Sudan University of Science and Technology

Collage of Engineering

Mechanical Engineering

Study the Effect of Thermal Insulation Materials on TheBuildingsupon Air Conditioning System

دراسة تأثير العوازل الحرارية في المباني على أجهزة التكييف

A Project Submitted In Partial Fulfillment for the Requirement of the Degree of B.Eng (HONOR) In Mechanical Engineering

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October 2017

الاية

قال تعالي:

" اللَّهُ نُورُ السَّمَاوَاتِ وَالْأَرْضِ مَثَلُ نُورِهِ كَمِشْكَاةٍ فِيهَا مِصْبَاحٌ الْمِصْبَاحُ فِي زُجَاجَةٍ الزُّجَاجَةُ كَأَنَّهَا كَوْكَبٌ دُرِّيٌّ يُوقَدُ مِنْ شَجَرَةٍ مُبَارَكَةٍ زَيْتُونَةٍ لَا شَرْقِيَّةٍ وَلَا غَرْبِيَّةٍ يَكَادُ زَيْتُهَا يُضِيءُ وَلَوْ لَمْ تَمْسَسْهُ نَارٌ نُورٌ عَلَى نُورٍ يَهْدِي اللَّهُ لِنُورِهِ مَنْ يَشَاءُ وَيَضْرِبُ اللَّهُ الْأَمْثَالَ لِلنَّاسِ وَاللَّهُ بِكُلِّ شَيْءٍ عَلِيمٌ (35)"

النور {35}

DEDICATION

To my inspiring and wonderful parents, brothers and sisters, for being the pillows, role models, cheerleading squad and sounding boards, I have needed. Special words to my hero my father, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to the phenomenal and superwoman, to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time

To my uncles, aunts and beloved friends, and at lastly specialdonationfor myinstructed, lover and granular the prophet Mohammedpeace and blessings of Allah be upon himwho taught me and set to mepathwaymap to the salvation.

ACKANOWLAGE

First and above all, we praise God, the most beneficent, the most merciful, for granting us the capability to succeed. This research would not have been possible without the assistance and guidance of several people. We would therefore like to offer our sincere gratitude and thanks to them all.

We would like to give our warmest and most sincere gratitude to our supervisor Dr.EihabAbdelraouf who throughout the duration of our Project has provided us with invaluable guidance, experience and support to enable us to successfully complete our Project.. We would like to thank our University for providing us a good environmental operation to our study. At last we want to thank our families for pray to us and support.

And we prorate many thanks and acknowledgement for all of who help in modestwork, starting with our helpersupervisorto all dispersions professoriate in section ofmechanicalengineering

And we ask your god to bless on this fine effort, and the

god owner of the adjustment

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ABSTRACT

Thermal loads have been measured for a sample Hall (1)from Sudan University of Science and Technology, based on mathematical models and HAP software.

The measurement was based on comparison when without any thermal insulation material used in the wall and roof, and use one of material from three difference of thermal insulation(10cm thickness) in wall and roof (Extruded polystyrene material, Spray polyurethane material, Air cavity) .

The decremental has been calculated wall load and roof load which led to decrease in annual operational cost, and results are shown below:

- The first once (without any thermal insulation material), the thermal load was 166.76Kw.
- The second once (Extruded polystyrene), the difference in thermal load was 53.9Kw, which led to decrease in annual operational cost with percentage (32.32%) out of total annual operational cost.
- The third once (Spray polyurethane), the difference in thermal load was 56Kw, which led to decrease in annual operational cost with percentage (33.58%) out of total annual operational cost.
- The fourth once (Air cavity), the difference in thermal load was 28.24 Kw, which led to decrease in annual operational cost with percentage (16.99%) out of total annual operational cost.

المستخلص

تم حساب الحمل الحراري لعينة (القاعة 13) من جامعة السودان للعلوم والتكنولوجيا , وذلك باستخدام العلاقات الرياضية واستخدام برنامج الهاب . قامت الحسابات على المقارنة بين الحمل الحراري عندما تكون العينة بدون مادة عازلة حرارية في الحائط والسقف مرة واستخدام مادة في كل مرة من ثلاثة عوازل حرارية (سمك 10سم) في الحائط وفي السقف (مادة البولسترين الممدد, مادة رغاوي البولي إريسان, فراغ هواء) حيث تم حساب النقصان في حمل الحائط وحمل السقف والذي ادى الى النقصان في التكلفة التشغيلية السنوية وكانت النتائج عبارة عن الاتي :-

- المرة الاولى (بدون مادة عازلة للحرارة) كان الحمل الحراري 166.76 كيلوات

- المرة الثانية (مادة البولسترين الممدد) كان الفرق في الحمل الحراري 53.9 كيلوات مما ادى الى نقصان التكلفة التشغيلية بنسبة32.32% من التكلفة التشغيلية السنوية.

- المرة الثالثة (مادة رغاوي البولي إريسان) كان الفرق في الحمل الحراري 56 كيلوات مما ادى الى نقصان التكلفة التشغيلية بنسبة 33.58% من التكلفة التشغيلية السنوية.

- المرة الرابعة (فراغ هواء) كان الفرق في الحمل الحراري 28.34 كيلوات مما ادى الى نقصان التكلفة التشغيلية بنسبة 16.99% من التكلفة التشغيلية السنوية.

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LIST OF SYMBOLS:

Symbols	Meaning
Q_{Trans}	Heat transfer through, walls, roof, floor.
U	the overall heat transfer coefficient
A	The heat transfer area of the surface on the side of the conditioned space.
ΔT	temperature difference
CLTD	Cooling Load Temperature Difference
K	corrected factor color of wall
LM	corrected factor due longitude, latitude
Q_w	Heat transfer through a windows and doors
$SHGF_{max}$	Solar Heat Gain Factor Max
SC	Shading Coefficient
CLF	cooling load factor
m_{inf}	amount of air infiltration
m_{ven}	amount of air ventilation
V_a	air velocity
V	volume of building
P	density of air
c_{pa}	the average specific heat of moist air
ω_o	outdoor humidity ratios
ω_i	indoor humidity ratios
h_{fg}	the latent heat of vaporization of water
H_s	Sensible heat gain per person.
H_L	Latent heat gain per person.
N_p	Number of people.
H	Efficiency

CHAPTER ONE

INTRODUCTION

1.1 Introduction:

Air conditioning is a very important process that is used in industrial areas, commercial areas, residential areas, etc.
The purpose of air conditioning is to provide a comfortable temperature for human beings and machines and equipment to be protected.

Air conditioning can either be for cooling or heating. This project is used the Thermal Insulation Materials in the building for retard the flow of heat energy, there are three type of insulation is used called polystyrene, Polyurethane, air cavity, thermal insulations can serve one or more of the following thermal functions such as Conserve energy by reducing heat loss or gain of equipment, and structures also Control surface temperatures of equipment and structures for personnel protection and comfort.

Thermal insulation can serve additional functions, although such secondary functions should be consistent with its capabilities and primary purpose. Add structural strength to a wall, ceiling, or floor section also Impede water vapor transmission and air infiltration, Prevent or reduce damage to equipment and structures from exposure to fire and freezing conditions.[1]

1.2 Problem Statement:

Reducing the heat load to as much as possible and conservation the air coolness for along time by using thermal insulation materials in the building also reduce heat transfer between inside and outside which decrease the consumption of power.

1.3 Objective:

- The study ofthe effect of thermal insulation materials in the buildings for air conditioning systems.
- Calculate the thermal load manually.
- Calculate the thermal load by HAP application.

1.4 Significant of Study:

The importance of this research and its essence in preserving the energy and money, Where use the thermal insulation materials in wall and roof ,Which result in decrease the rate of operating air conditioningunits and increase the life of unit.

1.5 Scope of Study:

The scope of this project is to study the different between three of thermal insulation materials (Polystyrene – Polyurethane – air cavity) and effectiveness on air conditioning systems The thermal load is calculated by manually and using simulation software (HAP) for three insulation materials and without thermal insulate and comparing with them.

CHATER TWO

LITERATURE REVIEW

2.1 Literature Review:

2.1.1 Introduction:

The Thermal Insulation Materials decrease the thermal load of the building and a result increase the air conditioningunit life, Control temperature of inside surfaces also conserve energy by reducing heat transmission through building sections.

2.2 Thermal Load Calculation:

The accurate calculation of heating and cooling loads is essentialto provide a sound bridge between fundamental building designdecisions and an operating building. If loads are substantiallyunderestimated, occupants and users will likely be hot or cold. Ifloads are substantially overestimated, equipment will be oversized(usually wasting money, reducing efficiency,increasing energy consumption,and often imperiling comfort). Accurate load calculationsare an important part of the design process. This importance isunderscored by the constant evolution of load calculation methodologies—which has steadily made load calculations more complex, less intuitive, and more dependent upon computers [1].

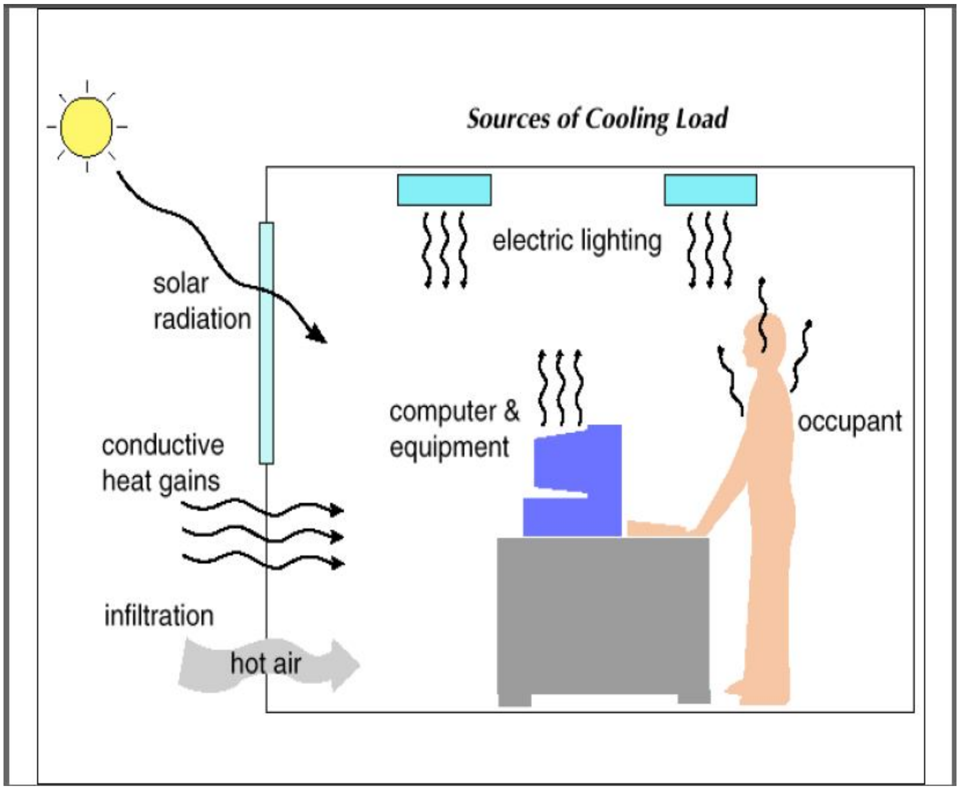

Figure2-1: Thermal loads of building

2.2.1 Outdoor and Indoor Design Conditions:

Before performing heating and cooling load calculations, the designer must establish appropriate outdoor and indoor design conditions. Outdoor conditions can be obtained from the "Climatic Design Information" chapter in the ASHRAE Handbook—Fundamentals (and an accompanying CD). Design conditions specified by Standard 90.1 are the 99.6% and 1% values for heating and cooling, respectively. For special projects or spaces where precise control of indoor temperature and humidity is required, other design values may be more appropriate.

Indoor design conditions are governed either by thermal comfort conditions or by special requirements for materials or processes housed in a space. In most buildings, such as offices and residences, thermal comfort is the only requirement, and small fluctuations in both temperature and humidity within the comfort zone are not objectionable. In other occupancies, however, more precise control of temperature and humidity may be required; refer to the appropriate chapter in the ASHRAE Handbook—HVAC Applications for recommendations. Standard 55 provides guidance on appropriate winter and summer indoor design conditions. State or local energy codes and particular owner requirements may also affect the establishment of criteria for indoor design conditions [1].

2.2.2 External Loads:

External loads are highly variable, both by season and by time of day. They cause significant changes in the heating and cooling requirements over time, not only in the perimeter building spaces, but for the total building heating/cooling plant.

2.2.2.1 Heat Transfer through Opaque Surfaces:

This is a sensible heat transfer process. The heat transfer rate through opaque surfaces such as walls, roof, floor, doors etc is given by Eq(3-1).

For sunlit surfaces, CLTD has to be obtained from the CLTD tables. Adjustment to the values obtained from the table is needed if actual conditions are different from those based on which the CLTD tables are prepared.

