05	0.7279
12.3	16.98	14.64	3	1.2265	0.02473336	1.46683E-05	1.80027E-05	0.7324
14.4	39.33	26.865	4.7	1.1765	0.02564801	1.57916E-05	1.83395E-05	0.7291
13.4	49.96	31.68	2.8	1.1576	0.02600432	1.62379E-05	1.85673E-05	0.7277
13.5	46.59	30.045	1.6	1.1638	0.02588333	1.60842E-05	1.84921E-05	0.7282
13.7	34.46	24.08	2.1	1.1877	0.02544192	1.55354E-05	0.00001825	0.7298
12.5	17.71	15.105	3	1.2246	0.02476798	1.47097E-05	1.80248E-05	0.7323
12.8	29.21	21.005	3.6	1.2	0.02521437	1.52525E-05	0.00001825	0.7306

APPENDIX E

PROPERTIES OF BUILDING MATERIALS (Delhi, 2008)

Material	Density (kg/m^3)	Specific heat (kJ/kg-K)	Thermal conductivity (W/m-K)
Burnt brick	1820	0.88	0.811
Mud brick	1731	0.88	0.750
Dense concrete	2410	0.88	1.740
RCC	2288	0.88	1.580
Limestone	2420	0.84	1.800
Slate	2750	0.84	1.720
Reinforced concrete	1920	0.84	1.100
Brick tile	1892	0.88	0.798
Lime concrete	1646	0.88	0.730
Mud phuska	1622	0.88	0.519
Cement mortar	1648	0.92	0.719
Cement plaster	1762	0.84	0.721
Cinder concrete	1406	0.84	0.686
Foam slag concrete	1320	0.88	0.285
Gypsum plaster	1120	0.96	0.512
Cellular concrete	704	1.05	0.188
AC sheet	1520	0.84	0.245
GI sheet	7520	0.50	61.060
Timber	480	1.68	0.072
Plywood	640	1.76	0.174
Glass	2350	0.88	0.814
Sand	2240	0.84	1.740
Expanded polystyrene	34	1.34	0.035
Foam glass	160	0.75	0.055
Foam concrete	704	0.92	0.149
Rock wool (unbonded)	150	0.84	0.043
Mineral wool (unbonded)	73.5	0.92	0.030
Glass wool (unbonded)	189	0.92	0.040
Resin bonded mineral wool	99	1.00	0.036
Resin bonded glass wool	24	1.00	0.036
Asbestos mill board	1397	0.84	0.249
Hard board	979	1.42	0.279
Straw board	310	1.30	0.057
Soft board	249	1.30	0.047
Wall board	262	1.26	0.047
Chip board	432	1.26	0.067
Particle board	750	1.30	0.098
Coconut pith insulation board	520	1.09	0.060
Jute fibre	329	1.09	0.067

Wood wool board (bonded with cement)	674	1.13	0.108
Coir board	97	1.00	0.038
Saw dust	188	1.00	0.051
Rice husk	120	1.00	0.051
Aluminium Composite panels (Alucopan – 150)*	150	0.902	0.060
Face bricks*	2083	1.004	1.30
Polycarbonate sheet*	1350	1.17	0.21
Fly ash brick*	1570	0.8	0.54 to 0.70
Fibre reinforced plastic (FRP) sheet (Durostone standard)*	1850	0.96	0.260
Polyurethane foam (PUF)*	30	1.570	0.026
Polyvinyl chloride sheet*	1350	1.255	0.160
Cork tile*	540	1.00	0.085
Plastic tile*	1050	1.07	0.50
PVC asbestos tile*	2000	1.00	0.85
Gypsum plasterboard*	950	0.82	0.16
Brown cellulose fibres*	37-51	1.35	0.045
Thatch (reed)*	270	1.00	0.09
Thatch (straw)*	240	1.00	0.07
Acoustic tile*	290	1.34	0.058

APPENDIX F

VALUES OF SURFACE HEAT TRANSFER COEFFICIENT (Delhi, 2008)

Serial No.	Wind Speed	Position of Surface	Direction of Heat Flow	Surface Heat Transfer Coefficient (W/m^2-K)
1.	Still air	Horizontal	Up	9.3
		Sloping 45^o	Up	9.1
		Vertical	Horizontal	8.3
		Sloping 45^o	Down	7.5
		Horizontal	Down	6.1
2.	Moving air 12 (km/h)	Any position	Any direction	22.7
	Moving air 24 (km/h)	Any position	Any direction	34.1