Designing and Optimization of a High Efficiency Single Family House Located in the TRNC

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ABSTRACT

The conscious design of building parameters and the awareness of the available materials that could be used in construction could decrease or in some cases eliminate the need for HVAC systems, and thus, optimizing building parameters could help eliminating undesired energy losses through the building's envelope.

This work highlights the benefits of some of the materials which are newly dragged to the North Cyprus market. Possibility of manufacturing and casting of lightweight Pumice concrete using ordinary concrete planet is discussed. Heat conductivity test, as well as the cooling time, of those new materials has been done and results have been tabulated. A case study is introduced for a house in N. Cyprus to find the impact of those construction materials. The house has been hypothetically constructed using ordinary materials which are considered as the norm in N. Cyprus in Case A. On the other hand, the house (hypothetical) in Case B is constructed with thermal comfort criteria in mind, and by using the new materials experimentally tested as a part of this work. Energy losses during the heating season and gains during the cooling seasons are calculated for both cases using heat transfer methods. The energy needed to compensate for the loss and gain are presented. The study shows that about 50% of the energy needed for the HVAC can be eliminated in Case B.

Keywords: Pumice concrete, Pumice bricks, U-value, Low energy houses, PBP.

ÖZ

Bina parametrelerinin tasarımındaki farkındalık ve mevcut yapı malzemelerinin bilinmesi, ısıtma havalandırma ve iklimlendirme sistemlerine duyulan ihtiyacı azaltabilir hatta bazen ortadan kaldırabilir. Bina parametrelerinin optimizasyonu bina cephesindeki arzu edilmeyen enerji kayıplarını ortadan kaldıracaktır.

Bu çalışma yakın geçmişte piyasaya sürülen bazı yapı malzemelerinin faydalarına dikkat çekmektedir. Beton karıştırıcalarında süngertaşı betonunun (hafif beton) imalatı ve dökümünün olasılığı tartışıldı. Yeni malzemelerin kondaktivite testleri, ayni zamanda soğuma zamanı bulunarak tablolar halinde sunuldu. Yeni yapı malzemelerinin etkisini ölçmek için KKTC'deki farazi evler için olay çalışma sunuldu. Olay A'da, KKTC'deki tipik bir ev, olay B'de ısıl konfor kriterleri göz önünde tutularak deneysel olarak test edilen piyasadaki yeni malzemeler kulanıldı.

Isıtma sezonundaki enerji kayıpları ve soğutma sezonundaki ısı kazançları ısı transferi denklemlerini kullanarak Microsoft Excel'de geliştirilen bir program sayesinde hesaplanmıştır. Isı kayıpları ve kazanımları dengelemek için gerekli enerji miktarları belirlendi. Bu çalışmada Olay B'de ısıtma havalandırma ve iklimlendirmede gerekli enerji miktarında %50 azalma vardır.

Anahtar Kelimeler: Bims betonu, BimsBlok, U-değeri, Düşük enerji evleri, PBP.

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To my lovely wife for her continual support and forbearance

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Chapter 1

INTRODUCTION

1.1 State of Knowledge and Aim of Work

Due to environmental concerns and the continuous rising in energy prices, energy efficiency of a building envelope is considered to provide the cornerstone of a building's green rating.

In the US, Europe, and other developed countries, greenness certification of a building is awarded depending on several factors such as, energy efficiency, envelope design, location, indoor air quality, emissions, mechanical system, HVAC, lighting, control system, water usage, materials used for construction, etc. The U.S. EPA's ENERGY STAR program developed an energy performance rating system that rates a building's energy efficiency on a scale of 1-100. A building that scores in a 75 or above on this scale can earn an ENERGY STAR label.

The 2,500 buildings that have earned the ENERGY STAR label for energy efficiency through 2005 save a combined $350 million on their energy bills when compared with similar buildings having average energy consumption [21].

The situation in North Cyprus is no way similar to that in those developed countries. There is neither a regulation for energy-efficient buildings construction nor a concern for energy performance of those buildings. There is an increase of energy consumption due to high energy losses during winter and heavy cooling loads during summer caused by poor thermal insulation and by the lack of respect to bioclimatic principles in the design stage. Unfortunately KIB-TEK (state owned utility company in the TRNC) authorities kept the energy prices very low until early 2000s and people indiscriminately used electricity for space heating, water heating and etc. Traditionally houses were designed and built without considering thermal insulation of the residential buildings. In the TRNC electrical resistance heaters, radiators and for about a decade heat pumps are extensively used for heating. Heat pumps are also extensively used for cooling in the cooling season. The price of electricity has increased substantially during the last few years and the average price is more than 0.45 TL/kWh (i.e., 0.33 USD/kWh). Due to the low prices in the past years more than 92 % of the houses do not have any thermal insulation and 79.2% of residential buildings have single glazed windows. This simply means that more energy (most of which will be wasted) is needed to create a comfortable environment in these buildings. Today high energy prices have doubled or tripled the energy bills for homeowners. Monthly electric bills reached up to 500 USD have made electrical energy unaffordable. Some homeowners have started to use non-electric heating equipment such as gas portable heaters. A better solution is to increase the public's awareness for energy conservation to make sure they reflect it through the permanent and the daily decisions they take regarding to the energy usage in the long run.

Engineers, should play a vital role in the public awareness campaign by providing energy efficient and thus environmentally friendly solutions through promoting, providing sustainable energy efficient construction materials that is available in the market, that contribute to energy savings.

There is no doubt that the best and the most economical way to own energy-efficient buildings is by making the design decisions while keeping the energy efficiency in mind. For those existing energy-inefficient buildings, on the other hand, some modifications could be done to switch them to energy saving ones.

Energy-efficient design strategies encompass a wide range of traditional building construction elements, including building envelope design, mechanical systems, HVAC, lighting, controls systems, and so on. For decades now, researchers have attempted to create low energy consumption houses by optimizing buildings envelope; paying attention to the structure, design, construction materials besides to the use of the renewable energy sources. In the early 1990s the Florida Solar Energy Center undertook a simulation exercise that looked to examine whether it was possible to reduce all home energy end-uses (cooling, heating, water heating, refrigerators, lighting and appliances) such that with photovoltaic electricity it might be possible to realize an annual zero net energy load [1]. A similar work has been done in the UK provides optimal design strategies for typical homes and energy systems considering building materials, window sizes and orientations using EnergyPlus simulations and investigates the feasibility of zero energy houses with renewable electricity using TRNSYS [2].

Indeed lots of researches and studies, considering building materials, window sizes and orientations, have been done towards proving the possibility of building low and Zero Energy Homes (ZEH) [3, 4, and 5]

Gustafsson [6] discussed the ability for optimization of the buildings that would be subjected to refurbishment in the future, in Sweden, with emphasis on minimizing the life cycle cost of a building considering envelope's insulation and redesigning the heating systems.

While in some cold European regions only heating energy consumption is usually considered, and for regions like the Gulf countries only cooling energy consumption is considered, countries like those in the Mediterranean climate makes it essential to consider both heating and cooling energy uses. Thus, optimization of building energy performance is more complex to deal with. CHEOPS have developed optimization algorithm coupling the generic algorithms' techniques to the thermal assessment simplified tool for Mediterranean buildings [7]. The suggested algorithm is claimed to identify the best configurations from both energetic and economic points of view and that the optimization algorithm proved its effectiveness by determining the most adequate architectural design to the considered climate [8].

The energy performance of a building mainly depends on the response of its sections, as a complete system, to the outdoor environment and the indoor conditions. Considering this, focuses drawn towards optimization of materials used in constructing the outer sections of a building. Parameters like material thickness, the section's overall U factor (i.e., overall heat transfer coefficient), their absorption coefficients, and color effects of the sections' surfaces were intensively studied [9-12].

This work aims to introduce some of the recent alternatives to the typically used construction materials in N. Cyprus. More details are given in the next chapter.

1.2 Thesis Organization

This thesis contains 6 chapters. A brief summary of the remaining chapters are as follows.

The second chapter introduces the development and production of a new construction material i.e., pumice concrete, which is mainly used for thermal insulation and applied to the top of buildings by casting it using an ordinary concrete pump.

The third chapter is devoted to the experimental work that has been done on some of the newly introduced, and rarely used in N. Cyprus, which are constructional materials that are mainly used for thermal insulation and energy conservation. Heat transfer conduction tests and the related experimental error analysis have been done for four different specimens. The first specimen was ordinary concrete, and it was tested for comparison reasons. The second and third specimens were dense and light pumice concrete respectively. The fourth specimen was foam concrete, the concrete mainly used for leveling and insulating slabs between storeys. Cooling time experiments are also conducted for the specimens.

The fourth chapter describes the methodology for the heat losses and gains calculations from and to residential buildings through their enclosures. The main attention was given to the sensible heat gains and losses due to the different properties of the materials used in construction of the enclosure sections.

The fifth chapter deals with the economical aspects of the problem. Cases are introduced in this chapter emphasizing the economical effect of using some alternative constructional materials available in the market and the payback period (PBP) was used for economic analysis.

The sixth chapter is devoted for conclusions and recommendations.

Chapter 2

INSULATOR LIGHT WEIGHT CONCRETE

2.1 Introduction

Lightweight concrete, weighing from 400 to 1400 kg per cubic meter, has been used around the world for long time. The compressive strength is not as great as ordinary concrete, but it is considered to be sustainable. Among its advantages are less requirement for structural steel reinforcement, smaller foundation requirements, better fire resistance and most importantly, the fact that it can serve as an insulation material.

Light weight concrete is produced by using lightweight aggregates, or by the use of foaming agents, such as aluminum powder, which generates gas while the concrete is still plastic. Natural lightweight aggregates used in this industry include pumice, scoria, volcanic cinders, tuff, diatomite and expanded pearlite.

The major challenge facing light weight concrete industry is the ability of casting on the top of buildings using ordinary concrete pumper. Using an ordinary concrete pumping machine research has been conducted on the capability of pumping a light weight concrete, of which the main aggregate was pumice. From the first couple of trials it became clear that the process was not as easy as anyone can think and that it demands a systematical way of experimental work to succeed.

2.2 Producing Pumpable Pumice Concrete

One of the aims of this work is to produce a pumpable light weight concrete, using pumice aggregates as the main compound, to act as a durable, sustainable, and environmentally benign, thermal and acoustic insulator layer for covering flat roofs in N. Cyprus.

2.2.1 Criteria

Criteria of such concrete stated according to the Europe norms and the Turkish standards are the concrete's light weight, pumpability, and its compressive strength.

TSE EN 206-1, 2002 (Turkish Standards) classifies light concretes into three classes depending on their physical characteristics. These characteristics are illustrated in table 1.

Table 1: Classifications of concretes according to TSE EN 206-1, 2002 standard.

Characteristics	Classification		
	I taşıyıcı	II taşyıcı/yalıtım	III yalıtım
Compressive strength (N/mm^2)	>15.0	>3.5	>0.5
Thermal conductance (W/mK)		<0.75	<0.30
Specific weight (kg/m^3)	1600-2000	<1600	<1450

2.2.2 The Composite

The composite consists of pumice as the main aggregate, cement as the binder material, water as a catalyst, fine crashed stone and gravel are used to ease the pumping process, and some necessary additives are also included. Air circulator was used to create air bubbles in the mixture in order to increases the thermal resistance and decrease the specific weight of the concrete. On the other hand a liquefier was used to liquefy the mixture to the desired consistency instead of using excess water that causes cracks during the dehydration process of the concrete. It also helps increasing the strength of the material by decreasing the Water-Cement ratio "W/C" of the concrete as well. The additives were used according to the recommended amount in the manufacturer's manual with relation to the weight of the cement content of a mixture.

2.2.3 Mixture Design

The experimental mix design work was conducted in a laboratory. With the aid of a pan mixer, the first mixture was prepared and was casted in cubic containers having side lengths of 15cm. Next day the concrete blocks were placed in a curing tank of water with nearly constant temperature (between 20 and 22˚C). In standards, water treatment in a curing tank should last 28 days before testing the compressive strength of a concrete specimen. Compressive strength of the product was undesirably low, thus the amount of cement in the mixture was increased by %25. Upon testing the specimen of the second trial, the compressive strength was fair but still not enough, though; it was decided to test the possibility of pumping the mixture in hand. The formula was prepared for 2 m^3 and inserted to the program to be dispatched. The mixture was good but needed more water for greater slump value. The concrete pump used for the test was a mobile, piston type pump. It has two hydraulically powered pistons to suck and pump the concrete to 37 meters high above its level. As in every hydraulic system there is a barometer to check and control the pressure delivered from the pump to the system during the idle and working conditions of the machine. The first pumping trial was a failure but during the trial the barometer's pointer was indicating the maximum. The pumping was stopped and the material in the piston was taken to the laboratory for inspection. Technically, in practice, traditional concretes would behave with about %10 error than its behavior in the laboratory environment.

In the case of light weight concrete it may increase to more than %50. Pumice is a very porous material. Under high pressure, water tends to penetrate and reaches to the core of the pumice grains. In order to solve this problem and to maintain the consistency of the mixture, pre-wetting of the pumice aggregate is required.