For surfaces which are not sunlit or which have negligible thermal mass (such as doors), the CLTD value is simply equal to the temperature difference across the wall or roof. For example, for external doors the CLTD value is simply equal to the difference between the design outdoor and indoor dry bulb temperatures, Tout-Tin. For interior air conditioned rooms surrounded by non-air conditioned spaces, the CLTD of the interior walls is equal to the temperature difference between the surrounding non-air conditioned space and the conditioned space. Obviously, if an air conditioned room is surrounded by other air conditioned rooms, with all of them at the same temperature, the CLTD values of the walls of the interior room will be zero. Estimation of CLTD values of floor and roof with false ceiling could be tricky. For floors standing on ground, one has to use the temperature of the ground for estimating CLTD. However, the ground temperature depends on the location and varies with time. ASHRAE suggests suitable temperature difference values for estimating heat transfer through ground. If the floor stands on a basement or on the roof of another room, then the CLTD values for the floor are the temperature difference across the floor (i.e., difference between the temperature of the basement or room below and the conditioned space). This discussion also holds good for roofs. the U value may be obtained by assuming the false ceiling to be an air space.

However, the CLTD values obtained from the tables may not exactly fit the specific roof. Then one has to use his judgment and select suitable CLTD values [1].

2.2.2.2 Heat Transfer through Fenestration:

Heat transfer through transparent surface such as a window, includes heat transfer by conduction due to temperature difference across the window and heat transfer due to solar radiation through the window. with CLTD being equal to the temperature difference across the window and A equal to the total area of the window.

The sun shaded area has to be obtained from the dimensions of the external shade and solar geometry. SHGFmax and SC are obtained from ASHRAE tables based on the orientation of the window, location, month of the year and the type of glass and internal shading device.

The Cooling Load Factor (CLF) accounts for the fact that all the radiant energy that enters the conditioned space at a particular time does not become a part of the cooling load1 instantly. As solar radiation enters the conditioned space, only a negligible portion of it is absorbed by the air particles in the conditioned space instantaneously leading to a minute change in its temperature. Most of the radiation is first absorbed by the internal surfaces, which include ceiling, floor, internal walls, furniture etc. Due to the large but finite thermal capacity of the roof, floor, walls etc., their temperature increases slowly due to absorption of solar radiation. As the surface temperature increases, heat transfer takes place between these surfaces and the air in the conditioned space. Depending upon the thermal capacity of the wall and the outside temperature, some of the absorbed energy due to solar radiation may be conducted to the outer surface and may be lost to the outdoors. Only that fraction of the solar radiation that is transferred to the air in the conditioned [1].

2.2.2.3 Heat Transfer Due to Infiltration:

Heat transfer due to infiltration consists of both sensible as well as latent components.

The infiltration rate depends upon several factors such as the tightness of the building that includes the walls, windows, doors etc and the prevailing wind speed and direction. As mentioned before, the infiltration rate is obtained by using either the air change method or the crack method.

Semi-empirical expressions have been obtained for evaluating pressure

Difference due to wind and stack effects as functions of prevailing wind velocity and direction, inside and outside temperatures, building dimensions and geometry etc. Representative values of infiltration rate [1].

2.2.2.4 Ventilation Load:

The outdoor air ventilation load does not have a direct impact on the conditioned space (except when provided via open windows), but it does impose a load on the HVAC&R equipment. Outdoor air is normally introduced through the HVAC system and adds a load (sensible and latent) to the heating and cooling coils, thus affecting their sizing and selection. The amount of ventilation depends upon the occupancy and function of each space. Refer to Standards 62.1 and 62.2 for recommended ventilation rates; see also the requirements of the local building, mechanical, and energy codes [1].

2.2.2.3 Solar Heat Gain through Glazing:

Solar radiation often represents a major cooling load and is highly variable with time and orientation. Careful analysis of heat gains through windows, skylights, and glazed doors is imperative.

Facade self-shadowing, adjacent building shadowing, and reflections from the ground, water, snow, and parking areas must be considered in the loads analysis. Spaces with extensively glazed areas must be analyzed for occupant comfort relative to radiant conditions.

Supply air for cooling must enter such spaces in a manner that will offset the potential for warm glass surfaces or otherwise provide adequate cooling to offset mean radiant temperature effects. Exterior or interior shading devices to keep direct solar radiation from falling on occupants should be considered. Close coordination between the architect and HVAC engineer is critical in buildings with extensive glazing[1].

2.2.3 Internal Load:

While external loads can be heat gains or heat losses, internal loads are always heat gains.

The internal loads consist of load due to occupants, due to lighting, due to equipment and appliances and due to products stored or processes being performed in the conditioned space [1].

2.2.3.1 Load Due to Occupants:

The internal cooling load due to occupants consists of both sensible and latent heat components. The rate at which the sensible and latent heat transfer take place depends mainly on the population and activity level of the occupants [1].

2.2.3.2 Load Due to Lighting:

Lighting adds sensible heat to the conditioned space. Since the heat transferred from the lighting system consists of both radiation and convection, a Cooling Load Factor is used to account for the time lag.

The usage factor accounts for any lamps that are installed but are not switched on at the time at which load calculations are performed. The ballast factor takes into account the load imposed by ballasts used in fluorescent lights. A typical ballast factor value of 1.25 is taken for fluorescent lights, while it is equal to 1.0 for incandescent lamps. The values of CLF as a function of the number of hours after[1].

2.2.3.3 Internal Load Due to Equipment and Appliances:

The equipment and appliances used in the conditioned space may add both sensible as well as latent loads to the conditioned space. Again, the sensible load may be in the form of radiation and/or convection [1].

2.3 Type of Air Condition

2.3.1 Window Type:

The type of Window air conditioners are one of the most commonly used and cheapest type of air conditioners .Window air conditioners are comprised of components like the compressor, condenser, expansion valve or expansion coil, and the evaporator or the cooling coil, all housed in a single box. There is also a motor which has shafts on both sides. On one side of the shaft the blower is connected, which sucks hot air from the room and blows it over the cooling coil, thus cooling it and sending it to the room. On the other shaft the fan is connected, which blows the air over Freon gas passing through the condenser.

One of the complaints that window air conditioners have had is that they tend to make noise inside the room. But this problem has been greatly overcome by the present day efficient and less noisy rotary compressors, which also consume less electricity. Today a number of fancy and elegant looking models of window air conditioners are available that enhance the beauty of your rooms [2].

Figure 2.2: Window type

2.3.2 Split Type:

Split air conditioners are used for small rooms and halls, usually in places where window air conditioners cannot be installed. However, these days many people prefer split air conditioner units even for places where window air conditioners can be fitted.

The split air conditioner can be installed in rooms and offices where you don't want to disturb the setup of the room and avoid demolitions in your favorite space. The split air conditioner takes up a very small space of your room, looks aesthetically cool and makes very little noise, ensuring sound sleep for you when you return from your day's hard work [2].

Figure 2.3: spilt type

2.3.3 Central Type:

The central air conditioning plants or the systems are used when large buildings, hotels, theaters, airports, shopping malls etc are to be air conditioned completely. The window and split air conditioners are used for single rooms or small office spaces. If the whole building is to be cooled it is not economically viable to put window or split air conditioner in each and every room. Further, these small units cannot satisfactorily cool the large halls, auditoriums, receptions areas etc.

The chilled is passed via the ducts to all the rooms, halls and other spaces that are to be air conditioned. Thus in all the rooms there is only the duct passing the chilled air and there are no individual cooling coils, and other parts of the refrigeration system in the rooms. What is we get in each room is the completely silent and highly effective air conditions system in the room. Further, the amount of chilled air that is needed in the room can be controlled by the openings depending on the total heat load inside the room.

The central air conditioning systems are highly sophisticated applications of the air conditioning systems and many a times they tend to be complicated. It is due to this reason that there are very few companies in the world that specialize in these systems. In the modern era of computerization a number of additional electronic utilities have been added to the central conditioning systems [2].

2.3.4 Package Air Condition with Water Cooled Condense:

In these package air condition the condenser is cooled by the water. The condenser is of shell and tube type, with refrigerant flowing along the tube side and the cooling water flowing along the shell side. The water has to be supplied continuously in these systems to maintain functioning of the air conditioning system.

In the packaged units with the water cooled condenser, the compressor is located at the bottom along with the condenser (refer the figure below). Above these components the evaporator or the cooling coil is located. The air handling unit comprising of the centrifugal blower and the air filter is located above the cooling coil. The centrifugal blower has the capacity to handle large volume of air required for cooling a number of rooms. From the top of the package air conditioners the duct comes out that extends to the various rooms that are to be cooled [2].

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Figure 2.4: package type

2.3.5 Evaporative Type:

An evaporative cooler (also swamp cooler, desert cooler and wet air cooler) is a device that cools air through the evaporation of water. Evaporative cooling differs from typical air conditioning systems which use vapor-compression or absorption refrigeration cycles. Evaporative cooling works by employing water's large enthalpy of vaporization. The temperature of dry air can be dropped significantly through the phase transition of liquid water to water vapor (evaporation), which can cool air using much less energy than refrigeration. In extremely dry climates, evaporative cooling of air has the added benefit of conditioning the air with more moisture for the comfort of building occupants [5].

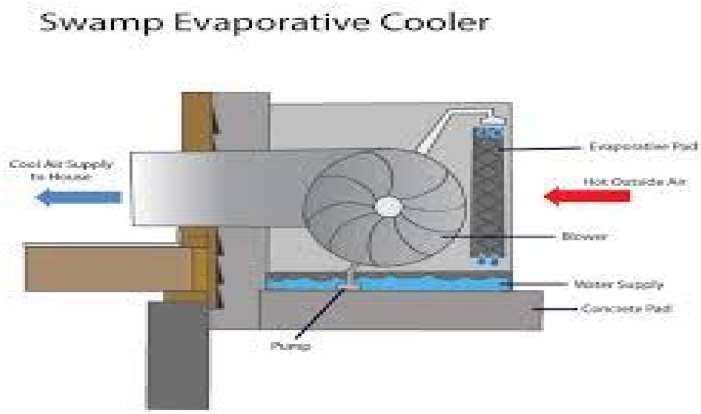

Figure 2.5: evaporator type

2.4 Thermal Insulating Materials:

Heat flows from a higher temperature region to one at lower level of temperature. Hence there is a continuous flow of heat: (1) from the surrounding to the air conditioned space (2) from the heated space to the outside.

Any material that retards or offers resistance to the flow of heat through is known as a thermal insulator. thermal insulation however cannot stop . the heat flow completely but it can only retard or reeduced the rate of heat flow through it by insulating thee walls , ceeiling of air condition space with thermal insulation .

In air condituoing applications however it is not ecnomical to insulate the as advantages derived from it are not much but in case the roof surface temperature attains a much higher temperature than the outside temperature due to direct sun's radiation on the surface therfore, for this reason it is necessary to insulate the exposed roofs even for air condition applications [3].

Classification of thermal insulating material:

2.4.1 Natural insulation materials:

2.4.1.1 COTTON:

Cotton insulation consists of 85% recycled cotton and 15% plastic fibers that have been treated with borate the same flame retardant and insect rodent repellent used in cellulose insulation. One product uses recycled blue jean manufacturing trim waste. As a result of its recycled content, this product uses minimal energy to manufacture.

Cotton insulation is also nontoxic, and you can install it without using respiratory or skin exposure protection. However, cotton insulation costs about 15% to 20% more than fiberglass batt insulation [3].

Figure 2.6: cotton insulation

2.4.1.2 SHEEP’S WOOL:

For use as insulation, sheep's wool is also treated with borate to resist pests, fire, and mold. It can hold large quantities of water, which is an advantage for use in some walls, but repeated wetting and drying can leach out the borate, similar to other fibrous insulation types [3].

Figure 2.7: sheep’s wool insulation

2.4.1.3 STRAW:

Straw bale construction, popular 150 years ago on the Great Plains of the United States, has received renewed interest. Straw bales tested by Oak Ridge National Laboratory yielded, But at least one straw bale expert claims R-value is more representative of typical straw bale construction due to the many gaps between the stacked bales.

The process of fusing straw into boards without adhesives was developed in the 1930s. Panels are usually (5 to 102 mm) thick and faced with heavyweight kraft paper on each side. Although manufacturers claims vary, The boards also make effective sound-absorbing panels for interior partitions. Some manufacturers have developed structural insulated panels from multiple-layered, compressed-straw panels [3].

Figure 2.8: straw insulation

2.4.1.4 HEMP:

Hemp insulation is relatively unknown and not commonly used in the United States. Its similar to other fibrous insulation types [3].

2.4.2 Industrial insulation materials:

2.4.2.1 ExtrudedPolystyrene insulation materials:

polystyrene is a homogeneous product consisting of fine, closed cells containing a mixture of air and an insulating gas also used in other industries as a refrigerant. [2].

Available brands of extruded polystyrene are easily recognized by their colors: blue, pink, green, or yellow.

polystyrene is often referred to by one of its proprietary names (Styrofoam),Styrofoam extruded polystyrene insulation was developed originally by the Dow Chemical Company in the early 1940s as a flotation material in life rafts and life boats.

polystyrene is manufactured by pushing freshly expanded foam through an extrusion die. A number of edge configurations are available, some straight and some with a profile designed to inter lock toensure a continuous thermal break and help to seal the joints between the panels.

polystyrene is used for insulating foundations and concrete slabs, for residing underlayments, and for exterior wall sheathing, for protected membrane roof applications, , It is also installed either on the interior or exterior where space is limited such as cathedral ceilings, flat roofs [3].

Figure 2.9: Extruded polystyrene

2.4.2.2 Polyisocyanurate insulation materials:

Polyisocyanurate rigid insulation is actually a mixture of rigid By incorporating the chemical benefits of both products, and is sometimes referred to as PUR/PIR foam. Other monikers include iso boardand polyiso. Most commonly sold with a shiny foil facer on one or both sides, polyiso foam board rigid insulationhas the highest R-value of any common insulation material.

Although somewhat water resistant, and is not recommended for below-grade applications [3].

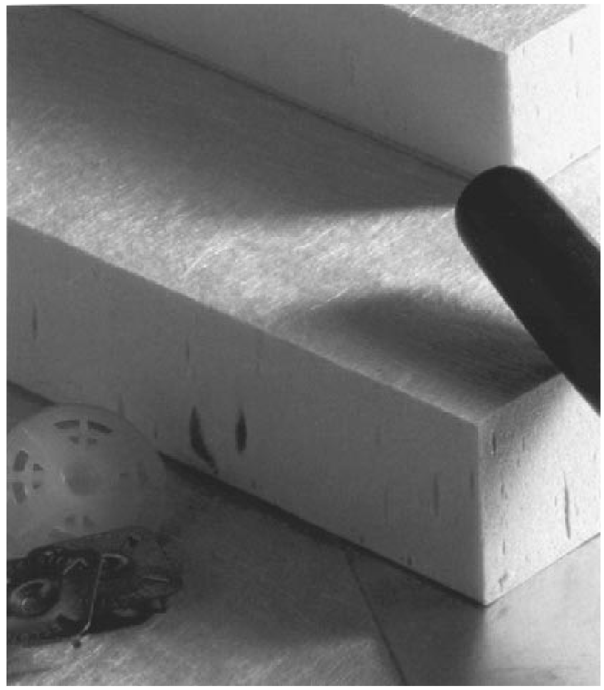

Figure 2.10: Polyisocyanurate rigid insulation

2.4.2.3 Spray Polyurethane Foam:

Foamed-in-place polyurethane foam, typically referred to as spray polyurethane foam, is a closed-cell, higher-R-value foamedplastic insulation that is fabricated by an installer at the home sitefrom two liquid components. Closed-cell foams insulate differentlyfrom conventional mass insulations. For example, a sample ofpolyurethane foam consists of millions of tiny closed plastic cellsfilled with an inert gas. The inert gas resists heat transfer betterthan regular air.

Application equipment allows for the materials to be metered, mixed, and then either sprayed in place or poured into cavities.

Typically used for sealing around windows, doors, etc., it is available in spray cans at just about any hardware or home improvement store [3].

Figure 2.11: polyurethane foam insulation

2.4.2.4 Fiberglass:

Fiberglass loose-fill insulation is available in two forms: processed either from a by-product of manufacturing batts or rolls or from “prime” fibers produced especially for blowing applications.

Both must be applied through pneumatic means using a mechanical blowing machine, whether it be “open blow” applications such as attic spaces or closed-cavity applications such as those found inside walls or covered attic floors.

Fiberglass loose-fill insulation is inorganic and noncombustible [3].

Figure 2.12: Fiberglass insulation

2.4.2.5 Perlite:

perlite is a granular type insulation made from a naturally occurring silicous rock quarried mainly in the western United States Used for low-slope roofing systems, perlite insulation is manufactured as a rigid board that is composed of these expanded volcanic minerals combined with organic fibers and binders the color of expanded perlite ranges from snowy white to grayish white[3].

2.4.2.6 Cementitious insulation material:

Cementitious insulation material is a cement-based foam used as sprayed-foam or foamed-in-placed insulation. One type of cementitious spray foam insulation known as air krete contains magnesium silicate and. With an initial consistency similar to shaving cream, air krete® is pumped into closed cavities. Cementitious foam costs about as much as polyurethane foam, is nontoxic and nonflammable, and is made from minerals (like magnesium oxide) extracted from seawater[3].

2.4.2.7 phenolic foam:

The phenolic foam insulation board industry in both Canada and the United States declined rapidly and essentially disappeared in 1993–1994, Incidents of deck corrosion have been reported in cases where the insulation is in direct contact with steel roof decks and moisture is present, Phenolic foam board products were manufactured from phenol formaldehyde resin as an open- or closed-cell product for several years, a high-R-value phenolic rigid insulation board was on the Market [3].

CHAPTER THREE

METHODOLOGY

3.1Methodology:

The main objective of this project is study of effectiveness the thermal insulation materials on the building for air conditioning units , (13) hall were taken to calculate the thermal load (without thermal insulation materials and use one of them in wall and ceiling) ,and were select three of thermal insulation materials (Polystyrene ,Polyurethane, air cavity) , Calculation of thermal loads was according to an internal and external conditions of the (13) hall according to their location in Khartoum city , where the conditions of the external design of a perfect summer day is to 45 DPT temperature and 26 WPT temperature and Interior design conditions suppose the temperature to the thermal comfort 24 DPT and relative humidity 50%RH.

For the (13) hall the dimensions of walls , Doors and windows were measured , and number of air conditioning units , lighting units and the number of people could have been in conditioning place , loads accounted . And calculating the amount of heat transmitted through the ceiling, walls and floor and were also calculate the amount of transmitted heat through the doors and windows from the solar radiation. also the Interior loads been calculated which was lighting , appliances , people , ventilation and infiltration loads without thermal insulation materials. And Calculation of thermal loads When we use the thermal insulation materials for any insulation material , When we use this materials the wall and ceiling load is very few and , that means we account the heat load in four cases , where the first case without insulation material and the second case as use of Polyurethane and compare of them.

3.2 Calculation of thermal load by Relation:

3.2.1 External loads:

External loads are highly variable, both by season and by time of day. They cause significant changes in the heating and cooling requirements over time, not only in the perimeter building spaces, but for the total building heating/cooling plant.

3.2.1.1 Heat Transfer through Opaque Surfaces:

This is a sensible heat transfer process. The heat transfer rate through opaque surfaces such as walls, roof, floor, doors etc. is given by:-

$Q_{Trans} = U \times A \times \Delta T$ -------------- (3-1)

U = the overall heat transfer coefficient

A = the heat transfer area of the surface on the side of the conditioned space.

ΔT= temperature difference.

$\Delta T = (CLTD + LM)\, K + (25.5 - T_i) + (T_o - 29.4)$ -------------- (3-2)

CLTD= **C**ooling **L**oad **T**emperature **D**ifference

K=corrected factor color of wall, dark (K=1), medium (K=0.85), light (K=0.65).

LM= corrected factor due longitude, latitude.

3.2.1.2 Heat Transfer through fenestration:

Heat transfer through transparent surface such as a window, includes heat transfer by conduction due to temperature difference across the window and heat transfer due to solar radiation through the window, and given by:-

$Q_w = A \times (U \times \Delta T + SC \times SHGF_{max} \times CLF)$ --------- (3-3)

$\Delta T = CLTD + (25.5 - T_i) + (T_o - 29.4)$ -------------- (3-4)

$SHGF_{max}$ = Solar Heat Gain Factor Max.

SC = Shading Coefficient.

CLF= cooling load factor.

3.2.1.3 Heat transfer due infiltration and ventilation:

Heat transfer due to infiltration and ventilation consists of both sensible as well as latent components. The sensible heat transfer rate due to infiltration and ventilation is given by:-

$Q_{S.leak} = Q_{S.leak} \times c_{pa} (T_o - T_i)$ ---------------- (3-5).

$m_{inf} = N_A \times V \times \rho$ ---------------- (3-6)

$N_A = a + b \times V_a + c \times (T_o - T_i)$ ----------------- (3-7).

m_{inf} = amount of air infiltration.

V_a= air velocity.

V=volume of building.

a, b, and c = constant, and calculating from table (14).

$m_{ven} = N_p \times \dot{V} \times \rho$ -------------- (3-8)

m_{ven} = amount of air ventilation.

N_p= number of people.

$\dot{V}$ = ventilation rate of one person.

ρ = density of air.

c_{pa}= the average specific heat of moist air.

The latent heat transfer rate due to infiltration and ventilation is given by:-

$Q_{L.leak} = (m_{ven} + m_{inf}) \times (\omega_o - \omega_i) \times h_{fg}$ -------------- (3-9).

ω_o= outdoor humidity ratios.

ω_i= indoor humidity ratios.

h_{fg}= the latent heat of vaporization of water.

3.2.2 Internal loads:

The internal loads consist of load due to occupants, due to lighting, due to equipment and appliances and due to products stored or processes being performed in the conditioned space.

3.2.2.1 Person load:

The internal cooling load due to occupants consists of both sensible and latent heat components.

$Q_{s.per} = N_p \times H_s$ -------------- (3-10).

$Q_{L.per} = N_p \times H_L$ ------------- (3-11).

N_p= number of people.

H_s= sensible heat gain per person.

H_L=latent heat gain per person.

3.2.2.2 Lighting load:

Lighting adds sensible heat to the conditioned space. Since the heat transferred from the lighting system consists of both radiation and convection, a Cooling Load Factor is used to account for the time lag. Thus the cooling load due to lighting system is given by:

$Q_{light} = F_u \times F_b \times L_R \times CLF$ -------------- (3-12).

3.2.2.3 Equipment load:

The equipment and appliances used in the conditioned space may add both sensible as well as latent loads to the conditioned space.

$Q_{app} = \sum power \times (1 - \eta)$ -------------- (3-13).

3.3Calculation by software Hourly analysis Program (HAP)

Carrier's Hourly Analysis Program is two powerful tools in one package. HAP provides versatile features for designing HVAC systems for commercial buildings. It also offers powerful energy analysis capabilities for comparing energy consumption and operating costs of design alternatives. By combining both tools in one package significant time savings are achieved. Input data and results from system design calculations can be used directly in energy studies.

Who Can Benefit from HAP?

HAP is designed for consulting engineers, design/build contractors, HVAC contractors, facility engineers and other professionals involved in the design and analysis of commercial building HVAC systems.

3.3.1 Useful Application:

The program is a powerful tool for designing systems and sizing system components. HAP can easily handle projects involving:

The program is a powerful tool for designing systems and sizing system components.

3.4 Data input in Hourly analysis software:

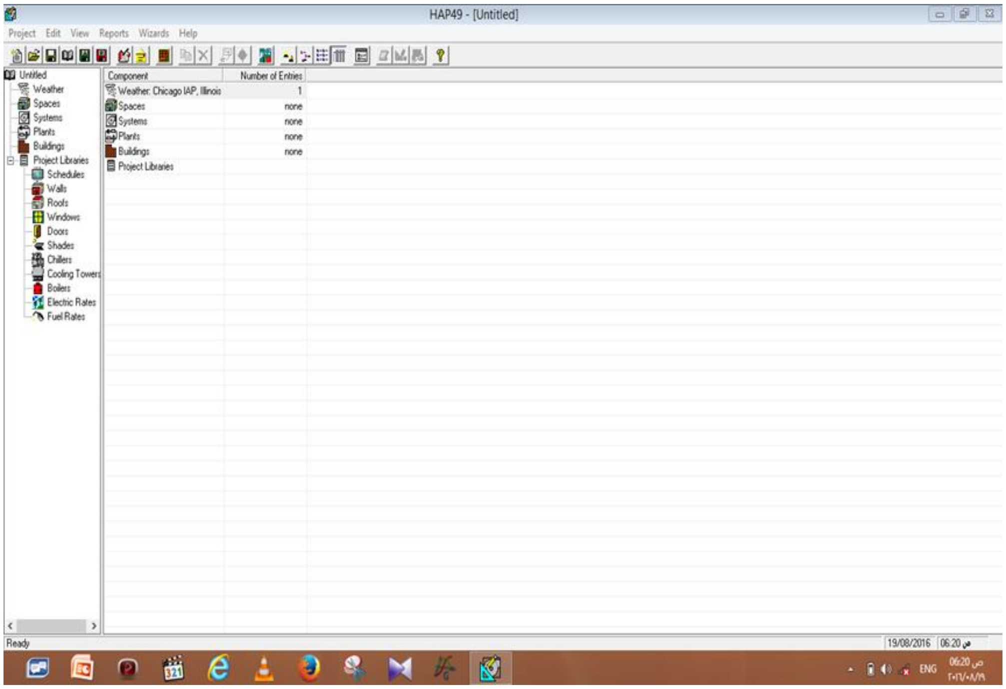

Fig 3-1: The user interface of hourly analysis software

3.4.1 Weather properties:

This window is used to enter the weather conditions in the area which include the latitude, longitude, elevation, summer design bulb temperature and summer design wet bulb temperature.