As most of the control systems of the automated patching plants have a sequence for the mixing operation of ordinary concretes. In a closed loop system a PLC program sends signals to the actuators and upon the respond of the feedback signals, from sensors or timers, the PLC program completes the chain of sequences. Fortunately, the computer program connected to the PLC enabled the changes needed to be done for the order of the PLC sequences, except for the additives which couldn’t be put in the required order and subsequently added manually.

Pre-wetting of the aggregates was useful for three purposes;

1. Acquire a saturated aggregate to prevent the slump loss before pumping and water loss under pumping pressure, and thus maintain the consistency.

2. Prevent cement from filling the porous surface of the pumice aggregates to provide a maximum use of the cement added to the mixture.

3. Preparing additives comes in the mixing sequence before water. Indeed, after preparing the amount of additives they mix with the prepared water before the concrete mixing process starts, which employs that a great amount of those additives would be absorbed, as well as water, by the aggregates without

serving the actual purpose sought from them. For this reason additives were added manually after each dispatching process.

The first trial, after the changes took place, gave better but results were still unsatisfactory, the pressure indicator was at the maximum all the time and pumping process end up with hydraulic hose damages.

After couple of failures, adjusting the aggregate appeared to promise good results. Pumice's absolute porosity reached 65% of its volume, but the apparent porosity reached 45% of its volume. Pre-wetting for the aggregate for 40 - 60 seconds or even for a couple of minutes wouldn't bring the grains to saturation. Again high pressure would force water in causing the same difficulties as well. Adding excess water to compensate for the lost water during the pumping process didn't work since most of the bigger grains floated on the top causing separation in the mixture. The floating grains have been extracted and taken to the laboratory for investigation. Most of the grains were of bigger sized and by crushing them, it was noticed that they were not saturated, i.e., they have ability to absorb more water. As a result, bigger sized aggregates were not used in the concrete mixture. The answer to the question what should be the maximum aggregate size is given below. The aggregates were sieved and classified according to the maximum diameter sizes as 0-2, 2-4, 4-8, 8-12, and 12-16 mm. The pumice aggregate were gently put in water according to their sizes and their sinking times were recorded. The grains had the following timing for sinking. Two sec for grains with 0-2mm diameter, 5 sec for 2-4mm, 10 sec for 4-8mm , 25 sec for about 90% and 50 sec for the rest of the 8-12mm. The rest of the grains, with diameters more than 12mm, took longer time to sink and some of them floated for hours. From the results presented above, excluding the grains having diameters of 12mm or more from the aggregate appeared to be logical. This action results in fining the composite's aggregate and apparently results in increase in the overall surface area of the aggregates for the same volume. Thus, more cement is needed to cover this area in order to have better consistency for a complete reaction and for a maximum compressive strength.

As a result of fining the aggregate and increasing the cement amount in the composite, an increase of about 10% in the specific weight of the light concrete was recorded. In the field, the prepared formula (i.e., mixture) by carefully adjusting mixing time and careful sequencing in the mixing stages indicated better results. The mixture maintained its consistency and the pump could deliver it but with high pressure (i.e. 80% of the maximum pressure). According to the pump manufacturer, high pressure is not desirable and could damage components of the hydraulic system of the concrete pump.

To get a good mixture for the proper pumping pressure, experimental work was continued. Bringing to mind that the main aim from this project was to create a pumpable, sustainable, and a thermal insulator light weight concrete, care was taken in every step in altering the process. Although the last product was pumpable, its compressive strength was not enough for the application it was designed for. Some fine crashed stone was added to the mixture in order to increase the compressive strength of the light concrete. Cement content, and thus the liquefier amount was also increased as the aggregate was increased.

2.2.4 Results

After a couple of trials, the desired concrete mixture was found and relations for the specific weight vs. pumpabilty (Figure 1), the specific weight vs. compressive strength (Figure 2), and the specific weight vs. thermal conductivity (Figure 3) are presented. From the figures it is clear that the increase of the specific weight of the concrete results in an increase in the compressive strength and a decrease in the thermal conductivity and the pressure needed to pump the mixture. Conductivity results obtained from the experimental work are presented in the following chapter.

It should be noted that the results obtained in this work may have different values if different pumice aggregate from different places in the world, even from different places in Turkey are used. This is because pumice from different places would have different structure, porosity, and thus, different specific weight.

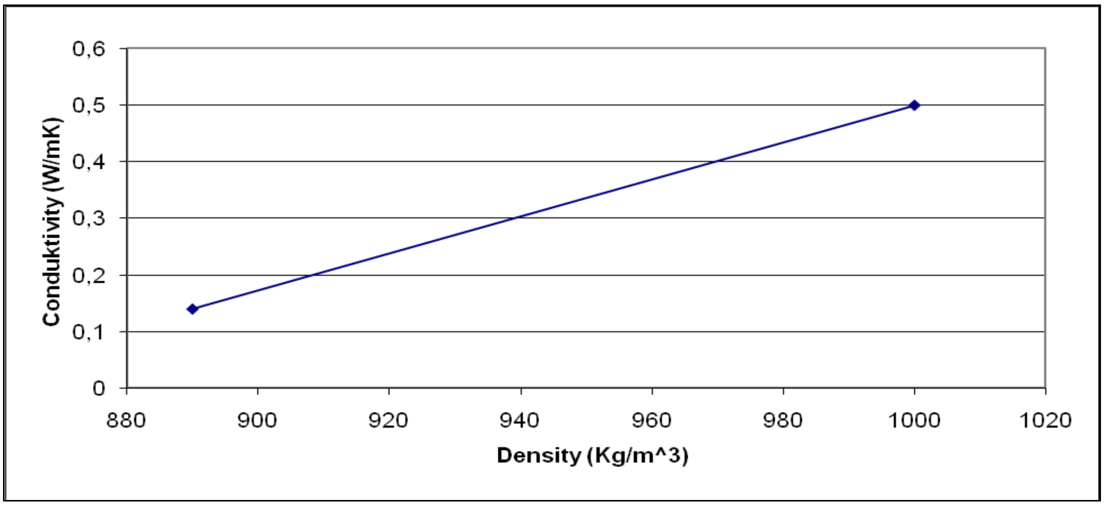

Figure 1: Conductivity vs. density of pumice concrete

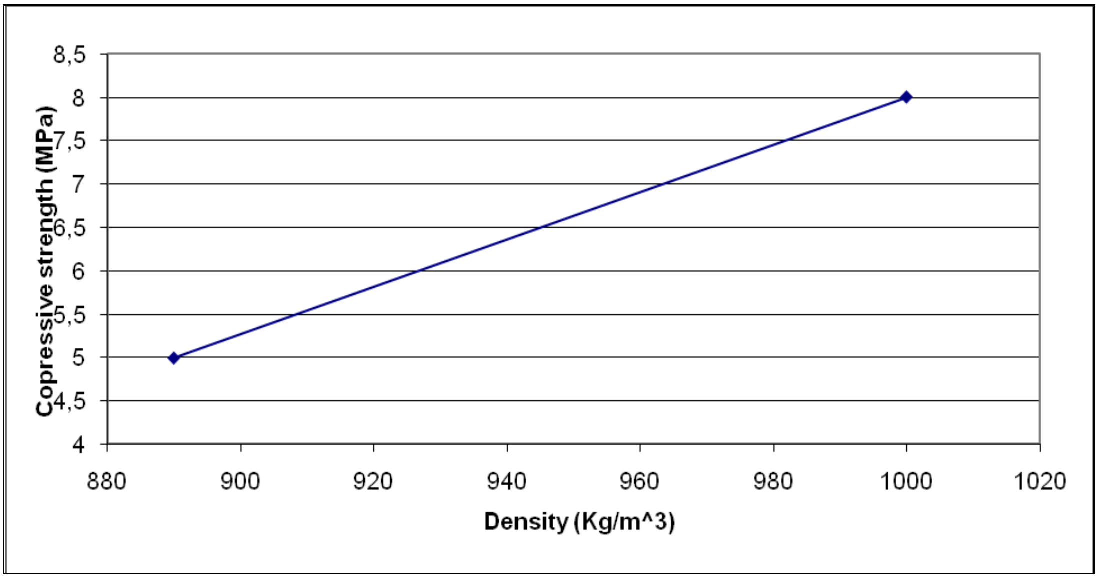

Figure 2: Compressive strength verses density of pumice concrete

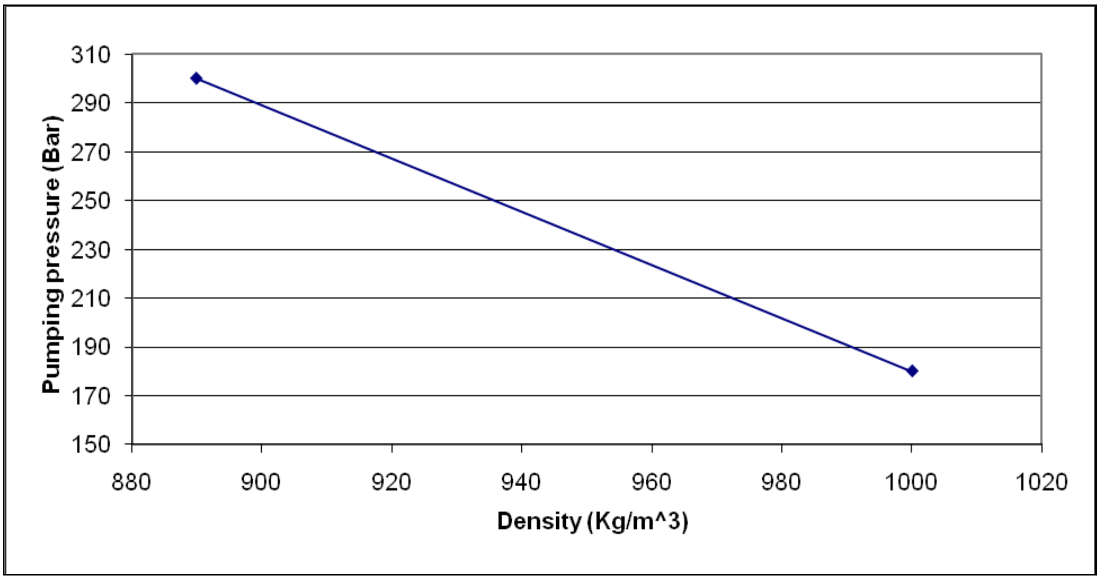

Figure 3: Pumping pressure needed to pump the concrete vs. density of pumice concrete

Chapter 3

MATERIAL TESTING AND PROPERTIES

3.1 Introduction

Heat is a form of energy that can be transferred from one system to another, through their boundaries, as a result of temperature differences. Heat transfer rate is directly related to the physical properties of the barrier between two mediums as well as the temperature difference between them. The most important of these properties is the thermal conductivity "*k*" of the barrier's composite. In buildings, the overall heat transfer coefficient "U-value" of the construction envelope is the main factor which characterizes the building's thermal behavior. The lower the U-value of an envelope, the higher the resistance to the heat transfers through it.

3.2 Conductivity of a Building Material

It is essential to use construction materials with low conductivity in order to get an optimum thermal comfort indoors. It is important as well to be aware of the fact that thermal conductivity changes with the change in the structure and heat capacity of the construction material.

3.2.1 Conductivity Determination

There are several ways for predicting the conductivity "*k*" of any building material. Some of them are analytical based and others are experimentally determined in laboratories. Among the wide range, the most common methods used are the followings:

a) Using the plaque technique,

b) Calibrated Hotbox technique,

c) Numerical technique-based on the geometry and on some of the material specifications.

3.2.1.1 The Plaque Technique

Thermal conductivity determination using the plaque technique is given in several standards such as, ISO8302 or TS388 April 1977 standards. The results from that test would be calculated according to the TS415 standards of calculating the conductivity and the heat transfer resistance of a building material. This technique is usually preferred for determining the conductivity of a solid bulk material rather than a hollow one. This method also gives acceptable results for hollow materials as well.

3.2.1.2 Hotbox Technique

This technique tests the resistance of material against heat transfer for both steady state and transient states. It allows testing a whole building element's thermal conductivity and the overall thermal resistance to heat transfer and therefore the overall thermal behavior of a building composite. Thus, this method is advantageous since it treats walls, for example, as a whole no matter what the structure of the construction elements are, in turn, it gives more realistic results compared to other methods. Using this method, the effect of paste, plaster, and mortar is considered experimentally rather than analytically.

The hotbox apparatus consists of two boxes see Figure 4. One of which is hot and the other is cold box-representing the indoor and the outdoor environments. Both are separated and super insulated. Steady-state hotbox test is normally conducted by maintaining constant indoor and outdoor temperatures. Results are to be calculated from data collected when specimen temperatures reach equilibrium and the rate of heat flow through the test wall is constant. Further details of the testing procedure, conditions, and calculations can be found in ISO 8990 standard.