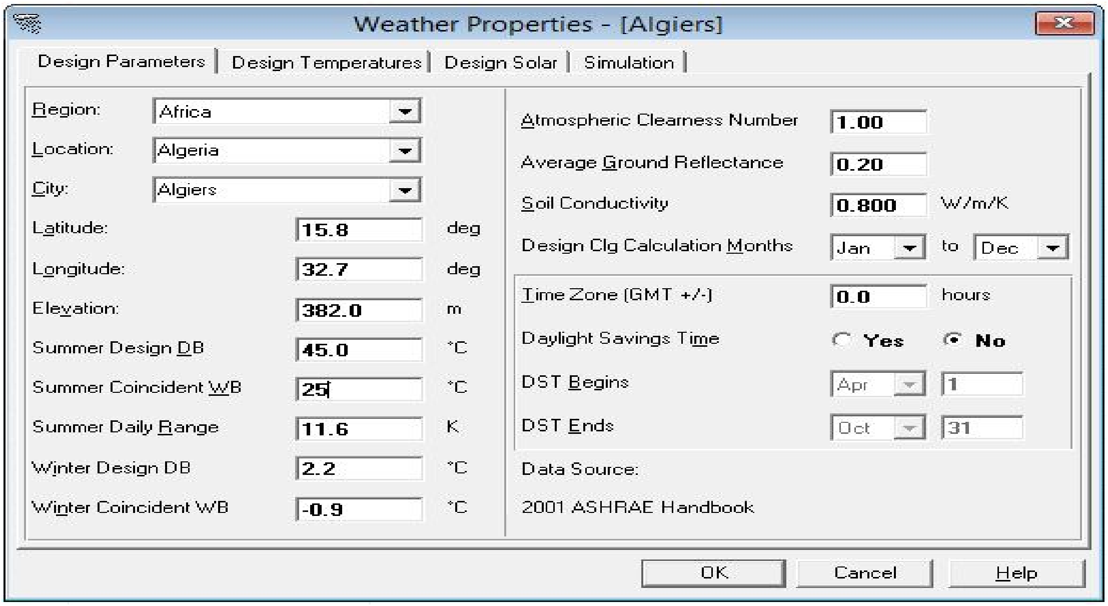

Fig 3-2: Weather properties

3.4.2 Space properties- general:

It contains the name, floor area, average ceiling height and ventilation requirements.

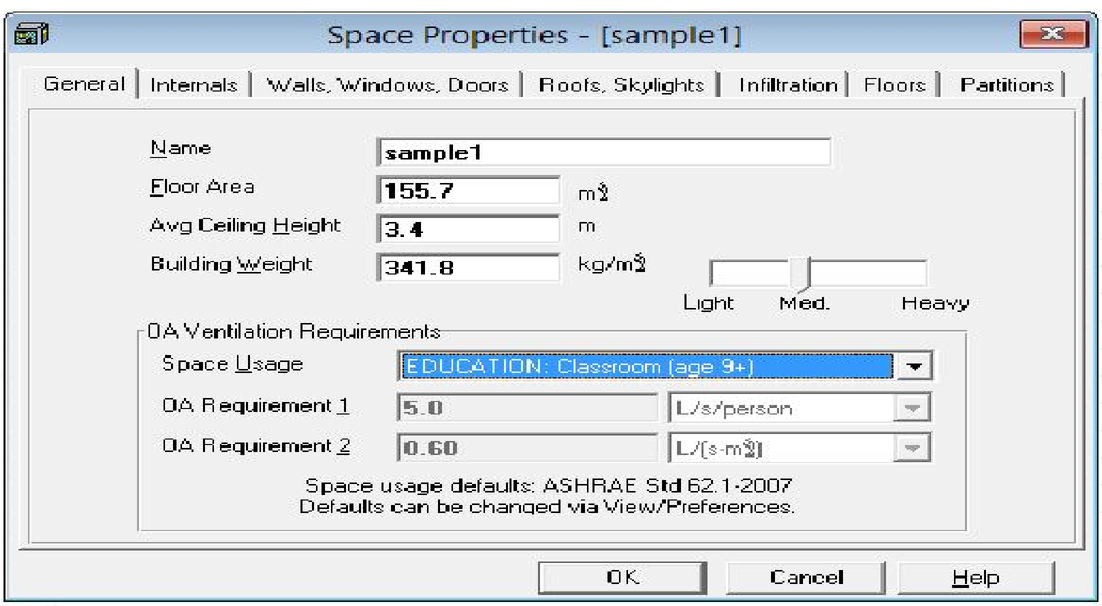

Fig 3-3: Space properties-general

3.4.3 Space properties-Internal load:

It consist of the type of light and the thermal load for lighting, equipment's, sensible load of people and latent load of people.

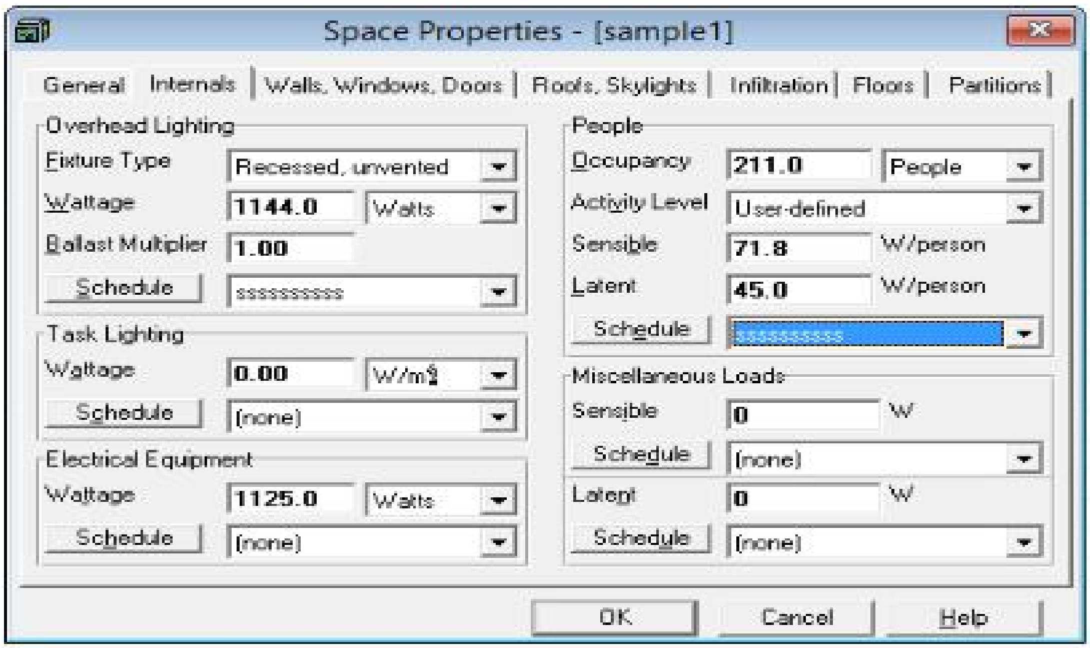

Fig 3-4: Space properties-internal load

3.4.4 Space properties-Wall, Window, doors:

In this window we define the walls that transfer heat to the system it is directions and number of doors and windows in each of these walls

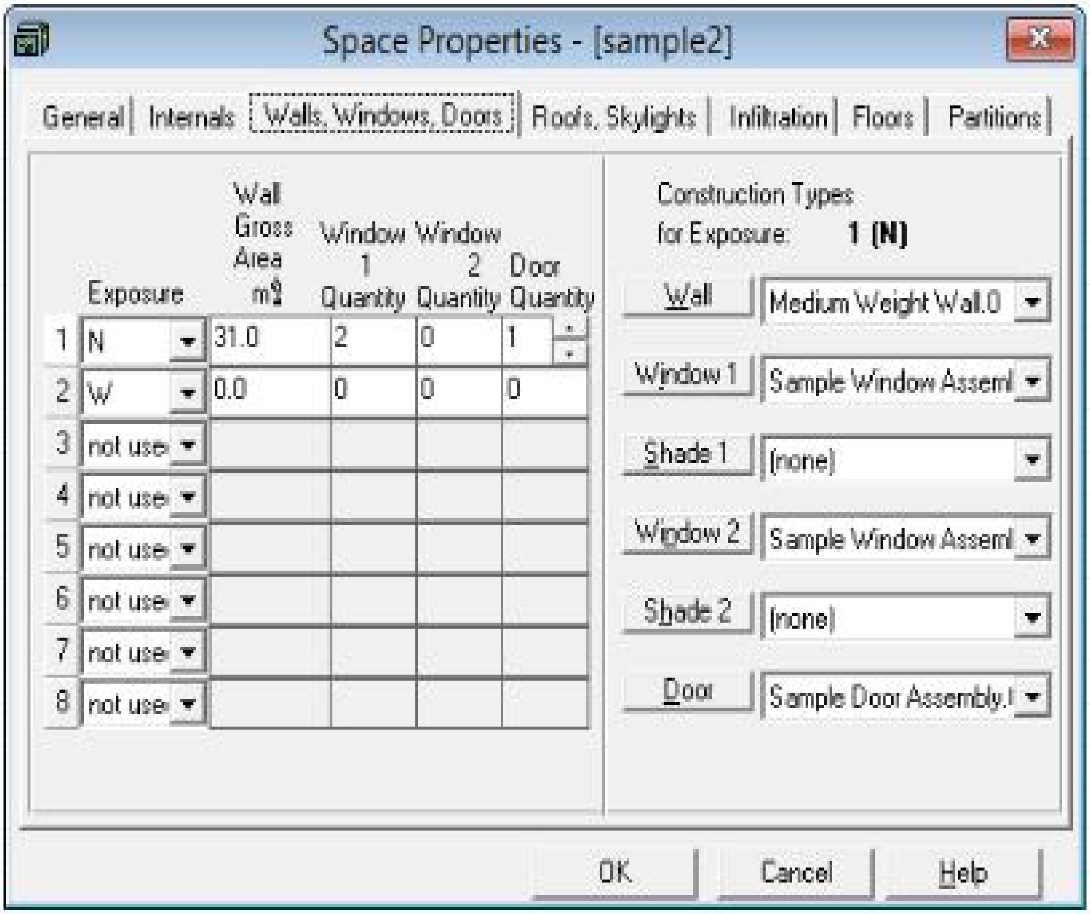

Fig 3-5: Space properties-wall, window and door

3.4.5 Wall properties:

It summarize the thickness of the wall layers and the color of the wall surface either dark medium or light chose from the software wall templates after entering this variables the software calculate the overall heat transfer coefficient.