Figure 4: Hot Box apparatus available in the Civil Engineering Department at the EMU

3.2.1.3 Numerical Method

Thermal conductivity of a composite is calculated by considering the thickness, area, and thermal conductivity of each element in the composite. Thus, multiplying each result by the percentage area it occupies gives the average thermal conductivity for that composite. The European standard EN 1745 gives two numerical methods for calculating the overall thermal conductivity of composite building elements using measured values and tabulated values based on density. K. Ghazi Wakili believes that in any case, using numerical methods should not give values less than those obtained experimentally. He has experimentally tested the thermal conductivity of a wall made of perforated porous clay bricks using the hotbox method and compared the result with those obtained using numerical methods in EN 1745. The results lead to a proposal for refinements of the model chosen for numerical analysis since the results obtained numerically were advantageous [13].

3.2.2 Conductivity Tests

The aim of this experiment is to test the conductivity of some of the construction materials available in the local market. The heat transfer coefficients are required for HVAC design and identifying heat transfer coefficients of locally available construction materials is necessary for proper heating/cooling load calculations. In this study a simple heat transfer method is used to predict the heat transfer coefficients of the materials. An insulating box was constructed where the specimens are placed. Five faces of the specimen placed in the box are insulated and one face is exposed to ambient. Heat source placed inside the box at the opposite side of the un-insulated face provides heating. Temperature measurements at the hot (i.e., surface where heat is supplied) and at the cold surface (i.e., surface exposed to the ambient) are recorded by using thermocouples. Then using heat transfer equations the overall heat transfer coefficient of the material can be obtained. Details of the calculation process are explained later in the chapter. The specimens and setup is explained in brief in the following subsections.

3.2.2.1 Specimens

Four specimens having different composites have been tested for their thermal conductivities. Each specimen was heated to 105 ^{o}C for 24 hours to dry the specimen in order to eliminate the effect of water content in the structure. Drying process is very important as water droplets and moist would replace air voids thus increasing the thermal conductivity of the material. Water's thermal conductivity is 20 times greater than that of air. The physical specifications of the specimens used in this test are given in Table 2. These specimens were tested in a box that provides heat flux from one side and where the opposite side is subjected to the ambient temperature with all other sides insulated.

Table 2: Physical specifications of the tested specimens.

Spec-imen	Materials	Length (cm)	Width (cm)	Height H (cm)	Volume (cm^3)	weight (dry) (g)	specific weight (kg/m^3)
#1	Regular concrete	30	10	5	1500	3360	2240
#2	high density pumice concrete	30	10	5	1500	1506	1004
#3	low density pumice concrete	30	10	5	1500	1344	896
#4	foam concrete	30	10	5.8	1740	928	533

3.2.2.2 Heating Element

Flexible Heater-type (Silicone rubber SRFG4 12/5) heating element was used to create heat flux. The element is 10 cm wide 30 cm long and 0.5 cm thick. The heater's maximum heat flux intensity is of 0.8 W/cm^2 (Figure 5).

Figure 5: Heating element.

3.2.2.3 Insulation Box

As mentioned earlier five faces of the cubic shaped specimens were insulated. An Insulation box was constructed by using materials having low thermal heat transfer coefficients. Several sheets of the insulating material were glued layer after layer and a cavity was created to place the specimen, see Figure 6 .The heating element was placed and centered inside the box and the specimen fitted with thermocouples was placed on top of it and the setup was carefully sealed to prevent infiltration heat losses See Figures 7 and 8. All probable heat leak from the box and the specimens were minimized by tightly sealing the cracks and edges.

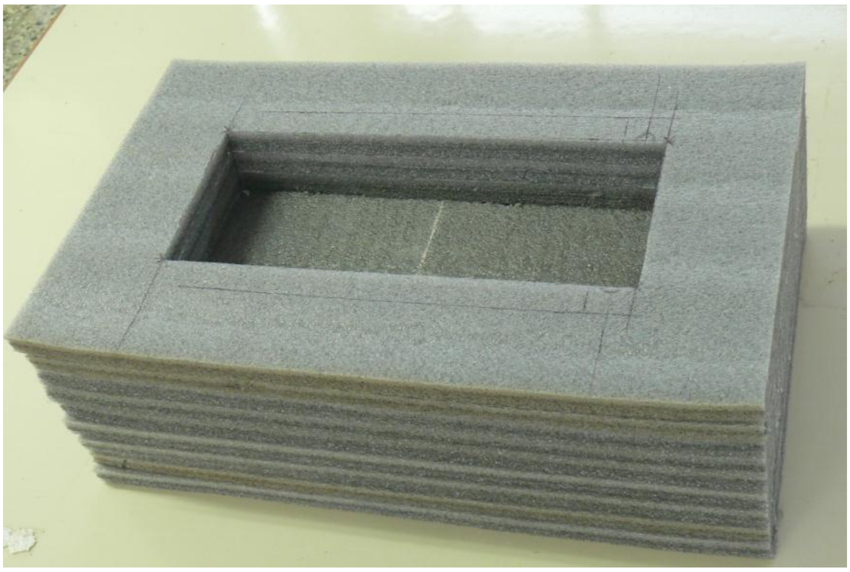

Figure 6: Insulating sheets forming the insulation box.

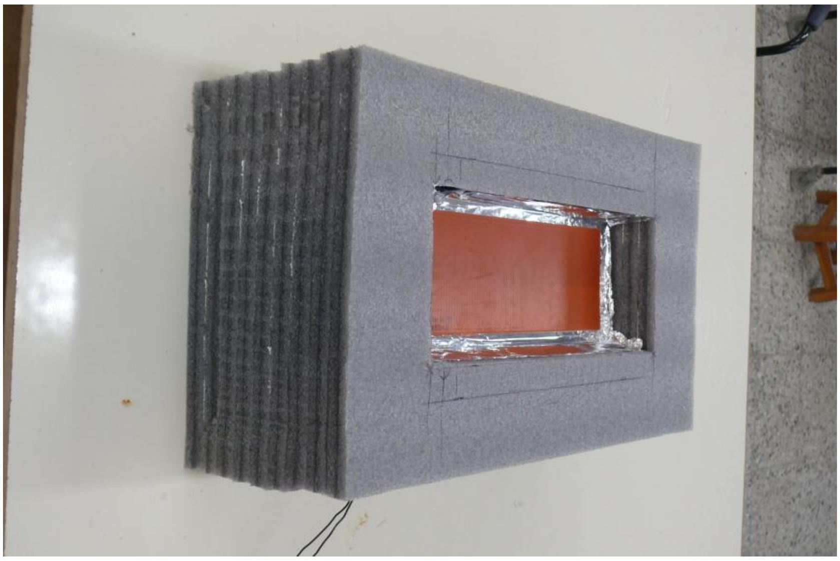

Figure 7: Heating element installed in the box.

Figure 8: The specimen inserted, fitted, and well sealed (except one surface).

3.2.2.4 Power Supply

Energy has been provided to the heating element by means of a variable voltage transformer which is a programmable DC PSU type TSX3510P manufactured by TTI (THURLBY THANDAR INSTRUMENTS) (see Figure 9).

A formula provided in the manufacturer's manual given below was used in order to determine the actual wattage developed at applied voltages lower than the rated one.

$$P_A = P_R \times \frac{V_A^2}{V_R^2} \tag{3.1}$$

Where:

P_R is the rated Wattage, P_A is the actual wattage, V_R is the rated voltage and V_A is the actual voltage.

The actual wattage for different voltages used during the experimental work is presented in Table 3. Multiplying the wattage intensity of the element with its area gives the rated wattage (P_R).

P_R = 0.8 *W/*cm^2 x 10 cm x 30 cm = 240 *W*,

The rated voltage of the heating element is provided in the product specification is V_R = 115 *V*.

Table 3: Actual voltage provided for the heating element and corresponding produced actual wattage

V_A (*V*)	10	11	12	13	14	15	16
P_A (*W*)	1.81	2.20	2.61	3.07	3.56	4.08	4.65

Figure 9: Variable voltage transformer (programmable DC PSU type TSX3510P-TTI).

3.2.2.5 Temperature Measurements

Nine copper-constantan T-type thermocouples were used for temperature measurements. Two thermocouples were placed at the surface facing the heat flux, two were placed at the un-insulated surface of the specimen, one on each four insulated faces, and the last one was used to measure the ambient temperature.

The other terminals of the thermocouples were attached to a ten channel data acquisition system - OMEGA series MDSSi8 see Figure 10.

Figure 10: A ten channel data acquisition box from OMEGA series MDSSi8.

3.2.2.6 Data Collection and Processing

Heating was achieved by using variable voltages from the power supply to the heating element. Temperature readings from the ten channel device were collected after 24 hours after every voltage adjustment to ensure that the specimens have reached to the steady state each time the heat flux were altered. Gathering data every 24 hours has the advantage of having ambient temperatures close to each other, and thus, due to the nearly close heat loss rates, provides more reliable data for comparison purpose.

The net heat transferred through the specimen (Q_{loss}) was less than P_A which was supplied from the heating element as heat lost (Q_{loss}) from the insulation box to the environment. Assuming that the rate of heat lost, from the specimen and the heating element, through the insulation material by conduction is equal to the rate of heat transferred from the surface of this insulation material to the environment by convection, Q_{loss} can be calculated as follows.

$$Q_{loss} = hA(T_{\infty 1} - T_{ins}) \tag{3.2}$$

Where

Q_{loss} : Rate of heat loss through the insulating box to the environment (W).
h : Convectional heat transfer coefficient (W/m.°C).
A : Total area of the insulation box that is exposed to the environment (m^2).
$T_{\infty 1}$: Ambient temperature (°C).
T_{ins} : Average temperature of the insulation box's surfaces (°C).

Then the thermal conductivity was determined for each heat flux and related temperatures were found from equations 3.3 and 3.4.

$$Q_{net} = kA(T_{s,av} - T_{i,av}) \tag{3.3}$$

And;

$$k = \frac{Q_{net}}{A(T_{s,av} - T_{i,av})} \tag{3.4}$$

Where;

Q_{net} : Rate of conductive heat transfer through a specimen (W).
k : Thermal conductivity (W/m.°C)
A : Surface area of any specimen (m^2).
$T_{s,av}$: Surface temperature of the specimen (°C).
$T_{i,av}$: Average temperature of the inner surface of the specimen (°C).

3.2.2.7 Results

Data collected were processed for each specimen and results were tabulated in Tables 4, 6-8.

Table 4: Collected and processed data for Ordinary Concrete.

Specimen #1	Readings					
	1ST	Average	2ND	Average	3RD	Average
V (Volts)	16.00		18.00		20.00	
I (Amperes)	0.31		0.35		0.39	
P_A (*W*)	4.65		5.88		7.26	
T01 (°C)	36.35	35.98	40.75	40.25	45.75	45.10
T03 (°C)	35.60		39.75		44.45	
T07 (°C)	29.15	29.40	32.00	32.20	34.95	35.20
T08 (°C)	29.65		32.40		35.45	
T04 (°C)	18.20	17.76	18.90	18.53	19.10	18.74
T06 (°C)	17.90		18.65		18.85	
T09 (°C)	17.15		18.00		18.15	
T10 (°C)	17.80		18.55		18.85	
$T_{ambient}$ (°C)	17.00		17.65		17.70	
Q_{loss} (*W*)	2.86		3.28		3.89	
Q_{net} (*W*)	1.79		2.60		3.37	
K (w/m.°C)	2.73		3.23		3.41	
T_{av} (°C)	32.7		36.2		40.2	
T_{diff} (°C)	6.58		8.05		9.90	

Figures 11-14 plots the conduction coefficients versus the temperature differences between the specimen inner and outer surfaces were plotted.

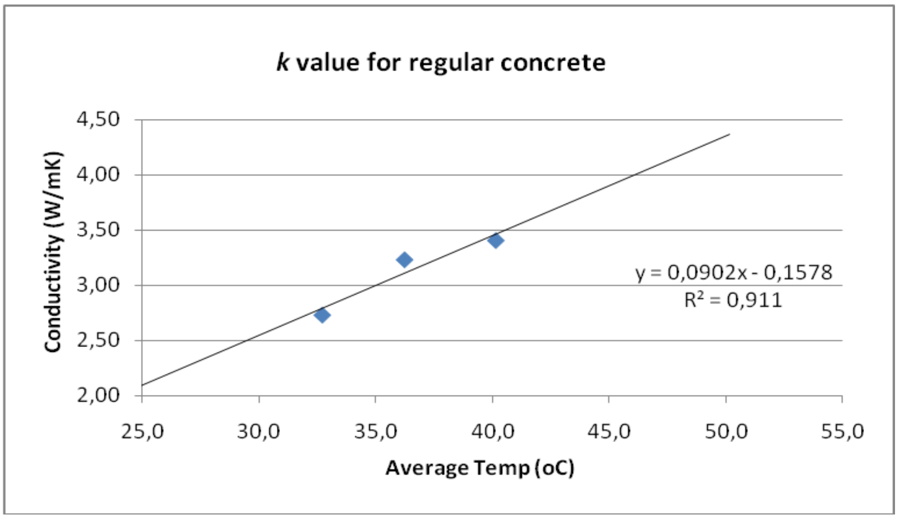

Figure 11: *k* value for regular concrete.