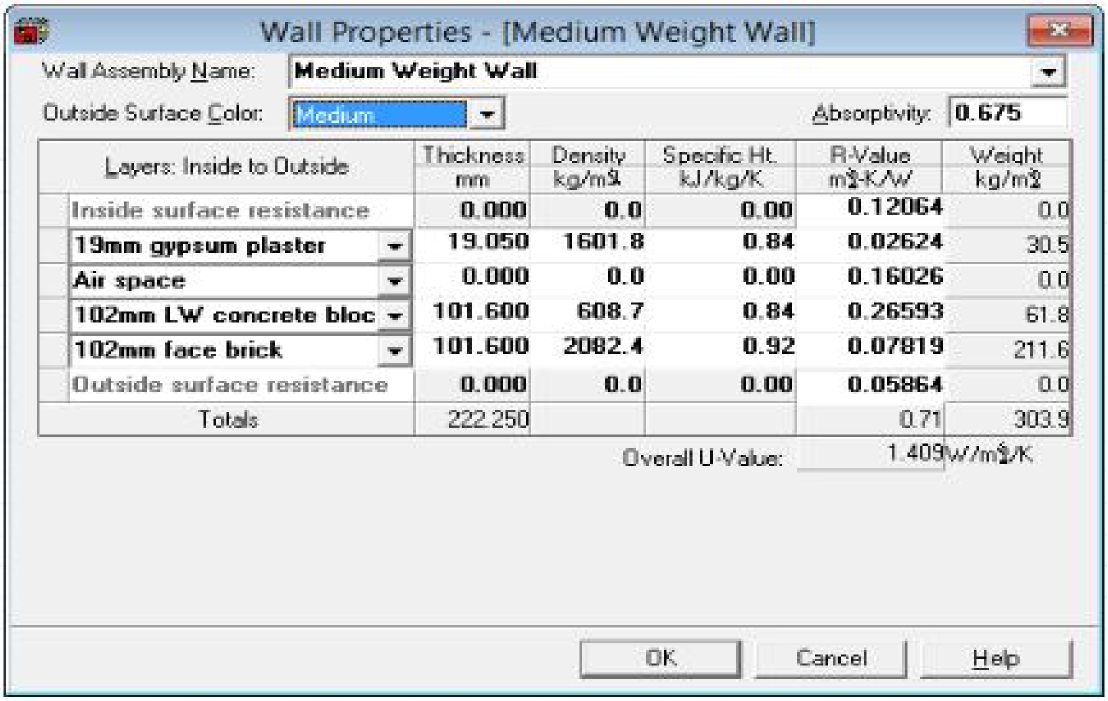

Fig 3-6: Wall thickness properties

3.4.6 Space properties-Roof:

It contain the roof thickness and type of the roof materials and the roof area

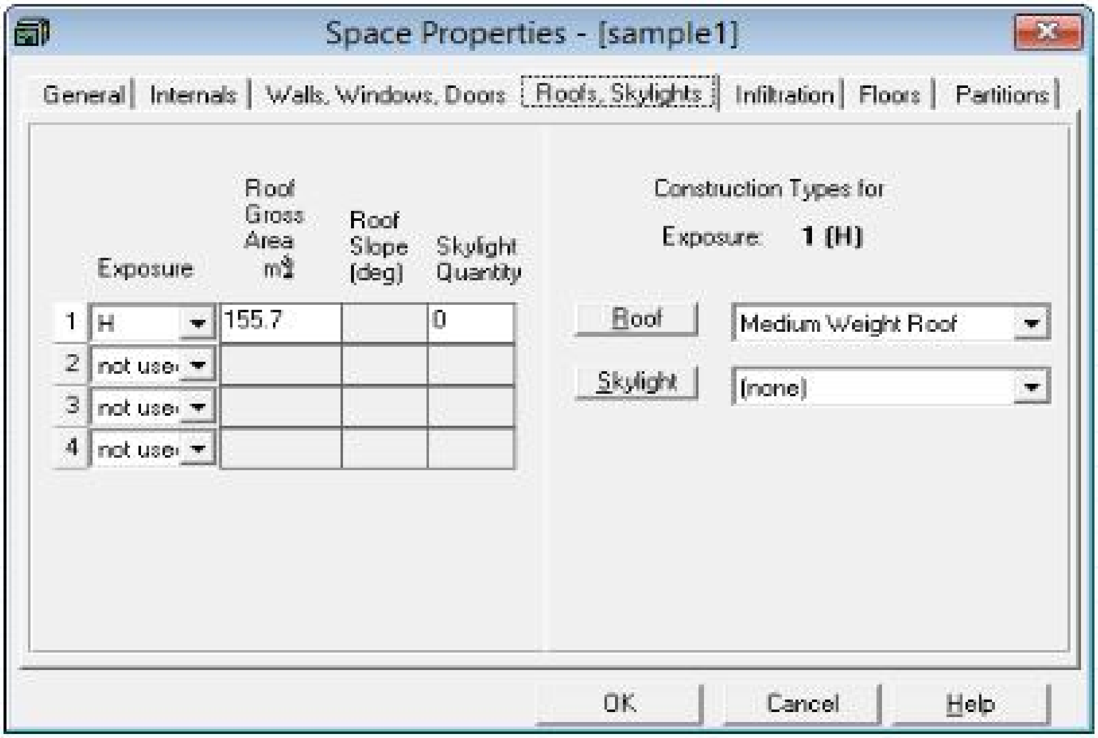

Fig 3-7: Space properties-roof data

3.4.7 Air system properties-General:

It contains the name, equipment type, air system type and the number of zones.

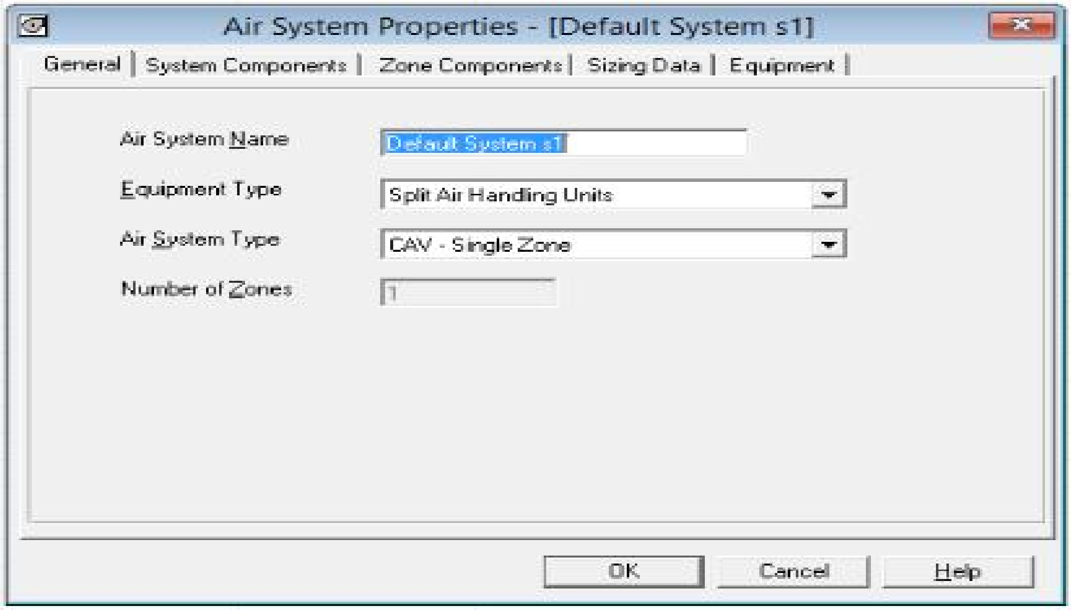

Fig 3-8: Air system general data

3.4.8 Air system properties- System component:

It contain the value of relative humidity and leave other variables to it is default values

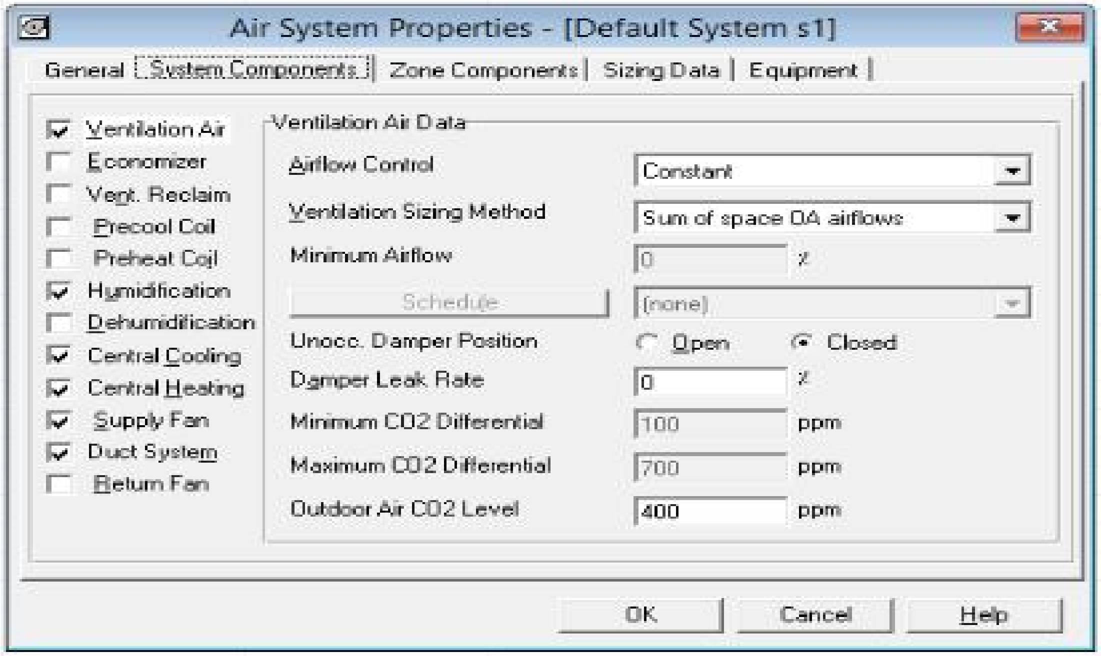

Fig 3-9: System component data

3.4.9 Air system properties- Zone component:

In thermostats menu to schedule the system operation time

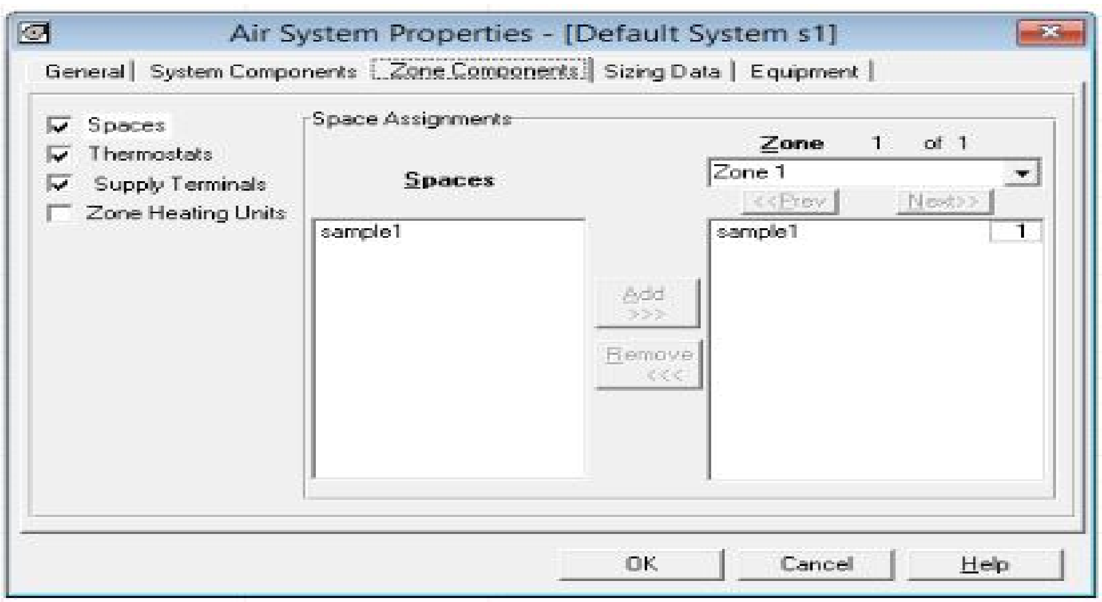

Fig 3-10: Zone component

3.4.10 System design Reports:

System results detailed report of the sizing of individual components and psychometrics.

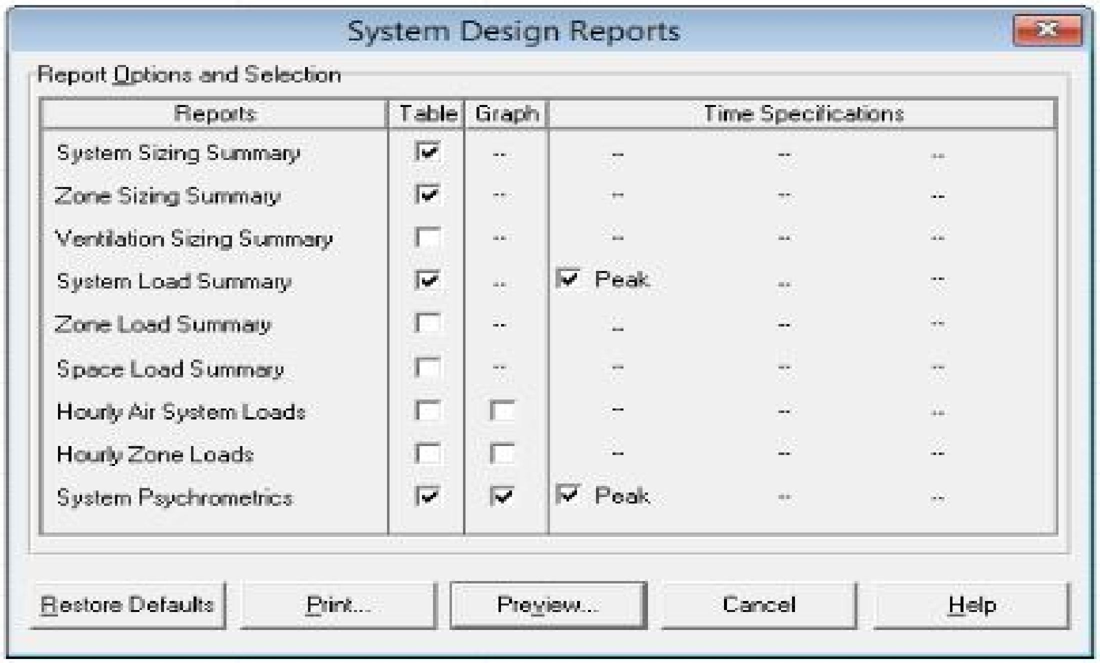

Fig 3-11: System design report

3.4.11 Air system summary for default system:

Air System Sizing Summary for Default System s1

Project Name: Untitled 08/19/2016
Prepared by: khalid alamin 08:05Ö

Air System Information

Air System Name	Default System s1	Number of zones	1
Equipment Class	SPLT AHU	Floor Area	155.7 m²
Air System Type	SZCAV	Location	Algiers, Algeria

Sizing Calculation Information

Calculation Months	Jan to Dec	Zone L/s Sizing	Sum of space airflow rates
Sizing Data	Calculated	Space L/s Sizing	Individual peak space loads

Central Cooling Coil Sizing Data

Total coil load	67.1 kW	Load occurs at	Jul 1600
Sensible coil load	54.3 kW	OA DB / WB	44.7 / 24.9 °C
Coil L/s at Jul 1600	2617 L/s	Entering DB / WB	33.5 / 21.6 °C
Max block L/s	2617 L/s	Leaving DB / WB	15.5 / 14.4 °C
Sum of peak zone L/s	2617 L/s	Coil ADP	13.5 °C
Sensible heat ratio	0.809	Bypass Factor	0.100
m²/kW	2.3	Resulting RH	57 %
W/m²	431.0	Design supply temp.	14.4 °C
Water flow @ 5.6 °K rise	N/A	Zone T-stat Check	0 of 1 OK
		Max zone temperature deviation	0.0 °K

Central Heating Coil Sizing Data

Max coil load	30.7 kW	Load occurs at	Des Htg
Coil L/s at Des Htg	2617 L/s	W/m²	197.0
Max coil L/s	2617 L/s	Ent. DB / Lvg DB	12.9 / 23.0 °C
Water flow @ 11.1 °K drop	N/A		

Fig 3-12: Air system summary for default system

3.5 Buildingdescription:

(13) hall at located at Sudan university of Science and Technology , Khartoum state (32° longitude, 15° latitude and 382° altitude) , The walls buildingare made of common bricks , buildingfaces thesuntowardthe east and west and south .