It is clearly seen in Fig 3.8 that the value of *k* of a specimen changes as temperature changes. The *k* value to be used in heating and cooling load calculations for a construction material can estimated by determining the average temperature between the expected maximum ambient temperature and the ideal inner temperature demanded for the structure. Assuming that the maximum outer temperature for Cyprus is 40 °C and the demanded inner temperature was 24 °C, the average temperature at which *k* value is determined would be T_{avr} = 32 °C (TS EN ISO 8990 and ATSM C 1363). From the equations of the lines fitted to the plotted results (see Figs. 3.8-3.11 and Tables 3.) for the tested specimens, *k* values can be found as:

Specimen #1: Regular concrete

$k = 0.0902T_{avr} - 0.1578$

$= 0.0902*32 - 0.1578 = 2.73$ W/m.°C

Specimen #2: High density pumice concrete

$k = 0.0377\ T_{avr} - 0.7058$

$= 0.0377 * 32 - 0.7058 = 0.50$ W/m.°C

Specimen #3: Low density pumice concrete

k = 0.0216T_{avr} - 0.5505

= 0.0216*32 - 0.5505= 0.14 W/m.°C

Specimen #4: Foam concrete

k = 0.0114 T_{avr} - 0.228

= 0.0114*32 - 0.228 = 0.14 W/m.°C

3.2.2.8 Error Analysis

Error in scientific measurement means the inevitable uncertainty that attends all measurements. As such, errors are not mistakes; one cannot eliminate them by being very careful. The best can be done is to ensure that errors are as small as reasonably possible and to have reliable estimate of how large they are. To estimate the inevitable occurrence of uncertainties in the measured data and the corresponding uncertainties in the results, the following methodology was used [20].

Supposing that the result R is a given function of the independent variables $x_1, x_2, x_3, \ldots\ldots, x_n$. Thus,

$$R = R(x_1, x_2, x_3, \ldots\ldots, x_n)$$

IF w_i represents the uncertainties in the independent variables, the uncertainty in the result (w_R) can be calculated using the following equation.

$$w_R = \left[\left(\frac{\partial R}{\partial x_1} w_1 \right)^2 + \left(\frac{\partial R}{\partial x_2} w_2 \right)^2 + \ldots\ldots + \left(\frac{\partial R}{\partial x_n} w_n \right)^2 \right]^{1/2} \tag{3.5}$$

The independent parameters measured in the conducted experiment are: the supplied voltage and current to the heating element, and the temperature differences between the specimens' surfaces. These independent variables were used in the determination of the flux applied to the specimens as well as the thermal conductivity value of them. T-type thermocouples with an accuracy of 0.01°C, a variable voltage transformer with an accuracy of 0.01v and 0.01A for voltage and current respectively were used in this study. The total uncertainty for the net flux applied to the specimens and for the corresponding thermal conductivity is as follows as processed according to the above equation.

$$w_{Q_{net}} = \left[(0.01v)^2 + (0.01I)^2 + (0.0511)^2\right]^{1/2} \tag{3.6}$$

$$w_k = \left[\left(\frac{1}{0.03\Delta T}\right)^2 \left((0.01v)^2 + (0.01I)^2 + (0.0511)^2\right) + \left(\frac{0.471 Q_{net}}{(\Delta T)^2}\right)^2\right]^{1/2} \tag{3.7}$$

The corresponding uncertainties for the acquired results are as given in Table 5.

Table 5: The total uncertainties in determining the thermal conductivity.

Readings	V	I	ΔT	Q_{net}	k	$w_{Q_{net}}$	w_k	$w_{Q_{net}}$	w_k
	volt	A	°C	w	W/m.°C	w	W/m.°C	%	%
#1	16	0,31	6,6	1,79	2,73	0,168	0,808	9,4%	29,6%
#2	18	0,35	8,1	2,6	3,23	0,187	0,741	7,2%	22,9%
#3	20	0,39	9,9	3,37	3,41	0,206	0,674	6,1%	19,8%

3.2.2.9 Discussion

The *(k)* value found for regular concrete is close to the values used as reference which is available in any heat transfer book (i.e., 2.6 W/m.°C) which validates the results obtained from the performed test.

Low density pumice concrete's specific weight is 12 % less than the high density pumice concrete and the corresponding decrease in value of *k* is about 72 %. The specific weight of the pumice concrete (specimen #3) is about 68 % greater than the foam concrete (Specimen #4), but the K values for both light concretes were found to be same.

Table 6: Collected and processed data for Dense pumice concrete.

Specimen #2	Readings					
	1ST	Average	2ND	Average	3RD	Average
V (Volts)	12.00		14.00		16.00	
I (Amperes)	0.24		0.27		0.31	
P_A (*W*)	2.61		3.56		4.65	
T01 (°C)	33.40		39.15		46.05	
T03 (°C)	33.30	33.35	38.95	39.05	45.85	45.95
T07 (°C)	22.15		24.35		27.15	
T08 (°C)	23.15	22.65	25.55	24.95	28.05	27.60
T04 (°C)	16.90		17.40		18.55	
T06 (°C)	16.70		17.40		18.55	
T09 (°C)	15.70		16.40		17.45	
T10 (°C)	16.60	16.48	17.25	17.11	18.45	18.25
$T_{ambient}$ (°C)	15.85		16.35		17.30	
Q_{loss} (*W*)	2.27		2.77		3.45	
Q_{net} (*W*)	0.34		0.79		1.20	
K (w/m.°C)	0.32		0.56		0.65	
T_{av} (°C)	28.0		32.0		36.8	
T_{diff} (°C)	10.70		14.10		18.35	

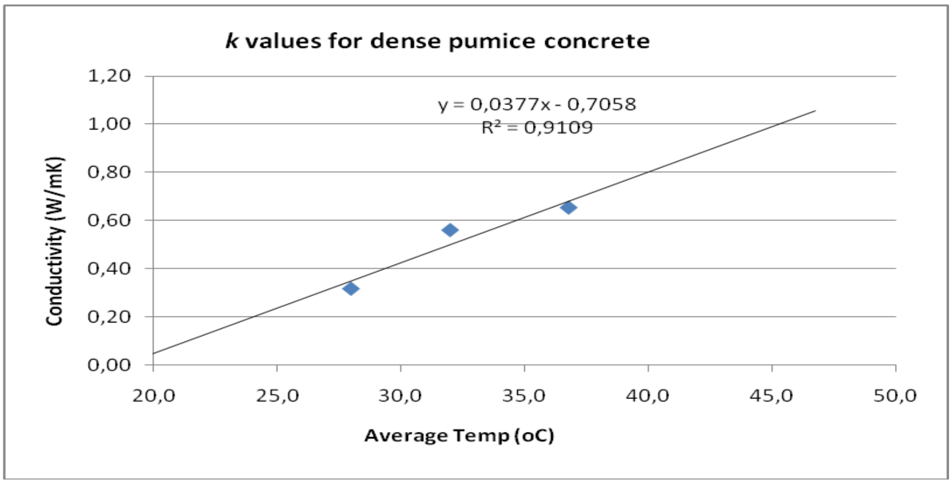

Figure 12: *k* values for dense pumice concrete

Table 7: Collected and processed data for light pumice concrete.

Specimen #3	Readings							
	1ST	Average	2ND	Average	3RD	Average	4TH	Average
V (Volts)	10.00		13.00		15.00		16.00	
I (Amperes)	0.20		0.25		0.29		0.31	
P_A (*W*)	1.81		3.07		4.08		4.65	
T01 (°C)	31.85	32.00	40.35	40.53	47.20	47.40	49.30	49.45
T03 (°C)	32.15		40.70		47.60		49.60	
T07 (°C)	21.50	21.35	22.30	22.18	23.75	23.55	23.95	23.65
T08 (°C)	21.20		22.05		23.35		23.35	
T04 (°C)	18.95	18.61	18.05	17.58	18.40	17.88	18.25	18.06
T06 (°C)	18.65		17.65		18.05		18.40	
T09 (°C)	18.20		16.85		16.85		17.35	
T10 (°C)	18.65		17.75		18.20		18.25	
$T_{ambient}$ (°C)	18.10		16.75		16.85		16.90	
Q_{loss} (*W*)	1.78		2.86		3.55		4.03	
Q_{net} (*W*)	0.03		0.21		0.53		0.62	
K (w/m.°C)	0.03		0.12		0.22		0.24	
T_{av} (°C)	26.68		31.35		35.48		36.55	
T_{diff} (°C)	10.65		18.35		23.85		25.80	

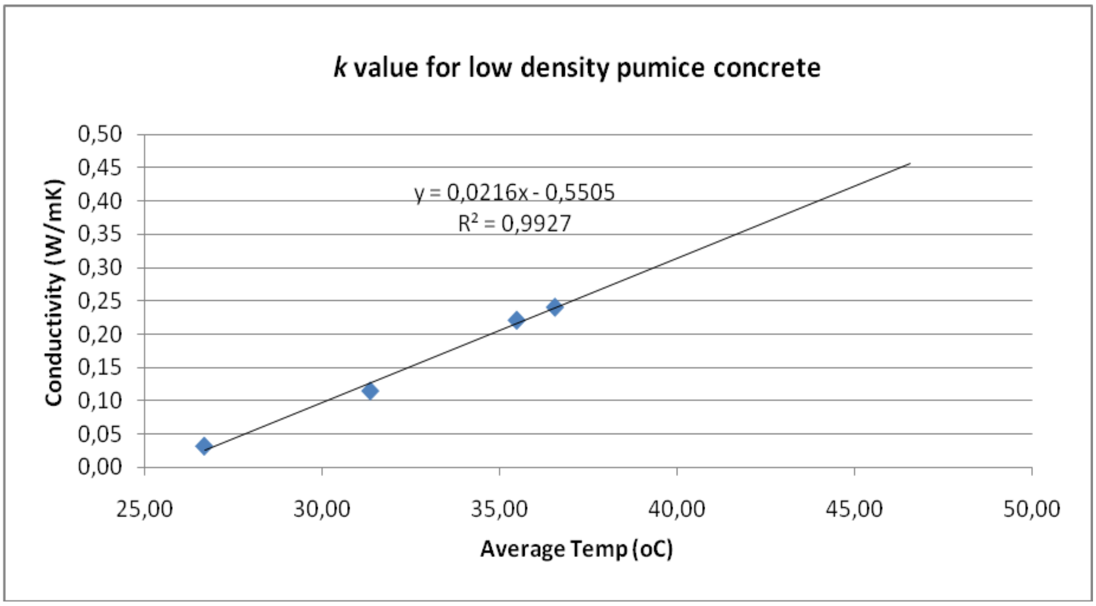

Figure 13: *k* values for light pumice concrete

Table 8: Collected and processed data for foam concrete.

Specimen #4	Readings					
	1ST	Average	2ND	Average	3RD	Average
V (Volts)	10.00		14.00		16.00	
I (Amperes)	0.20		0.27		0.31	
P_A (*W*)	1.81		3.56		4.65	
T01 (°C)	31.65	31.30	45.75	45.08	53.45	52.13
T03 (°C)	30.95		44.40		50.80	
T07 (°C)	17.95	18.00	20.15	20.15	20.20	20.98
T08 (°C)	18.05		20.15		21.75	
T04 (°C)	15.85	15.50	15.85	15.59	16.25	16.11
T06 (°C)	15.85		15.85		16.65	
T09 (°C)	14.95		14.85		15.30	
T10 (°C)	15.35		15.80		16.25	
$T_{ambient}$ (°C)	15.00		14.65		14.95	
Q_{loss} (*W*)	1.73		3.25		4.03	
Q_{net} (*W*)	0.08		0.31		0.62	
K (w/m.°C)	0.06		0.13		0.20	
T_{av} (°C)	24.65		32.61		36.55	
T_{diff} (°C)	13.30		24.93		31.15	

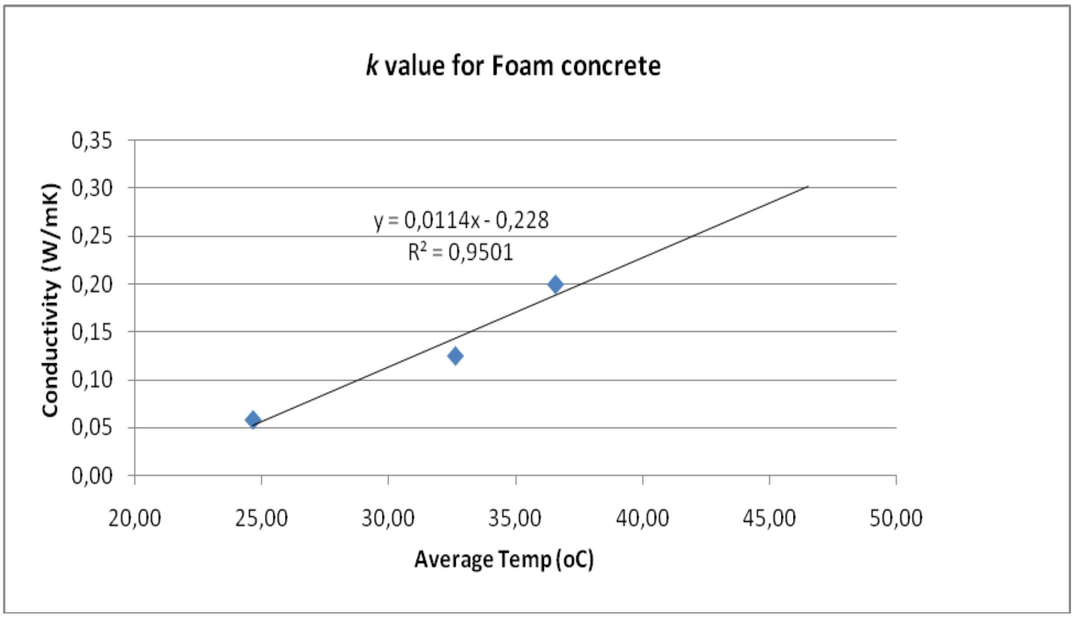

Figure 14: *k* values for Foam concrete

3.3 Thermal Diffusivity and Thermal Storage of a Material

The product (ρC_p), which is frequently encountered in heat transfer analysis, is called the heat capacity of a material. Both the specific heat (C_p) and the heat capacity (ρC_p) represents the heat storage capability of a material. But (C_p) expresses it per unit mass whereas (ρC_p) expresses it per unit volume, as can be noticed from their units, J/kg.˚C and J/m^3.˚C respectively.