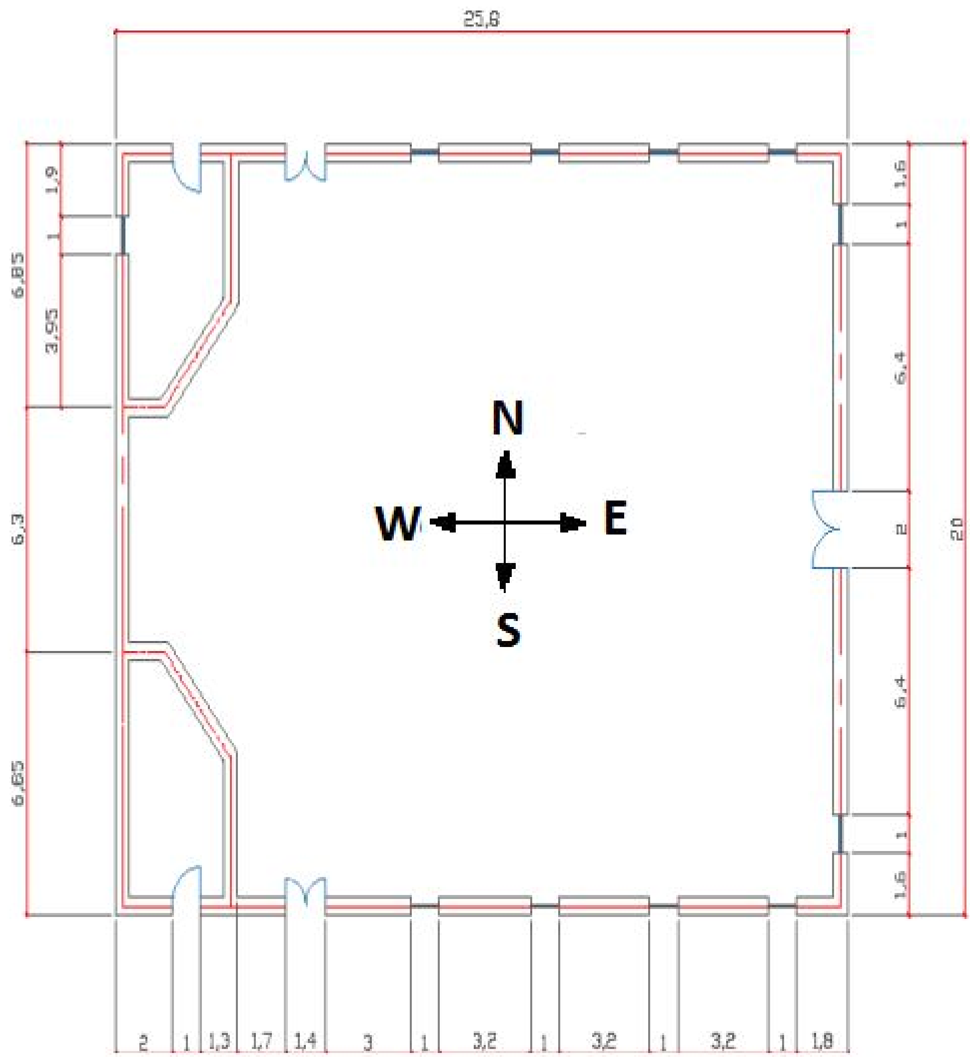

Fig 3-13: (13) hall

CHAPTER FOUR

CALCULATIONS

4.1 Calculation Thermal Loads Manually:

Data:-

Dimension hall (25.8×20×4.1) m3

Outdoor design conditions Dry Bulb temperature T_o (45)$c^o$and Wet bulb temperatureT_o(26)c^o

From table 1:-

h_o= 30 $W/m^{2}.^{O}c$

h_i=8.29 $w/m^2.c$

Data: -

t_{dbR}= 24°C, RH_R = 50%, t_{dbo} = 45°C , t_{wbo} = 26°C, N_p = 500, 32° N, 21 July, solar time 14 h, h_i = 8.3W/m^2.K, h_o = 30W/m^2.K, number of light 66 (20)w, ρ_a = 1.18 kg/m^3, c_{pa} = 1.005kJ/kg.K , and h_{fg} = 2570kJ/kg

Required: -

Q_T = ??

4.1.1 without use thermal insulation materials:

Heat transmission through walls:-

The wall is from common bricks of 47.46 cm and 1.27cm Gypsum plaster from inside and outside.

From table (1) $k_1 = k_3 = 0.8$, and $k_2 = 0.72$ W/m.K

$$\frac{1}{U} = \frac{1}{h_i} + \frac{\Delta x_1}{k_1} + \frac{\Delta x_2}{k_2} + \frac{\Delta x_3}{k_3} + \frac{1}{h_o} = \frac{1}{8.3} + \frac{0.0127}{0.8} + \frac{0.4746}{0.72} + \frac{0.0127}{0.8} + \frac{1}{30}$$

$\therefore U_{Wall} = 1.1838 W/m^2K$

$\Delta T = (CLTD + LM)\, K + (25.5 - T_i) + (T_o - 29.4)$

From table(2), at group B and 13hrs solar time, CLTD = (N = 6, E = 11, S = 8, and W = 10). From table (3) at latitude 15^o N, and at July, LM = (N = 0.5, E = W = 0.0, and S = -3.3). For wall color take K = 0.85.

$\therefore \Delta T_N = (6 + 0.5)\, 0.85 + (25.5 - 24) + (45 - 29.4) = 22.62^oC$

$\therefore \Delta T_E = (11 + 0.0)\, 0.85 + (25.5 - 24) + (45 - 29.4) = 26.45^oC$

$\therefore \Delta T_W = (10 + 0.0)\, 0.85 + (25.5 - 24) + (45 - 29.4) = 25.6^oC$

$\therefore \Delta T_S = (8 - 3.3)\, 0.85 + (25.5 - 24) + (45 - 29.4) = 22.8^oC$

From room figure the active wall area must be found for each side

$Q_N = U_{Wall} \times A_N \times \Delta T_N = 1.1838 \times 25.8 \times 4.1 \times 22.62 = 4397.86$ W

$Q_E = U_{Wall} \times A_E \times \Delta T_E = 1.1838 \times 20 \times 4.1 \times 27.3 = 3986.4$ W

$Q_S = U_{Wall} \times A_S \times \Delta T_S = 1.1838 \times 25.8 \times 4.1 \times 25.6 = 4977.25$ W

$Q_W = U_{Wall} \times A_W \times \Delta T_W = 1.1838 \times 20 \times 4.1 \times 22.8 = 3436.32$ W

$Q_{Walls} = 4397.86 + 3986.4 + 4977.25 + 3436.32 = 16797.87$ W

$Q_{Walls} = 16.798$ KW

Heat transmission through ceiling:-

From table (1) k_1 (Gypsum plaster)) = 0.8, k2 (steel sheet) = 46.5

$$\frac{1}{U_C} = \frac{1}{h_i} + \frac{\Delta x_1}{k_1} + \frac{\Delta x_2}{k_2} + \frac{1}{h_o} = \frac{1}{8.3} + \frac{0.0127}{0.8} + \frac{0.000853}{46.5} + \frac{1}{30}$$

$U_C = 5.89\ W/m^2.K$

$\Delta T_C = 14^O c$

$Q_{ceiling} = U_C \times A_C \times \Delta T_C = 5.89 \times 516 \times 14 = 42549.36$ W

$Q_{ceiling}$ = 42.5494 kW

Heat transmission through wooden doors:-

Assume the doors from steel sheet with thickness 0.25cm.

From table (1) ks = 46.5 W/m.K

$$\frac{1}{U_D} = \frac{1}{h_i} + \frac{\Delta x}{k} + \frac{1}{h_o} = \frac{1}{8.3} + \frac{0.025}{46.5} + \frac{1}{30}$$

$\therefore$ $U_D = 6.5\ W/m^2.K$

$Q_{D.N} = U_D \times A_{D.N} \times \Delta T_N = 6.5\times(4.6+2\times3+2\times2)\times 15 = 1423.5\ W$

Q_{Doors} = 1.4235KW

Solar heat gains through glass windows:-

Assume the glass is clear, 3mm thickness, and medium Venetian shade. From table (1), k for glass = 1.4

$$\frac{1}{U_G} = \frac{1}{h_i} + \frac{\Delta x}{k_G} + \frac{1}{h_o} = \frac{1}{8.3} + \frac{0.003}{1.4} + \frac{1}{30}$$

$U_G = 6.4\ W/m^2.K$

$\Delta T_G = CLTD + (25.5 - T_i) + (T_o - 29.4)$

From table (5), the CLTD for glass at 13hrs solar time is equal to 7

$\Delta T_G = 7 + (25.5 - 24) + (45 - 29.4) = 24.1^oC$

$Q_G = A_G\times (U_G \times \Delta T_G + SC \times SHGF_{max} \times CLF)$

From table (6), at medium Venetian and 3mm thickness the SC = 0.64.From table (9), at July $SHGF_{max}$ = 678, and from table (10) and 14hrs solar time the CLF values are equal to (S = 0.57).

$Q_{GE} = (3 \times 1.2\times 1) ((6.4 \times 24.1) + (0.64 \times 678 \times 0.53)) = 1383.18\ W$

Q_{GN} = (4 × 1.2 × 1)× ((6.4×24.1) + (0.64 × 126 × 0.53)) =945.5 W

Q_{GS} = (4 × 1.2 × 1)× ((6.4×24.1) + (0.64 × 227 × 0.53)) =1109.9 W

$Q_{Glass} = Q_{GE\&W} + Q_{GN} + Q_{GS}$ = 1383.18 + 945.5+1109.9 = 3438.6W

Q_{Glass} = 3.438 Kw

Ventilation and Infiltration:-

The volume of the hall =25.8 × 20 × 4.1 = 2115.6m^3, assume mediumhall, and $T_i = 24^oC$ Take V_A = 3.4m/s

a = 0.2, b = 0.015, and c = 0.014

$N_A = a + b \times V_A + c\,(T_o - T_i)$= 0.15 + 0.01 ×3.4 + 0.007 (45 - 24)

$\therefore N_A = 0.215$ Number of change per hour

$\dot{m}_{inf} = N_A \times V \times \rho$ = (0.215/3600) × 2115.6 × 1.18 = 0.15 kg/s

From table (15), assume no smoking person and seated rest,N_p = 2.5 liter/s/person

$m_{ven} = N_p \times \dot{V} \times \rho = 500 \times 2.5 \times 10^{-3} \times 1.18$ = 1.475 kg/s

$Q_{S.leak} = (m_{inf} + m_{ven}) \times c_{pa}\,(T_o - T_i)$ = (0.15 +1.475) × 1005×(45 -24) =34295.6W

$Q_{S.leak}$ = 34.2956 KW

From Psychometric chart and at (t_{dbR}= 24^{o}C, RH_R = 50%), ω_R = 0.0095. and at (t_{dbo} = 45^{o}C, t_{wbo} = 25^{o}C), ω_o = 0.012

$Q_{L.leak} = (m_{inf} + m_{ven}) \times (\omega_o - \omega_i) \times h_{fg}$

= (0.15 + 1.475) × (0.012 - 0.0095) × 2547 × 10^3 = 10347.19 W

$Q_{L.leak}$ = 10.34719 Kw

Lighting load:-

$Q_{light} = F_u \times F_b \times N_l \times CLF$

Take F_u = 1 (Full lighting), F_b = 1.2 (fluorescent), CLF = 0.92

$Q_{light} = 1 \times 66 \times 20 \times 1.2 \times 0.97 = 1536.48W$

$Q_{light} = 1.5365\ kW$

Persons load:-

From table (16), at 24^{o}C room dry bulb temperature, and seated rest H_s = 75, and H_L = 40W, for 13hrs CLF = 0.97

$Q_{S.per} = N_p \times H_s \times CLF = 500 \times 75 \times 0.97 = 36375W$

$Q_{S.per} = 36.375\ kW \times 13h = 472.875$

$Q_{L.per} = N_p \times H_L = 500 \times 40 = 20000W$

$Q_{L.per} = 20\ kW \times 13h =$

Total Sensible and Latent Heat:-

$Q_S = Q_{Walls} + Q_{ceiling} + Q_{Doors} + Q_{Glass} + Q_{S.leak} + Q_{light} + Q_{S.per}$

$= 16.798 + 42.55 + 1.4235 + 3.438 + 34.2956 + 1.5365 + 36.375 = 136.41\ kW$

$Q_L = Q_{L.leak} + Q_{L.per} = 10.3472 + 20 = 30.35\ kW$

$Q_T = Q_S + Q_L = 136.41 + 30.35 = 166.76\ kW$

$Q_T = 166.76kW$

4.1.2 Use polysterene:

From table (1) Kp = 0.04, th=10cm

In wall:

The wall is from Gypsum plaster 1.27cm common bricks of 23.73 cm, polysterne 10 cm, common bricks of 23.73 cm, and 1.27cm Gypsum plaster from inside and outside.