Heat storage capacity of the construction elements that are used in constructing the building enclosure is an important issue affecting the thermal comfort of the occupancies of that living space. For a better resistance to the heat transfer through building sections (wall, slab, roof, etc.) the overall heat storing capacity of the materials composed in these sections should be as low as possible. Different materials have different heat storage capacities due to the differences in the unit weight and the specific heat capacity for those materials.

Another material property that appears in heat transfer analysis is the thermal diffusivity, which represents how fast the heat diffuses through a material and it is defined as,

$$\alpha = \frac{Heat\,conducted}{Heat\,stored} = \frac{K}{\rho C_p} \tag{3.5}$$

Thermal conductivity (*k*) of a material represents how well a material conduct heat, whereas heat capacity (ρC_p) represents how much energy a material stores per unit volume. Therefore, the thermal diffusivity of a material can be considered as the ratio of the heat conducted to the volumetric heat storage of a material. The larger the thermal diffusivity is, the faster the propagation of heat into the material. Whereas, a smaller value means that heat is mostly absorbed by the material and a small amount of heat will be transferred through it. From the equation 3.5, it is clear that thermal diffusivity depends on two values, the heat conductance and the heat storage capacity of a material. This means that any increase in *k* or decrease in (ρC_p) would increase the thermal diffusivity of a material.

3.4 Cooling Time

Cooling time of a structural element is as important as its low heat storage capacity from heat comfort point of view. It is vital that a building element loses its stored heat in as longer period of time as possible. Practically, cooling time of a material is inversely related to its conductivity since it would conduct the pre-stored heat out of its body in a fast manner. In literature, cooling time of a material is known as the ratio of the storage capacity of a material to its resistance to heat transfer. Cooling times for some common building materials subjected to a temperature difference of 30 ^{o}C are given in Table 9 [18].

Table 9: Cooling time durations for some of building elements

Materials	Density	Cooling time
	(kg/m3)	(hour)
Building rock	2800	10
Regular concrete	2300	17
bricks	1200	21
BimsBlock	600	32
BimsBlock	800	31

In order to examine the cooling behavior of the pumice concrete, tests were performed on two pumice concrete specimens with different specific weights and tests were conducted using a regular concrete specimen for comparison purpose (see Figure 15). The physical properties of the tested specimens are given in table 10.

Table 10: Physical properties of the tested specimens.

		L (cm)	W (cm)	D (cm)	Volume	Weight (dry) (g)	Specific weight (kg/m3)
Spec. 1	Regular concrete	15	10	5.1	765	1680	2196
Spec. 2	High density pumice concrete	15	10	5	750	753	1004
Spec. 3	Low density pumice concrete	15.2	10	5	760	672	884

3.4.1 Testing Procedure

Specimens were drilled 7.5 cm deep from the surface having the smallest area in order to measure the center's temperature by inserting thermocouples in those holes (Figure 16). The specimens were put in an oven and subjected to 105 °C temperature for 48 hours. The dried specimens were connected to thermocouples for testing. Temperatures were taken, every thirty minutes and tabulated in Table 11 and plotted in Figures 17 and 18. The procedure was repeated three times for reliability.

Figure 15: The specimens used in the cooling test.

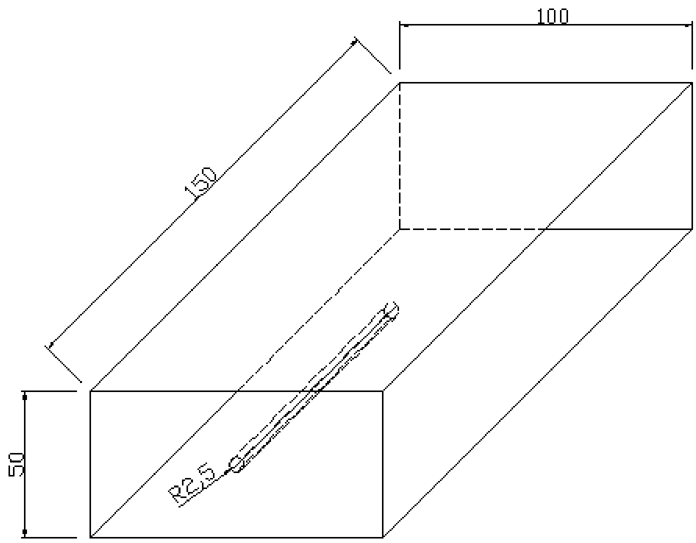

Figure 16: Illustration of the hole drilled into the specimens in order to insert the thermocouples

Table 11: Data collected for the cooling time test (Temperature verse time intervals)

Readings		Time Intervals (min)	0	30	60	90	120	150	180	210	240	270	300	330
#1	Temp. °C	Spec. 1	101,7	63,6	38,9	32,9	27,3	24,3	22,0	21,2	20,5	19,9	19,5	19,2
		Spec. 2	101,5	54,2	30,7	26,4	23,2	21,8	20,8	20,5	20,1	19,8	19,6	19,4
		Spec. 3	101	53,9	29,8	25,9	23,0	21,8	20,9	20,7	20,3	20,0	19,8	19,6
		Ambiant temp.	20,3	19,6	19,1	18,9	18,9	18,7	18,5	18,4	18,1	18,0	17,9	17,7
#2	Temp. °C	Spec. 1	100,0	57,0	40,0	31,7	27,7	25,4	24,0	23,0	22,4	22,0	21,6	21,4
		Spec. 2	113,0	57,0	35,3	27,3	24,5	23,4	22,7	22,3	22,0	21,6	21,3	21,1
		Spec. 3	113,0	54,0	33,0	27,0	23,6	22,7	22,3	22,0	21,7	21,4	21,1	21,0
		Ambiant temp.	18,0	18,3	18,0	18,7	18,8	18,9	19,3	19,2	19,2	19,3	19,3	19,2
#3	Temp. °C	Spec. 1	93,5	57,6	39,9	31,2	26,6	23,9	22,2	21,0	20,4	20,0	19,7	19,6
		Spec. 2	114,7	62,0	36,5	27,4	23,7	21,9	21,0	20,5	20,1	19,9	19,7	19,7
		Spec. 3	111,5	59,1	34,4	26,3	23,0	21,6	20,8	20,2	20,0	19,8	19,8	19,5
		Ambiant temp.	19,5	19,0	18,4	18,4	18,3	18,2	18,0	18,0	17,9	17,9	17,9	17,7
Average	Temp. °C	Spec. 1	98,4	59,4	39,6	31,9	27,2	24,5	22,7	21,7	21,1	20,6	20,3	20,1
		Spec. 2	109,7	57,7	34,2	27,0	23,8	22,4	21,5	21,1	20,7	20,4	20,2	20,1
		Spec. 3	108,5	55,7	32,4	26,4	23,2	22,0	21,3	21,0	20,7	20,4	20,2	20,0
		Ambiant temp.	19,3	19,0	18,5	18,7	18,7	18,6	18,6	18,5	18,4	18,4	18,4	18,2

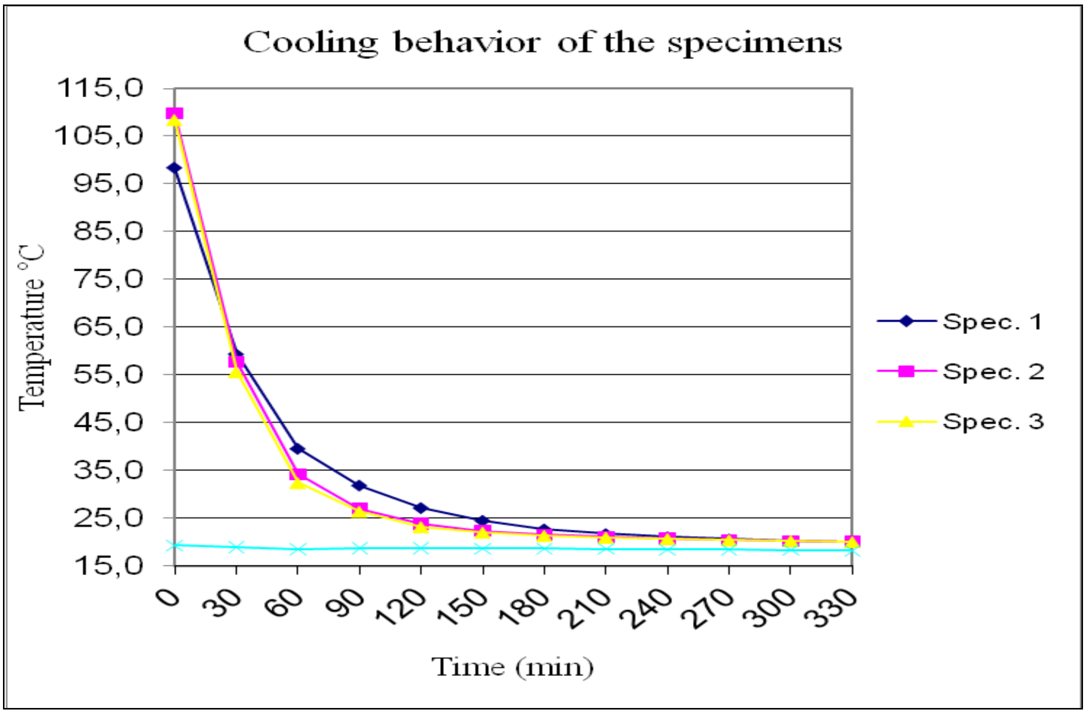

Figure 17: Average cooling time vs. temperature of specimens from time equals to 0 min.

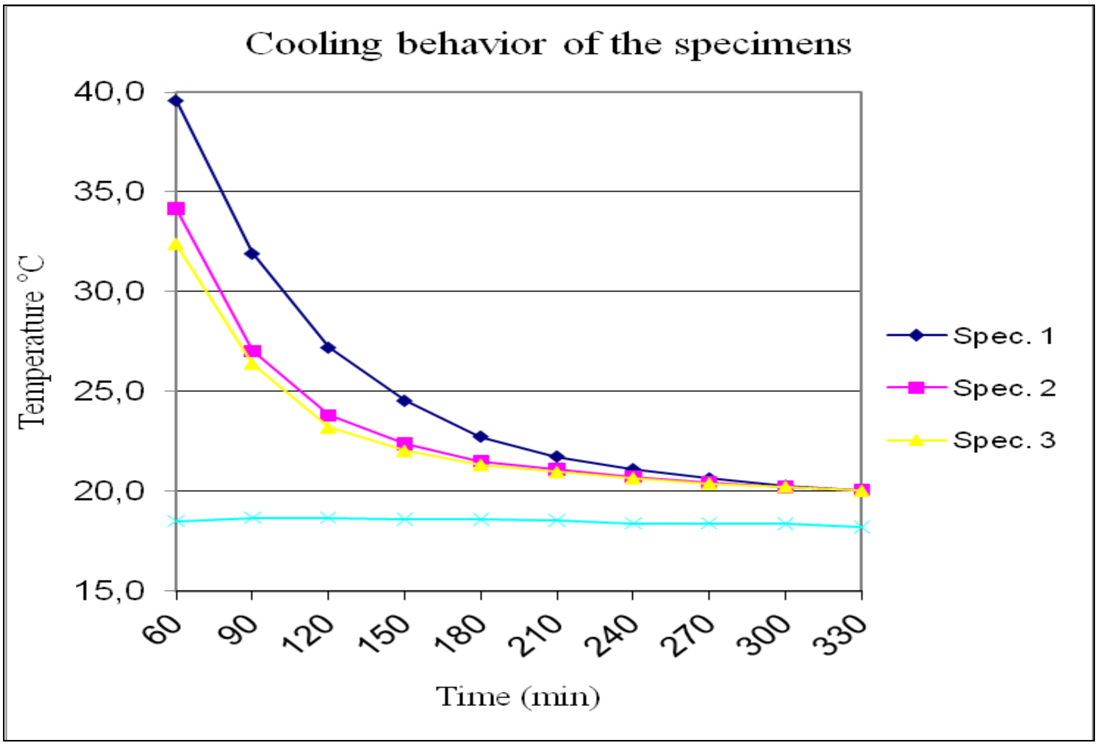

Figure 18: Average cooling time vs. temperature of specimens after 60 min.

3.4.2 Results and Discussion

From the plotted results for the Cooling test the followings were observed:

Though, at lower temperatures (i.e., temperatures less than 45 °C), temperature drop in each specimen follow similar paths; during the first 60 min. temperatures of the specimens #2 and #3 dropped more quickly than the temperature of specimen #1. In reality reaching temperatures up to 105 °C is not realistic and need not to be considered in residential buildings. The decrease in temperature of specimen #3 started to slow down compared to that of specimen #2 and that appears early after the first two hours.

The temperature of the specimen #1 starts to drop below that of the other specimens after four and a half hours. Although the temperature of specimen #3 started one degree less than that of specimen #2, it ended with nearly the same temperature. That could be related to the difference in their specific weights.

Chapter 4

LOAD CALCULATIONS

4.1 Overview

The actual heat loss problem is transient because the outdoor temperature, wind velocity, and sunlight are constantly changing. Heating load calculation is easier compared to cooling load calculations if the solar energy gains are not counted for during the heating season. The presence of solar gains makes it difficult to estimate the exact cooling load in summer.

Cooling load calculation methods have been developed and improved for decades. From the Total Equivalent Temperature Difference/Time Averaging (TETD/TA) method developed by ASHRAE in 1967, U.K.'s Admittance Method developed in 1968, Transfer Function method (TFM) developed by ASHRAE in 1972, and Cooling Load Temperature Difference/Solar Cooling Load/Cooling Load Factor (CLTD/SCL/CLF) method which is again developed by ASHRAE in 1977, to the most recent Heat Balance method (HBM) and Radiant Time Series Method (RTSM), all of them can be used in estimating cooling load for buildings. But even the most recent of the developed methods are subjected to modifications by researchers to the date. The following sections describe the methodology of heating and cooling loads calculations used in this study.

4.2 Heating Season

Generally heat loss from a residence occurs by conduction and convection through the enclosure and by infiltration of cold air inside through its boundaries, cracks.

4.2.1 Heat Loss through Opaque Surfaces and Windows

The easiest way to estimate the heat loss of a residence is to consider it as a simple heat transfer problem. Most of heat loss would occur at night. Therefore basic heat transfer relation equation 4.1 is considered to be applicable for such a problem.

$$Q = \Sigma(U_i A_i \Delta Ti)/1000 \tag{4.1}$$

Where:

U_i : the overall heat transfer coefficient for each part of the enclosure.
A_i : the surface area for each section.
ΔTi : the average assumed temperature differences for design purposes.

Thermal resistance concept (see Figure 19) is usually used to determine the rate of heat transfer through wall composite that consists of different layers. R value can be obtained by using Equations 4.2 and 4.3. The overall heat transmission of a building "U-Value" on the other hand represents the transmission of heat through the materials, which compose the building's "envelope," or outer shell.

"U" value has an inverse relationship to "R" value as can be seen in the Equation 4.4

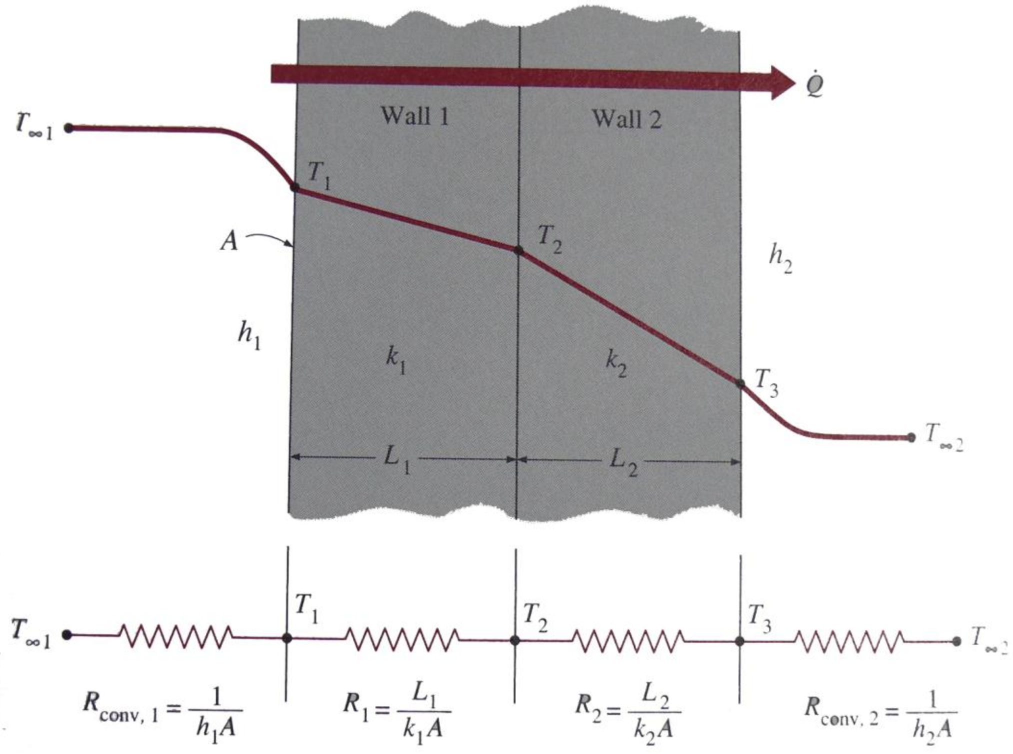

Figure 19: Thermal resistance concept

$$R_{total} = R_{conv,1} + R_{wall,1} + R_{wall,2} + R_{conv,2}$$

(4.2)

Where R_{total} is the total resistance to heat transfer of the combination.

$$R_{total} = \frac{1}{h_1 A} + \frac{L_1}{k_1 A} + \frac{L_2}{k_2 A} + \frac{1}{h_2 A} \tag{4.3}$$

$$U = \frac{1}{AR_{total}} = \frac{1}{\frac{1}{h_1} + \frac{L_1}{k_1} + \frac{L_2}{k_2} + \frac{1}{h_2}} \tag{4.4}$$

Among the various sections of a building envelope, windows offer the least resistance to heat flow. Thus special care should be taken when deciding about area and material used for windows. When considering their U-value, windows are divided into three regions; frame, edge of glass, and center of glass. Overall U factor of the window is calculated by using Equation 4.5.

$$U_{window} = (U_{center}A_{center} + U_{edge}A_{edge} + U_{frame}A_{frame})/(A_{window}) \qquad (4.5)$$

For simplicity, using a simulation program, ASHRAE presents tabulated values for the overall U factor of different types of windows.

Although space heating is a transient problem, generally steady state assumption is used by assigning constant values for outside and inside parameters for its calculations, and thus, all surfaces that are exposed to outdoor conditions are treated as of a simple one dimensional heat conduction problem.

4.3 Cooling Season

Heat gain to a residence known to be in the form of sensible heat gains, tending to cause a rise in temperature, or latent heat, causing an increase in moisture content. Cooling load calculation generally takes care of the following factors:

- Conduction and convection through walls, windows, etc;
- Absorption of solar radiation on walls, roofs and etc;
- Heat emissions of occupants;
- Infiltration of warm outdoor air;
- And heat emission of lights and other electrical or mechanical appliances.

This project focuses on the first two factors and considers the effect of optimizing the enclosure's structure of buildings using available construction materials.

4.3.1 Cooling Load Calculations

Radiation from the sun is the major source for the heat gain of a building since it is the main heat source of the earth.

4.3.2 Heat Gain through Opaque Surfaces

Transfer function method procedures in building cooling load calculation are used to calculate the hourly heat gains through opaque exterior surfaces.

To calculate the hourly average gain conducted through a building's exterior walls and roof, the following procedure is used (ASHRAE, 1993), [14]:

- The outdoor ambient condition is represented by sol-air temperature
- A constant indoor space temperature is assumed for cooling load calculation
- Interior and exterior surface combined coefficients are both set as constants

Generally, the temperature of any surface receiving solar radiation is always greater than that of the ambient. So calculations of heat flow should consider the surfaces' temperature rather than the ambient. This is done by replacing the ambient temperature in the heat transfer relation through the walls and roof by the sol-air temperature, which is defined as the equivalent outdoor temperature that gives the same rate of heat flow through a surface (Equation 4.6). Considering that the ambient temperature is equal to the surrounding temperature, sol-air temperature can be calculated using equation 4.7.

$$Q = UA(T_{s-a} - T_i) \tag{4.6}$$

$$T_{s-a} = T_{ambient} + \frac{\alpha_s q_{solar}}{h_0} \tag{4.7}$$

Where:

T_{s-a} : Sol-air temperature (˚C)

$T_{ambient}$: Ambient temperature (˚C)

q_{solar} : Solar radiation intensity (W/m^2)

α_s : Solar absorptivity.

h_0 : Heat transfer coefficient for combined convection and radiation on the outer surface of a building (W/m.°C)

As it can be noticed from the relation above, sol-air temperature of a surface depends greatly on the absorptivity of the surface for solar radiation. It is clear that dark surfaces absorb most of the incident solar radiation while light surfaces reflect most of it.

The effect of color on differently oriented surface temperatures is shown in Table12 for each month of the year. The peak solar radiation intensity used in Table 4.1 is calculated according to data abstracted from tables given in Carrier's handbook [22].

Table 12: Sol-air temperature for surfaces with different orientations (T_{s-a})

	T_{av}	Peak solar radiation intensity					Sol-air temp T_{s-a} Dark surface, α_s /ho =0.052					Sol-air temp T_{s-a} Light surface, α_s /ho =0.026				
	(˚C)	(W/m^2.˚C)					(˚C)					(˚C)				
		N	E	S	W	H	N	E	S	W	H	N	E	S	W	H
Jan.	12.3	23	405	610	405	466	13	33	44	33	37	13	23	28	23	24
Feb.	12	28	482	576	482	578	13	37	42	37	42	13	25	27	25	27
Mar.	14.2	34	576	460	576	741	16	44	38	44	53	15	29	26	29	33
Apr.	17.4	41	614	310	614	843	20	49	34	49	61	18	33	25	33	39
May	21.8	58	616	186	616	899	25	54	31	54	69	23	38	27	38	45
Jun.	25.7	69	606	141	606	914	29	57	33	57	73	28	41	29	41	49
Jul.	28.2	58	616	186	616	899	31	60	38	60	75	30	44	33	44	52
Aug.	28.5	41	614	310	614	843	31	60	45	60	72	30	44	37	44	50
Sep.	26.1	34	576	460	576	741	28	56	50	56	65	27	41	38	41	45
Oct.	22.8	28	482	576	482	578	24	48	53	48	53	24	35	38	35	38
Nov.	17.7	23	405	610	405	466	19	39	49	39	42	18	28	34	28	30
Dec.	13.7	21	359	616	359	405	15	32	46	32	35	14	23	30	23	24

Where N, E, S, W and H are north, east, south, west, and horizontally oriented surfaces respectively and α_s /ho is the ratio of the solar radiation that is absorbed by a surface.

4.3.3 Heat Gain through Fenestration

The heat gain caused by fenestration can be divided into two parts. One is the conduction heat transfer across the window material and the other is the solar radiative heat gain through the window glass. The conduction and transmitted parts of the heat gain can be calculated by Eqs. 4.8, 4.9, 4.10 , respectively [14].

Conductive

$$Q = UA(T_o - T_i) \tag{4.8}$$

Solar

$$Q = A_{glazing}(q_{sola,incident})(SHGC) \tag{4.9}$$

$$SHGC = \frac{\dot{q}_{solar,gain}}{\dot{q}_{solar,incident}} = \tau_s + f_i \alpha_s \qquad (4.10)$$

Where

T_o = Outdoor average temperature, ˚C

T_i = Inner design temperature, ˚C

A = glazing area of window, m^2

U = overall window heat transfer coefficient, W/m^2

$SHGC$ = solar heat gain factor

τ_s = fraction of directly transmitted radiation incident

$f_i \alpha_s$ = fraction of absorbed and reemitted portion of solar radiation incident

Shading coefficient (SC), solar heat gain fraction (SHGC), and solar transmissivity τ_s for some common glass types for summer design conditions are given in Table 13. These values are obtained from ASHRAE Handbook of Fundamentals [19].

Table 13: SHGC for different window assemblies.