From table (1) k_1 = 0.8 W/m.Kk_p = 0.04, k_3 = 0.72, and

$$\frac{1}{U} = \frac{1}{h_i} + \frac{\Delta x_1}{k_1} + \frac{\Delta x_p}{k_p} + \frac{\Delta x_2}{k_2} + \frac{\Delta x_3}{k_3} + \frac{1}{h_o} = \frac{1}{8.3} + \frac{0.0127}{0.8} + \frac{0.1}{0.04} + \frac{0.2373}{0.72} \times 2 + \frac{0.0127}{0.8} + \frac{1}{30}$$

$\therefore U_{Wall} = 0.299\ W/m^2K$

$Q_N = U_{Wall} \times A_N \times \Delta T_N = 0.299 \times 25.8 \times 4.1 \times 22.62 = 715.43$ W

$Q_E = U_{Wall} \times A_E \times \Delta T_E = 0.299 \times 20 \times 4.1 \times 26.45 = 648.51$ W

$Q_S = U_{Wall} \times A_S \times \Delta T_S = 0.299 \times 25.8 \times 4.1 \times 25.6 = 809.68$W

$Q_W = U_{Wall} \times A_W \times \Delta T_W = 0.299 \times 20 \times 4.1 \times 22.8 = 559$W

Q_{Walls} = 715.43+ 648.51+ 809.68+559 = 2732.61 W

Q_{Walls}= 2.73261 KW

Onceiling:

From table (1) k_1 (Gypsum plaster)) = 0.8, k2 (steel sheet) = 46.5

$$\frac{1}{Uc} = \frac{1}{h_i} + \frac{\Delta x_1}{k_1} + \frac{\Delta x_2}{k_2} + \frac{\Delta x_3}{k_3} + \frac{1}{h_o} = \frac{1}{8.3} + \frac{0.0127}{0.8} + \frac{0.1}{0.04} + \frac{0.000853}{46.5} + \frac{1}{30}$$

$U_C = 0.3745\ W/m^2.K$

$\Delta T_C = 14$

$Q_{ceiling} = U_C \times A_C \times \Delta T_C = 0.3745 \times 516 \times 14 = 2732.61$ W

$Q_{ceiling}$ = 2.7054kW

Total Sensible and Latent Heat:-

$Q_S = Q_{Walls} + Q_{ceiling} + Q_{Doors} + Q_{Glass} + Q_{S.leak} + Q_{light} + Q_{S.per}$

$=2.7326+ 2.7054+1.4235 +3.438+34.2956+1.5365+36.375 = 82.5$ kW

$Q_L = Q_{L.leak} + Q_{L.per} = 10.3472+20 = 30.35$ kW

$Q_T = Q_S + Q_L = 82.5+ 30.35= 112.85$ kW

$Q_T = 112.85$ kW

4.1.3 Use Polyurethane:

From table (1) Kp = 0.023, th=10cm

In wall:

$$\frac{1}{U} = \frac{1}{h_i} + \frac{\Delta x_1}{k_1} + \frac{\Delta x_p}{k_p} + \frac{\Delta x_2}{k_2} + \frac{\Delta x_3}{k_3} + \frac{1}{h_o} = \frac{1}{8.3} + \frac{0.0127}{0.8} + \frac{0.1}{0.023} + \frac{0.2373}{0.72} \times 2 + \frac{0.0127}{0.8} + \frac{1}{30}$$

$\therefore U_{Wall} = 0.1926\ W/m^2K$

$Q_N = U_{Wall} \times A_N \times \Delta T_N = 0.1926 \times 25.8 \times 4.1 \times 22.62 = 460.84$ W

$Q_E = U_{Wall} \times A_E \times \Delta T_E = 0.1926 \times 20 \times 4.1 \times 26.45 = 417.73$ W

$Q_S = U_{Wall} \times A_S \times \Delta T_S = 0.1926 \times 25.8 \times 4.1 \times 25.6 = 521.55$ W

$Q_W = U_{Wall} \times A_W \times \Delta T_W = 0.1926 \times 20 \times 4.1 \times 22.8 = 360.08$W

$Q_{Walls} = 460.84 + 417.73 + 521.55 + 360.08 = 1760.2$ W

$Q_{Walls} = 1.76$ KW

Onceiling:

From table (1) k_1 (Gypsum plaster)) = 0.8, k2 (steel sheet) = 46.5

$$\frac{1}{U_C} = \frac{1}{h_i} + \frac{\Delta x_1}{k_1} + \frac{\Delta x_2}{k_2} + \frac{\Delta x_3}{k_3} + \frac{1}{h_o} = \frac{1}{8.3} + \frac{0.0127}{0.8} + \frac{0.1}{0.04} + \frac{0.000853}{46.5} + \frac{1}{30}$$

$U_C = 0.2213\ W/m^2.K$

$\Delta T_C = 14$

$Q_{ceiling} = U_C \times A_C \times \Delta T_C = 0.2213 \times 516 \times 14 = 1598.67\ W$

$Q_{ceiling} = 1.598\ kW$

Total Sensible and Latent Heat:-

$Q_S = Q_{Walls} + Q_{ceiling} + Q_{Doors} + Q_{Glass} + Q_{S.leak} + Q_{light} + Q_{S.per}$

$= 1.76 + 1.598 + 1.4235 + 3.438 + 34.2956 + 1.5365 + 36.375 = 80.41\ kW$

$Q_L = Q_{L.leak} + Q_{L.per} = 10.3472 + 20 = 30.35\ kW$

$Q_T = Q_S + Q_L = 80.41 + 30.35 = 110.76\ kW$

$Q_T = 110.76\ kW$

4.1.4 Use air space:

In wall:

From table (1) $\frac{1}{U} = 0.16$, th=10cm

$$\frac{1}{U} = \frac{1}{h_i} + \frac{\Delta x_1}{k_1} + 0.16 + \frac{\Delta x_2}{k_2} + \frac{\Delta x_3}{k_3} + \frac{1}{h_o} = \frac{1}{8.3} + \frac{0.0127}{0.8} + 0.16 + \frac{0.2373}{0.72} \times 2 + \frac{0.0127}{0.8} + \frac{1}{30}$$

$\therefore U_{Wall} = 0.9953\ W/m^2K$

$Q_N = U_{Wall} \times A_N \times \Delta T_N = 0.9953 \times 25.8 \times 4.1 \times 22.62 = 2380.78\ W$

$Q_E = U_{Wall} \times A_E \times \Delta T_E = 0.9953 \times 20 \times 4.1 \times 26.45 = 2458.06\ W$

$Q_S = U_{Wall} \times A_S \times \Delta T_S = 0.9953 \times 25.8 \times 4.1 \times 25.6 = 2694.4\ W$

$Q_W = U_{Wall} \times A_W \times \Delta T_W = 0.9953 \times 20 \times 4.1 \times 22.8 = 1860.25W$

Q_{Walls} = 2380.78 + 2458.06+ 2694.4+1860.25 = 9093.5 W

Q_{Walls} = 9.093 KW

Onceiling:

From table (1) k_1 (Gypsum plaster)) = 0.8, k2 (steel sheet) = 46.5

$$\frac{1}{U_C} = \frac{1}{h_i} + \frac{\Delta x_1}{k_1} + \frac{\Delta x_2}{k_2} + \frac{\Delta x_3}{k_3} + \frac{1}{h_o} = \frac{1}{8.3} + \frac{0.0127}{0.8} + 0.16 + \frac{0.000853}{46.5} + \frac{1}{30}$$

U_C = 3.033 $W/m^2.K$

ΔT_C = 14

$Q_{ceiling} = U_C \times A_C \times \Delta T_C$ = 3.033× 516 × 14 = 21910.4 W

$Q_{ceiling}$ = 21.91 kW

Total Sensible and Latent Heat:-

$Q_S = Q_{Walls} + Q_{ceiling} + Q_{Doors} + Q_{Glass} + Q_{S.leak} + Q_{light} + Q_{S.per}$

=9.094+ 21.91+1.4235 +3.438+34.2956+1.5365+36.375 = 108.07 kW

$Q_L = Q_{L.leak} + Q_{L.per}$ = 10.3472+20 = 30.35 kW

$Q_T = Q_S + Q_L$ = 99.5+ 30.35= 138.42 kW

Q_T = 138.42 kW

4.2 Total Cost Operation:

166.76 Kw Consume 55.59 kW/h

Total loads per year: 55.59×12×365 = 243484.2 KW /year

Total Cost per year: 243484.2×0.26 = 63305.89 SDG /year

Use Polysterene :

112.85 Kw Consume 37.5 kW/ h

Total loads per year: 37.5×12×365 = 164264.6 kW /year

Total Cost per year: 164264.6×0.26 = 42708.8 SDG /year

Total Cost Operation Ratio: 63305.89–42708.8/63305.89 = 32.32%

Use Polyurethane:

110.65 Kw Consume 36.88 kW/ h

Total loads per year: 36.88×12×365 = 161549 kW /year

Total Cost per year: 161549×0.26 = 42002.74 SDG /year

Total Cost Operation Ratio: (63305.89–42002.74)/ 63305.89 = 33.58%

Use air space :

138.42 Kw Consume 46.14 kW/ h

Total loads per year: 46.14×12×365 = 202093.2 kW /year

Total Cost per year: 202093.2×0.26 =52544.23 SDG /year

Total Cost Operation Ratio: (63305.89–52544.23)/63305.89 = 16.99%

4.3 Compare between with and without using thermal insulation materials:

Table 5-1: compare between with and without using thermal insulation materials

Insulation Materials	Calculation (Kw)	Software (Kw)	e%
1-Total load	166.76	163.84	-
2-Use polysterene	112.85	114.34	32.32%
3-Use polyuerthane	110.76	109.5	33.58%
4-Air cavity	138.42	139.85	16.99%

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

4.2 Conclusion:

From the result the Thermal insu rials which decrease the Thermal load of the building and the ef air conditioning unit and also the cost of the operation.

We find the Polysterene material which decrease represent (53.9KW) from the thermal load of the building, and the average operation cost yearly due Polysterene material represent (32.32%) from the total cost operation yearly.

Also the Polyurethane material which decrease represent (56KW) from the thermal load of the building, and the average operation cost yearly due Polyurethane material represent (33.58%) from the total cost operation yearly.

Air cavity decrease represent (28.34KW) from the thermal load of the building, and the average operation cost yearly due Polyurethane material represent (16.99%) from the total cost operation yearly.

Also HAP (Hourly analysis program) it is one of the best program of the calculation thermal loads , it provide lot of potential , time and gives an accurate results by comparing to manual calculating which takes time.

4.3 Recommendation:

1- Use package air condition because it introduces best efficiency, consume less energy and have long operating life.
2- Improve high quality thermal insulation material with leas cost and more effectiveness.
3- Use good material for building according to the specialization so as to avoid any defect in the building so as clefts or slits.
4- Using doors with high quality in order to prevent outdoor air inter the building.

References:

1- Refrigeration & air conditioning 40 lessons on refrigeration and air conditioning EE IIT, Kharagpur, India 2008.

2- http://www.brighthubengineering.com/hvac.