		Thickness (mm)	τ_s	SC	SHGC
Single Glazing	Clear	3	0.86	1	0.87
		6	0.78	0.95	0.83
	Heat absorbing	3	0.64	0.85	0.74
		6	0.46	0.73	0.64
Double Glazing	Clear in, clear out	3	0.71	0.88	0.77
		6	0.61	0.82	0.71
	Clear in, absorbing out	6	0.36	0.58	0.50

4.4 Overall Annual Heating and Cooling Energy Consumption

Since the main idea of this project is to lay emphasis on the effect of some of the materials available in market on the energy consumption of a building due to heating and cooling, the heat loss encountered by infiltration has not been considered.

Estimation of the overall heating load requirement for a residence can be calculated using the Degree-Day concept (Equation 4.11) [15]:

$$Q_{heatingyear} = \frac{DD_{heating}}{(T_i - T_o)} \times \dot{Q}_{design} \times \frac{24h}{day} \quad (4.11)$$

Degree days are a type of weather data, calculated from using of outside air temperature. They are commonly used in monitoring and targeting to model the relationship between energy consumption and outside air temperature.

Heating degree days and cooling degree days are the two types of degree days that are used extensively in calculations of building energy consumption.

In general, degree-day figures come with a "*base temperature*", and provide a measure of how much (in degrees), and for how long (in days), the outside temperature is below, for heating, or above, for cooling, compared to the base temperatures.

Heating Base Temperature of a building is the outside temperature above which the building does not require heating. Cooling Base Temperature of a building, on the other hand, is the outside temperature below which cooling of a building is not required. Obviously, higher base temperature for cooling and lower base temperature for heating, providing the thermal comfort factor is preserved, is desirable to attain energy savings. In Cyprus, 18 ˚C for heating and 25 ˚C for cooling could be appropriate base temperatures to consider.

Although degree day method is a quite reliable method for monitoring energy performance of a building in different time periods, it is an approximate method to estimate expected energy consumption in new buildings or buildings under renovation.

"This method is rather acceptable for heating load calculation but is less accurate for cooling load calculation and should be handled with care when used to evaluate different type of buildings in different circumstances", [16].

Degree-day-based calculations can be greatly affected by the base temperature of the degree days used. Tables 14 and 15 shows monthly average Heating and Cooling Degree days, for different base temperatures, according to data collected from Ercan airport's weather station for the last twelve months.

Table 14: Celsius-based heating degree days for base temperatures from 14 to 23˚C

Base Temperature	14	15	16	17	18	19	20	21	22	23
Month starting										
11/1/2008	18	26	35	48	63	79	100	123	146	171
12/1/2008	93	114	137	163	189	215	243	272	301	332
1/1/2009	106	129	154	181	209	238	269	300	331	362
2/1/2009	98	120	144	170	196	222	250	278	306	334
3/1/2009	98	121	145	170	197	226	255	285	315	346
4/1/2009	33	41	51	64	80	101	122	145	167	191
5/1/2009	7	11	17	23	31	42	54	69	85	102
6/1/2009	0	0	0	0	1	2	4	9	14	20
7/1/2009	0	0	0	0	0	0	0	2	4	7
8/1/2009	0	0	0	0	0	0	1	3	7	12
9/1/2009	0	1	1	2	3	6	11	18	26	35
10/1/2009	0	1	4	8	15	22	30	40	51	64
	453	564	688	829	984	1153	1339	1544	1753	1976

Table 15: Celsius-based cooling degree days for base temperatures from 18.0 to 27˚C

Base Temperature	18	19	20	21	22	23	24	25	26	27
Month starting										
11/1/2008	50	36	27	20	14	9	5	3	1	0
12/1/2008	12	8	4	2	0	0	0	0	0	0
1/1/2009	2	0	0	0	0	0	0	0	0	0
2/1/2009	2	0	0	0	0	0	0	0	0	0
3/1/2009	7	4	2	1	0	0	0	0	0	0
4/1/2009	52	42	34	26	19	13	8	5	3	2
5/1/2009	141	121	102	85	71	57	44	35	27	21
6/1/2009	298	269	241	215	190	166	143	121	100	82
7/1/2009	373	342	312	282	253	225	199	174	150	125
8/1/2009	349	318	287	258	231	205	180	156	133	109
9/1/2009	222	195	170	147	125	103	84	67	52	40
10/1/2009	179	155	132	111	91	73	58	46	37	29
	1687	1490	1311	1147	994	851	721	607	503	408

Source: www.degreedays.net (using temperature data from ww.wunderground.com)

In the following chapter a case study in the TRNC will be carried out to improve energy consumption behavior of a detached two storey house and to emphasis the economical impact of using some environmentally friendly materials available in the market.

Chapter 5

CASE STUDY

A typical residential house in North Cyprus, for the last 20 years, is between 150 to 350 square meters of area. Of which reinforced concretes are the dominant types of construction materials that make up their escalators (i.e. foundation, columns, beams, slabs, and roofs). Walls mainly incorporate traditional clay blocks or the recently introduced BimsBlocks. Two layers of plaster and paint for the inner and outer surfaces coat the building sections. Thickness of at least 25 cm is a strict requirement declared by the government for the width of column used in construction. Therefore, the majority of house holders use bricks with 25 cm thickness for the enclosure between the columns of the perimeter. Architecturally, it is vital to fill between the columns, and mechanically, it is important for the sake of insulation and energy conservation.

5.1 Description of the Case

The house has two levels. The lower level floor is at the grade height. The floor plan for the upper and lower levels can be found in appendix A. The lower level includes halls, kitchen, dinning room, living room, office room, toilette, and a garage. The upper floor on the other hand includes three rooms, 2 toilettes, wardrobe room, and a laundry room.

This case study evaluates the energy performance of the house under the effect of the materials that can be used during construction process. The house is hypothetically constructed using different materials in two cases, A and B. For both cases, ordinary reinforced concrete was used for construction of the escalator. The main changes were applied for the walls, floor, roof, and windows. Different available materials were used as alternatives and others as additions. Some of the materials used in these cases are given in Table 16. With the aid of Microsoft Excel and Visual Basic, a program was developed for calculations. The developed programs are presented in the Appendix B.

5.2 Basic Assumptions and Data for Both Cases

Main assumptions are as follows:

- Calculations have been done using the methodology described in the previous chapter.
- A Continuous (24h/d) operation of the heating and the cooling systems with a monthly calculation step.
- Design temperature difference for heating season is 15˚C
- Design outside temperature for cooling season is the monthly average
- Base temperatures are 18˚C for heating and 25˚C for cooling seasons.
- Average COP for air conditioner is 2.5 for heating and 2.25 for cooling
- Heat transfer coefficient for combined convection and radiation (h) for outer wall surface, inner wall surface and roof, outer roof, and for the floor of the building are 25, 7.7, 12.5, and 5.9 (W/m.°C) respectively.

Table 16: Conductivity of some of the constructional materials.

	Material	K W/m.°C
Data from material standards	Wooden Tile	0,15
	Paste	1,4
	sand	1,4
	Crashed stone	1,4
	Wooden Tile	0,15
	Ceramic tiles	0,85
	Gypsum	0,7
	BimsBlock	0,18
Experimental data	Foam concrete	0,18
	Ordinary concrete	2,73
	Pumice concrete	0,3

5.3 Performance Calculations

The performance of the house was examined for both heating and cooling periods.

5.3.1 Heating for Case A

5.3.1.1 Overall U Values for the Enclosure Sections Case A

The materials generally used for buildings in North Cyprus, their compositions, thicknesses heat conductivities and the overall heat conductance "**U**" for each section is as shown in Tables 17-19

Table 17: U-value for the wall assembly (Case A)

Material	**Thickness (cm)**	***k*** **W/m.°C**	**R m².°C/W**	**U W/m².°C**
Gypsum		0.7	0.000	
Interior Plaster	2	0.87	0.023	
Clay Brick	25	0.35	0.714	
Exterior Plaster	3	1.4	0.021	
		TOTAL =	0.759	**1.077**

Table 18: U-value for the floor assembly (Case A)

Material	Thickness	*k*	R	U
	(cm)	**W/m.˚C**	**m²˚C/W**	**W/m²˚C**
Ceramic tiles	1	0.85	0.012	
Paste	3	1.4	0.021	
Sand	10	1.4	0.071	
Concrete	15	2.73	0.055	
Crashed stone	20	1.4	0.143	
		TOTAL =	0.302	**2.119**

Table 19: U-value for the roof assembly (Case A)

Material	Thickness	*k*	R	U
	(cm)	**W/m.˚C**	**m²˚C/W**	**W/m²˚C**
Bituline	1	0.17	0.059	
concrete	17	2.73	0.062	
Plaster	2	0.87	0.023	
		TOTAL =	0.144	**2.825**

For windows, overall heat transfer coefficient for single glazed 3mm glass is given as 7.16 $W/m^2.^{\circ}C$ (ASHRAE handbook of Fundamentals, Ref. 1, Chap.27, Table 5), [17].

5.3.1.2 Energy Loss Calculations Case A

The energy loss encountered during the heating period of the house according to 15 degrees different between the inner of the house and the outer environment and 10 degrees between the floor and the ground. Areas of the sections subjected to heat loss and the amount of loss encountered for one hour is given in Table 20.

Table 20: Heat loss encountered during the heating period (Case A)

Case A	Direction	Area	U-Value	Temp Difference	Heat Loss
Building element		m^2	$W/(m^2 °C)$	°C	W
External walls	South	114.40	1.077	15	1848.0
	North	103.30	1.077	15	1668.7
	East	96.30	1.077	15	1555.6
	West	84.85	1.077	15	1370.7
Windows	South	18.90	7.16	15	2029.9
	North	25.40	7.16	15	2728.0
	East	12.22	7.16	15	1312.4
	West	23.65	7.16	15	2540.0
Doors	North	4.60	3.84	15	265.0
Flat roof	Horizontal	166.00	2.825	15	7034.8
Floor to ground	Horizontal	166.00	2.119	10	3517.6
Total surface loss (Total maximum design losses through the enclosure)					25870.6

5.3.1.3 Energy Consumption for Case A

Table 21 gives the estimated energy consumption using Degree Days method.

Table 21: Estimated energy consumption (Case A)

Description	Unit	Value
Calculated Total loss (at design temp.)	W	25,870.6
Design temperature differences	°C	15
Degree days (heating base 18C)	HDD	791
Operation hours per day	h/d	24
Energy needs (yearly)	KWh	32,742
COP	-	2.5
ENERGY CONSUMPTION	KWh	13,097

5.3.2 Heating for Case B

5.3.2.1 Overall U Values for the Enclosure Sections Case B

The materials suggested to be used for buildings in North Cyprus, their compositions, thicknesses heat conductivities and the overall heat conductance "**U**" for each section are as shown in Tables 22-24.

Table 22: U-value for the wall assembly (case B)

Material	Thickness (cm)	*k* W/m.˚C	R m².˚C/W	U W/m².˚C
Gypsum	1	0.7	0.014	
Interior Plaster	2	0.87	0.023	
BimsBlock	25	0.18	1.389	
Exterior Plaster	3	1.4	0.021	
		TOTAL =	1.448	**0.618**

Table 23: U-value for the floor assembly (case B)

Material	Thickness (cm)	*k* W/m.˚C	R m².˚C/W	U W/m².˚C
Wooden Tile	1	0.15	0.067	
Ceramic tiles	1	0.85	0.012	
Paste	1	1.4	0.007	
Foam concrete	10	0.14	0.714	
Ordinary concrete	15	2.73	0.055	
Crashed stone	20	1.4	0.143	
		TOTAL =	0.998	**0.857**

Table 24: U-value for the roof assembly (case B)

Material	Thickness	*k*	R	U
	(cm)	W/m.˚C	m².˚C/W	W/m².˚C
Bituline	1	0.17	0.059	
L.W.Concrete	12	0.3	0.400	
Concrete	17	2.73	0.062	
Plaster	2	0.87	0.023	
		TOTAL =	0.544	**1.326**

For windows, overall heat transfer coefficient for double glazed with 12.7 cm gap between sheets is given as 3.37 W/m^2.˚C (ASHRAE handbook of Fundamentals, Ref. 1, Chap.27, Table 5), [17].

5.3.2.2 Energy Loss Calculations Case B

The energy loss encountered during the heating period under the same conditions of Case B are given in Table 25.

Table 25: Energy loss during heating period (Case B).

Case B		Area	U-Value	Temp Difference	Heat Loss
Building element		m^2	$W/(m^2°C)$	°C	W
External walls	South	114.40	0.618	15	1060.9
	North	103.30	0.618	15	958.0
	East	96.30	0.618	15	893.1
	West	84.85	0.618	15	786.9
Windows	South	18.90	3.37	15	955.4
	North	25.40	3.37	15	1284.0
	East	12.22	3.37	15	617.7
	West	23.65	3.37	15	1195.5
Doors	North	4.60	3.84	15	265.0
Flat roof	Horizontal	166.00	1.326	15	3302.6
Floor to ground	Horizontal	166.00	0.857	10	1422.3
Total surface loss (Total maximum design losses through the enclosure)					12741.3

5.3.2.3 Energy Consumption for Case B

The annual energy needs for air conditioning as well as the energy consumption of the HVAC system to accomplish it, for the heating season, is estimated using degree days method Table 26.