3- Insulation Handbook Richard T. Bynum Jr., A.I.A.
4- Fundamentals volume of the ASHRAE Handbook. Ch. 27, ASHRAE, Inc., 2005.
5- https://en.wikipedia.org/wiki/Evaporative_cooler

Appendix:

Table (1) Data of construction material properties:

k (W/m.K)	Material

1.30	Face brick
1.1	Concrete
1.10	Tiles
0.72	Cement plaster
0.80	Gypsum plaster
0.16	Hard wood
0.116	Soft wood
1.72	Sand
0.036	Glass wool
0.040	Polystyrene
0.023	Polyurethane
0.67	Ceramic
1.40	Glass

Table 2 Walls $CLTD\ ^{o}C$ values from ASHRAE, 1985

	Solar time												
	6	7	8	9	10	11	12	13	14	15	16	17	18
Wall group A, common bricks 203 mm , $U = 0.874 \sim 1.379 \quad 1W/m^2.K$													
N	7	7	6	6	6	6	6	6	6	6	6	6	6
E	12	11	11	10	10	10	11	11	12	12	13	13	14
S	10	9	9	9	8	8	8	8	8	8	8	9	9
W	14	13	13	12	12	11	11	10	10	10	10	10	11
Wall group B, common bricks 203 mm , $U = 1.714 \quad 1W/m^2.K$													
N	6	6	6	5	5	5	5	5	5	5	6	6	7
E	10	9	8	8	9	9	10	12	12	13	14	14	15
S	9	8	7	7	6	6	6	6	7	8	9	10	11
W	13	12	11	10	9	9	8	8	8	8	8	9	11
Wall group C, concrete bricks 203 mm , $U = 1.255 \sim 1.561 \quad 1W/m^2.K$													
N	5	5	4	4	4	4	5	5	6	6	7	8	9
E	8	7	7	8	9	11	13	14	15	16	16	17	17
S	7	6	6	5	5	5	5	6	8	9	11	12	13
W	11	10	9	8	7	7	7	7	7	8	9	11	13
Wall group D, common bricks 101.6 mm , $U = 2.356 \quad 1W/m^2.K$													
N	4	3	3	3	3	4	4	5	6	6	7	8	9
E	5	5	5	7	10	13	15	17	18	18	18	18	18
S	5	4	4	2	3	4	5	7	9	11	13	15	16
W	9	7	6	5	5	5	5	6	6	8	10	13	17
Wall group E, concrete 101.6 mm , $U = 1.811 \quad 1W/m^2.K$													
N	2	2	2	3	3	4	5	6	7	8	10	10	11
E	3	3	6	10	15	18	20	21	21	20	19	18	18
S	3	2	2	2	3	5	7	10	14	16	18	19	18
W	5	4	3	3	3	4	4	5	6	8	11	15	20
Wall group F, hall bricks 101.6 mm , $U = 0.914 \sim 1.493 \quad 1W/m^2.K$													
N	1	1	2	3	4	5	6	8	9	11	12	12	13
E	1	4	9	16	21	24	25	24	22	20	19	18	17
S	1	1	1	2	4	7	11	15	19	21	22	21	19
W	2	2	2	2	3	4	6	8	11	16	22	27	32
Ceiling group 3, concrete 100 mm , $U = 1.209 \quad 1W/m^2.K$													
	-2	-2	1	5	11	18	25	31	36	39	40	40	37
Ceiling group 6, concrete 152 mm , $U = 0.897 \quad 1W/m^2.K$													
	2	1	0	2	4	8	13	18	24	29	33	35	36
Ceiling group 6, concrete 203 mm , $U = 0.715 \quad 1W/m^2.K$													
	8	6	5	4	4	5	7	11	14	18	22	25	28

Table 3 *LM* values for latitudes 24° to 40° of walls and roofs ASHRAE, 1989.

Latitude North	Month	N	NE NW	E W	SE SW	S	Horizontal
24	Dec	-2.7	-5.0	-3.8	1.6	7.2	-7.2
	Jan/Nov	-2.2	-4.4	-3.3	1.6	7.2	-6.1
	Feb/Oct	-2.2	-3.3	-1.6	1.6	5.5	-3.8
	Mar/Sep	-1.6	-1.6	-0.5	0.5	2.2	-1.6
	Apr/Aug	-1.1	0.0	-0.5	-0.5	-1.6	0.0
	May/Jul	0.5	1.1	0.0	-1.6	-3.3	0.5
	Jun	1.6	1.6	0.0	-2.2	-2.3	0.5
32	Dec	-2.7	-5.5	-4.4	1.1	6.6	-9.4
	Jan/Nov	-2.7	-5.0	-4.4	1.1	6.6	-8.3
	Feb/Oct	-2.2	-3.8	-2.2	2.2	6.1	-5.5
	Mar/Sep	-1.6	-2.2	-1.1	1.6	3.8	-2.7
	Apr/Aug	-1.1	-0.5	0.0	0.0	0.5	-0.5
	May/Jul	0.5	0.5	0.0	-0.5	-1.6	0.5
	Jun	0.5	1.1	0.0	-1.1	-2.2	1.1
40	Dec	-3.3	-5.5	-5.5	0.0	5.5	-11.6
	Jan/Nov	-2.7	-5.5	-5.0	0.5	6.1	-10.5
	Feb/Oct	-2.7	-4.4	-3.3	1.6	6.6	-7.7
	Mar/Sep	-2.2	-2.7	-1.6	2.2	5.5	-4.4
	Apr/Aug	-1.1	-1.1	0.0	1.1	2.2	1.6
	May/Jul	0.0	0.0	0.0	0.0	0.5	0.5
	Jun	0.5	0.5	0.5	0.0	-0.5	1.1

Table 4 Percentage of daily range, ASHARE 1997.

Solar Time, *hr*	ΔT_m %	Solar Time, *hr*	ΔT_m %	Solar Time, *hr*	ΔT_m %
1:00	87	9:00	71	17:00	10
2:00	92	10:00	56	18:00	21
3:00	96	11:00	39	19:00	34
4:00	99	12:00	23	20:00	47
5:00	100	13:00	11	21:00	58
6:00	98	14:00	3	22:00	68
7:00	93	15:00	0	23:00	76
8:00	84	16:00	3	24:00	82

Table 5 CLTD ^oC for glass windows

Solar time, *hr*	CLTD	Solar time, *hr*	CLTD	Solar time, *hr*	CLTD
6:00	-1	11.00	4	16:00	8
7:00	-1	12.00	5	17:00	7
8:00	0	13.00	7	18:00	7
9:00	1	14.00	7	19:00	6
10:00	2	15.00	8	20:00	4

Table 6 *SC* Shading coefficient for glass windows

Glass type	Thickness *mm*	Without Shading	With Shading				
			Venetian		Blind or Roller		
			Medium	Light	Dark	Medium	Light
		SC	*SC*				
Clear	3	1	0.64	0.55	0.59	0.25	0.39
	6	0.95					
	10	0.92					
	12	0.88					
Absorbent	3	0.85	0.57	0.53	0.45	0.30	0.36
	6	0.73					
	10	0.64					
	12	0.53					

Table 7 $SHGF_{max}$ W/m^2 from glass window exposed to solar radiation

Month	Latitude 24 °					
	N	NE NW	E W	SE SW	S	Horizontal
January	85	129	599	798	716	675
February	95	252	694	767	606	786
March	107	391	738	675	432	868
April	117	502	719	533	237	893
May	136	562	688	416	145	890
June	174	581	669	369	136	880
July	142	555	672	407	145	877
August	120	492	694	511	227	874
September	110	375	700	650	423	839
October	98	249	666	741	590	770
November	85	133	590	786	707	672
December	82	91	568	779	748	628

Table 8 $SHGF_{max}$ W/m^2 from glass window exposed to solar radiation

Month	Latitude 28 °					
	N	NE NW	E W	SE SW	S	Horizontal
January	79	110	577	792	751	618
February	91	227	672	776	653	738
March	104	366	729	697	495	836
April	114	476	719	562	297	877
May	126	543	691	454	183	883
June	161	562	672	404	155	877
July	129	536	678	442	180	870
August	120	470	694	543	287	858
September	107	350	691	672	486	808
October	95	224	644	751	637	722
November	82	110	571	779	741	615
December	75	76	543	782	776	565

Table 9 $SHGF_{max}$ W/m^2 from glass window exposed to solar radiation

Month	Latitude 32 °					
	N	NE NW	E W	SE SW	S	Horizontal
January	76	91	552	876	776	555
February	85	205	647	782	697	685
March	101	338	716	716	555	795
April	114	461	716	590	363	855
May	120	536	694	489	233	874
June	139	555	675	439	189	871
July	126	527	678	473	227	861
August	117	445	691	571	350	836
September	104	325	678	688	540	770
October	88	199	615	754	678	672
November	76	91	546	773	767	552
December	69	69	511	776	795	498

Table 10 CLF for glass windows without inside shade

Solar Time, *hr*	N			E			S			W		
	L	M	H	L	M	H	L	M	H	L	M	H
6.00	0.33	0.34	0.38	0.19	0.18	0.2	0.06	0.08	0.11	0.06	0.09	0.11
7.00	0.42	0.41	0.45	0.37	0.33	0.34	0.09	0.11	0.14	0.07	0.09	0.12
8.00	0.48	0.46	0.49	0.51	0.44	0.45	0.14	0.14	0.17	0.08	0.10	0.13
9.00	0.56	0.53	0.55	0.57	0.50	0.49	0.22	0.21	0.24	0.10	0.11	0.14
10.00	0.63	0.59	0.60	0.57	0.51	0.49	0.34	0.31	0.33	0.11	0.12	0.14
11.00	0.71	0.65	0.65	0.50	0.46	0.43	0.48	0.42	0.43	0.12	0.13	0.15
12.00	0.76	0.70	0.69	0.42	0.39	0.36	0.59	0.52	0.51	0.14	0.14	0.16
13.00	0.80	0.73	0.72	0.37	0.35	0.22	0.65	0.57	0.56	0.20	0.19	0.21
14.00	0.82	0.75	0.72	0.32	0.31	0.29	0.65	0.58	0.55	0.32	0.29	0.30
15.00	0.80	0.76	0.73	0.29	0.29	0.26	0.59	0.53	0.50	0.45	0.40	0.40
16.00	0.79	0.74	0.70	0.25	0.26	0.24	0.50	0.47	0.43	0.57	0.50	0.49
17.00	0.75	0.75	0.70	0.22	0.23	0.22	0.43	0.41	0.37	0.64	0.56	0.54
18.00	0.84	0.79	0.75	0.19	0.21	0.19	0.36	0.36	0.32	0.61	0.55	0.52
19.00	0.61	0.61	0.57	0.15	0.17	0.17	0.28	0.29	0.26	0.44	0.41	0.38
20.00	0.48	0.50	0.46	0.12	0.15	0.15	0.22	0.25	0.22	0.34	0.33	0.30

- L denotes light walls and ceiling of 50.8 mm concrete 146 kg/m^2 floor area, M denotes walls and ceiling of 101.6 mm concrete 341 kg/m^2 floor area,, H denotes walls and ceiling of 152.4 mm concrete 653 kg/m^2 floor area,.

Table 11 CLF for glass windows with inside shade

Solar time, *hr*	N	E	S	W	Horizontal
6.00	0.73	0.47	0.09	0.06	0.12
7.00	0.66	0.72	0.16	0.09	0.27
8.00	0.65	0.8	0.23	0.11	0.44
9.00	0.73	0.76	0.38	0.13	0.59
10.00	0.80	0.62	0.58	0.15	0.72
11.00	0.86	0.41	0.75	0.16	0.81
12.00	0.89	0.27	0.83	0.17	0.85
13.00	0.89	0.24	0.8	0.31	0.85
14.00	0.86	0.22	0.68	0.53	0.81
15.00	0.82	0.2	0.50	0.72	0.71
16.00	0.75	0.17	0.35	0.82	0.58
17.00	0.78	0.14	0.27	0.81	0.42
18.00	0.91	0.11	0.19	0.61	0.25
19.00	0.24	0.06	0.11	0.16	0.14
20.00	0.18	0.05	0.09	0.12	0.12

Table 12 Summer air change rate, McQuiston 1985.

	Outdoor Design Temperature, ^{o}C					
	29	32	35	38	41	43
Type	N_A Number of air change from room volume per hour					
Tight	0.33	0.34	0.35	0.36	0.37	0.38
Medium	0.46	0.48	0.50	0.52	0.54	0.56
Loose	0.68	0.70	0.72	0.74	0.76	0.78

Note: values for wind velocity of 3.4 m/s and indoor temperature of 24 °C.

Table 13 Winter air change rate, McQuiston 1985.

	Outdoor Design Temperature, ^{o}C					
	10	4	-1	-7	-12	-18
Type	N_A Number of air change from room volume per hour					
Tight	0.41	0.43	0.45	0.47	0.49	0.51
Medium	0.69	0.73	0.77	0.81	0.85	0.89
Loose	1.11	1.15	1.20	1.23	1.27	1.3

Note: values for wind velocity of 6.7 m/s and indoor temperature of 20 °C.

Table 14 Constants of Eq. for number of air change per hour.

Type	a	b	c
Tight	0.15	0.010	0.007
Medium	0.20	0.015	0.014
Loose	0.25	0.020	0.022

Table 15 Ventilation rate for persons.

Place	No. of persons per 100 m^2 of floor area	Ventilation per person in *lit/s*	
		Non smoking persons	Smoking persons
Offices	7	2.5	10
Conference or waiting halls	60	3.5	17.5
Seated rooms	30	2.5	7.5

Table 16 Heat gains from occupants.

Activity	Metabolic rate Q_P, W	Heat Liberated, W							
		Room dry bulb temperature, ^oC							
		20		22		24		26	
		H_S	H_L	H_S	H_L	H_S	H_L	H_S	H_L
Seated rest	115	90	25	80	35	75	40	65	50
Office work	140	100	40	90	50	80	40	70	70
Standing	150	105	45	95	55	82	68	72	78
Restaurant	160	110	50	100	60	85	75	75	85
Light work	235	130	105	115	120	100	135	80	155
Dancing	265	140	125	125	140	105	160	90	175

Table 17 ΔT ^oC to compensate solar effect on transmission load for cold storage

Surface types	East	West	South	Ceiling
Dark colored surfaces	5	5	3	11
Medium colored surfaces	4	4	3	9
Light colored surfaces	3	3	2	5

Dark colored surfaces as slate roofing, tar roofing, and black paint.

Medium colored surfaces as unpainted wood, brick, red tile, dark cement, and red, gray or green paint.

Light colored surfaces as white stone, light colored cement, and white paint.