Table 26: Annual energy consumption needed for air conditioning (Case B).

Description	Unit	Value
Calculated Total loss (at design temp.)	W	12741.3
Design temperature differences	˚C	15
Degree days (heating base 18C)	HDD	791
Operation hours per day	h/d	24
Energy needs (yearly)	KWh	16125
COP	-	2.5
ENERGY CONSUMPTION	KWh	6450.1

5.3.3 Cooling for Case A

Overall U factor is assumed to be the same for heating and cooling seasons.

5.3.3.1 Energy Gain Calculations for Case A

Energy gains take place through the building's section are given in Table 27.

Table 27: Total heat gain through the envelope of case A

Case A		Area	U-Value	T_{s-a} av.	Ti	DT	Q Dot	Total
Opaque surfaces		m^2	$W/(m^2 °C)$	°C	°C	°C	W	W
Walls	North	103,30	1,077	29,8	25	4,7605	529,6	
	East	96,30	1,077	58,5	25	33,482	3472	
	South	109,65	1,077	41,4	25	16,376	1934	
	West	89,60	1,077	58,5	25	33,482	3231	9167
Flat roof		166,00	2,825	71,3	25	46,294	21711	21711
Door	North	4,60	3,84	28,5	25	3,5	61,82	61,82
Case A								
Windows		Area(m^2)	U-Value	To (°C)	Ti (°C)	Dt(°C)	Q	
conduction	North	25,40	7,16	28,5	25	3,5	636,5	
	East	12,22	7,16	28,5	25	3,5	306,2	
	South	23,65	7,16	28,5	25	3,5	592,7	
	West	18,90	7,16	28,5	25	3,5	473,6	2009
Solar average		A-Glazing	SHGC	q			Q	
	North	22,86	0,83	51			957,6	
	East	11,00	0,83	603			5481	
	South	21,29	0,83	274			4821	
	West	17,01	0,83	603			8478	19738
							TOTAL	52687

5.3.3.3 Energy Consumption for Case A

The annual energy needs for air conditioning as well as the energy consumption of the HVAC system to accomplish it, for the cooling season, is estimated using degree days method see Table 28.

Table 28: Annual energy consumption needed for air conditioning (Case A).

Energy Analysis for Case A		
Description	Unit	Value
Calculated Total loss (at design temp.)	W	52686,9
Design temperature differences	C	15
Degree days (heating base 25C)	CDD	721
Operation hours per day	h/d	24
Energy needs (yearly)	KWh	60780
COP	-	2,25
ENERGY CONSUMPTION	KWh	27013

5.3.4 Cooling for Case B

Overall U factor is assumed to be the same for heating and cooling seasons.

5.3.4.1 Energy Gain Calculations for Case B

Energy gains take place through the building's section are given in Table 29.

5.3.4.2 Energy Consumption for Case B

The annual energy needs for air conditioning as well as the energy consumption of the HVAC system to accomplish it, for the cooling season, is estimated using degree days method Table 30.

Table 29: Total heat gain through the envelope of case B.

Case B		Area	U-Value	T_{s-a} av.	Ti	DT	Q Dot	TOTAL
Opaque surfaces		m^2	$W/(m^2 °C)$	°C	°C	°C	W	W
Walls	North	103,30	0,618	28,4	25	3,4427	219,9	
	East	96,30	0,618	42,8	25	17,804	1060	
	South	109,65	0,618	34,3	25	9,2506	627,1	
	West	89,60	0,618	42,8	25	17,804	986,2	2893
Flat roof		166,00	1,326	49,2	25	24,209	5330	5330
Doors	North	4,60	3,84	28,5	25	3,5	61,82	61,82
Case B								
fenestration		Area(m^2)	U-Value	To (°C)	Ti (°C)	Dt(°C)		
conduction	North	25,40	3,89	28,5	25	3,5	345,8	
	East	12,22	3,89	28,5	25	3,5	166,4	
	South	23,65	3,89	28,5	25	3,5	322	
	West	18,90	3,89	28,5	25	3,5	257,3	1092
Solar average		A-Glazing	SHGC	q			Q	
	North	22,86	0,71	51			822,6	
	East	11,00	0,71	603			4709	
	South	21,29	0,71	274			4142	
	West	17,01	0,71	603			7283	16956
							TOTAL	26333

Table 30: Annual energy consumption needed for air conditioning (Case B).

Energy Analysis for Case B		
Description	Unit	Value
Calculated Total loss (at design temp.)	W	26332,8
Design temperature differences	C	15
Degree days (heating base 18C)	CDD	721
Operation hours per day	h/d	24
Energy needs (yearly)	KWh	30377
COP	-	2,25
ENERGY CONSUMPTION	KWh	13501

5.3.5 Annual Energy Consumption Analysis; (A Comparison between the Cases A and B)

When it comes to Energy saving caused by materials that are claimed to have a positive effect, the best practice is to create a comparison between them and those that are usually used in practice. Table 31 encompasses results for the houses of our cases showing the heat gains and losses encountered through the building's sections during cooling and heating seasons.

Table 31: Energy Comparison- A comparison between the cases.

	Case A			Case B			Savings
	Heating	Cooling	Total	Heating	Cooling	Total	
	W	W	W	W	W	W	%
Walls	6443	9167	15609	3699	2893	6592	58%
Roof	7035	21711	28746	3303	5330	8633	70%
Floor	3518		3518	1422		1422	60%
Doors	265	62	327	265	62	327	0%
Windows	8610	21747	30357	4053	18047	22100	27%
Total Requirment	25871	52687	78557	12741	26333	39074	50%
Energy Consumption (**KWh**)	11325	27013	38338	5578	13501	19079	50%

5.3.6 Economic Analysis

The Pay Back Period (PBP) is perhaps the simplest method to investigate investment projects. The Payback Period method focuses on recovering the cost of investments. PBP represents the amount of time that it takes for a capital budgeting project to recover its initial cost. Cost of renovation and the net annual cost savings accompanied them besides to the Pay Back Period are determined Table 32.

Table 32: PBP for the applied renovations.

	Thickness	Application Area	Unit cost Difference	Renovat ion Cost	Energy Saved	Cost of saved energy	PBP
	cm	m^2	TL/m^2	TL	KWh	TL	Year
Walls	25	399	2	798	3.886	1.749	0,5
Roof	12	166	21,6	3.586	8.773	3.948	0,9
Floor	10	166	12,5	2.075	838	377	5,5
Windows	-	80	50	4.009	3.467	1.560	2,6

From the results it can be seen that walls pay for themselves in less than a year, pumice concrete pays for itself in 1 year, foam concrete in 5 to 6 years, and windows in 2 to 3 years. The results are pretty much acceptable and renovation is strongly recommended.

Different thicknesses for the applied materials would have different scenarios. Increasing the thickness of the applied Pumice concrete on the roof would increase the resistance of that roof to heat transfer increasing the energy savings but it also would cost more.

In Case B, 12 cm thickness of the applied Pumice concrete was considered to be optimum. Considering it as the base thickness of our concrete, values for different thicknesses are given in Table 33.

Table 33: Effect of pumice concrete thickness on the economic analysis.

Roof				
Thickness	PBP	Savings tot	Savings from base	Renovation Cost
cm	years	%	%	TL
6	0,5	46	-36	1.793
8	0,7	48	-21	2.390
10	0,8	49	-10	2.988
12	0,9	50	0	3.586
14	1	51	8	4.183
16	1,1	52	15	4.781
18	1,3	53	21	5.378
20	1,4	53	26	5.976
22	1,5	54	31	6.574

As it is given in Table 5.16, the reduction in the Energy use is 50% when all the renovations are considered. Table 5.18 gives the change of the total saving, PBP, and Renovation cost as an effect of the thickness changes of the pumice concrete. Moreover, it gives the percentage change in the energy saving contribution of the roof. For example, applying 18cm of pumice concrete would increase the total energy savings by 3%, increasing the PBP from 0.9 to 1.3 years, but increases the renovation cost by about 1,800 TL. Acceptance of this renovation depends on the tendency to pay for the cost. It should be born in mind that any increase in thickness implies increase in the weight applied to the building which is not so acceptable beyond some values.

Windows area reduction is another practice that can be taken to save more energy. For example, reduction of 25% of the total fenestration area would reduce the renovation cost by about 1000TL and increase the total energy savings by 4%. Reduction of the fenestration area by this much would allow less light to get in and thus increases the need for lightening using electricity sources.

Chapter 6

CONCLUSIONS

Innovative technologies and energy efficiency measures are nowadays well known and widely spread, and the main issue is to identify those that will be proven to be the more effective and reliable in the long term. With such a variety of proposed measures, the decision maker has to compensate environmental, energy, financial and social factors in order to reach the best possible solution that will ensure the maximization of the energy efficiency of a building satisfying at the same time the building's final user needs.

In this study, a light weight concrete has been introduced and made possible to be pumped using an ordinary concrete pumper. Conductivity and cooling-time tests have been performed for some of the construction elements available in the market. A case study has been done for a hypothetical family house in North Cyprus with some recommended renovations showed great reduction in the energy consumption when compared to the same house built using the generally used building elements. The house's walls were built using BimsBlocks instead of clay blocks, a 12 cm thick insulating Pumice concrete was casted on the top of the roof, Foam concrete was used instead of gravel and sand for leveling of the floors, and double glazed windows were used instead of the single glazed windows. The result was a 50% reduction of the energy needed to condition the family house of the study. With renovation cost not more than 10,000 TL, the total payback period for it is calculated to be about ten years.

Under the climatic changes that our planet practices, the best practice is to use materials with the lowest heat transfer. Some simple practices can result in significant energy savings in residential buildings while causing minimal discomfort. The annual energy consumption due to air conditioning can be reduced to the half by using energy conservative materials in building construction. Considering 1˚C greater base temperature in the cooling season and 1˚C lower base temperature in the heating season could reduce the energy consumption of the HVAC system by great amount as well.

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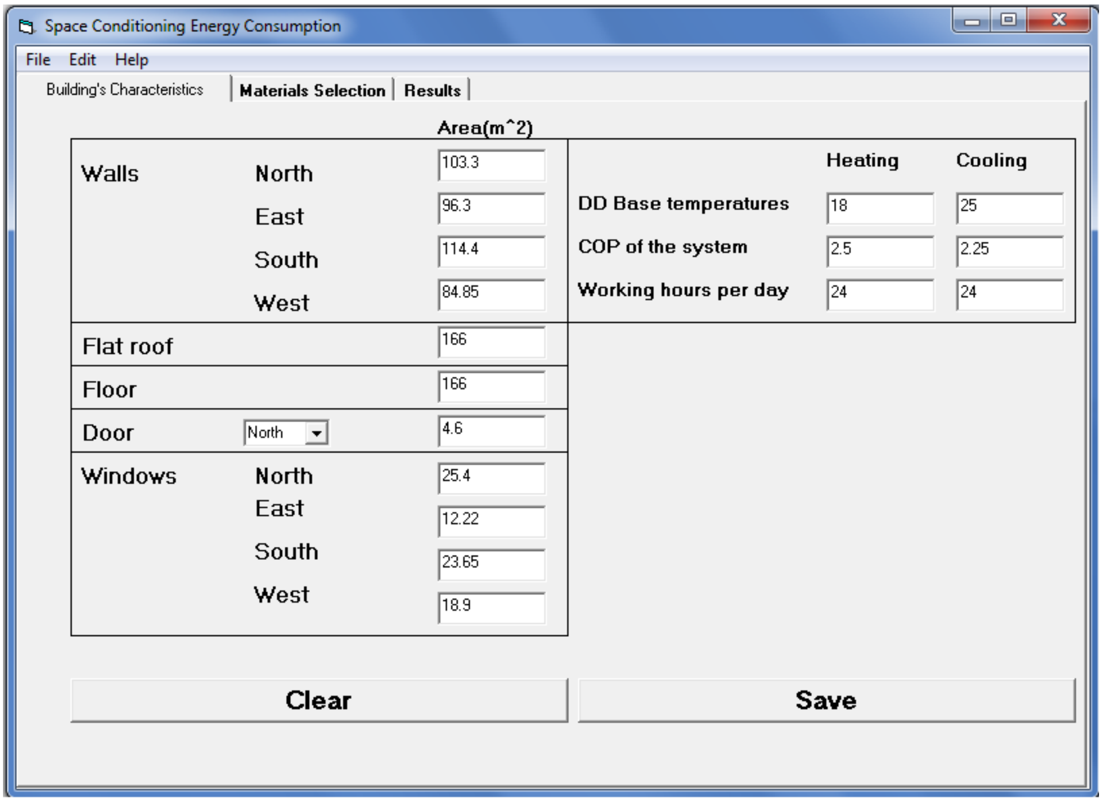
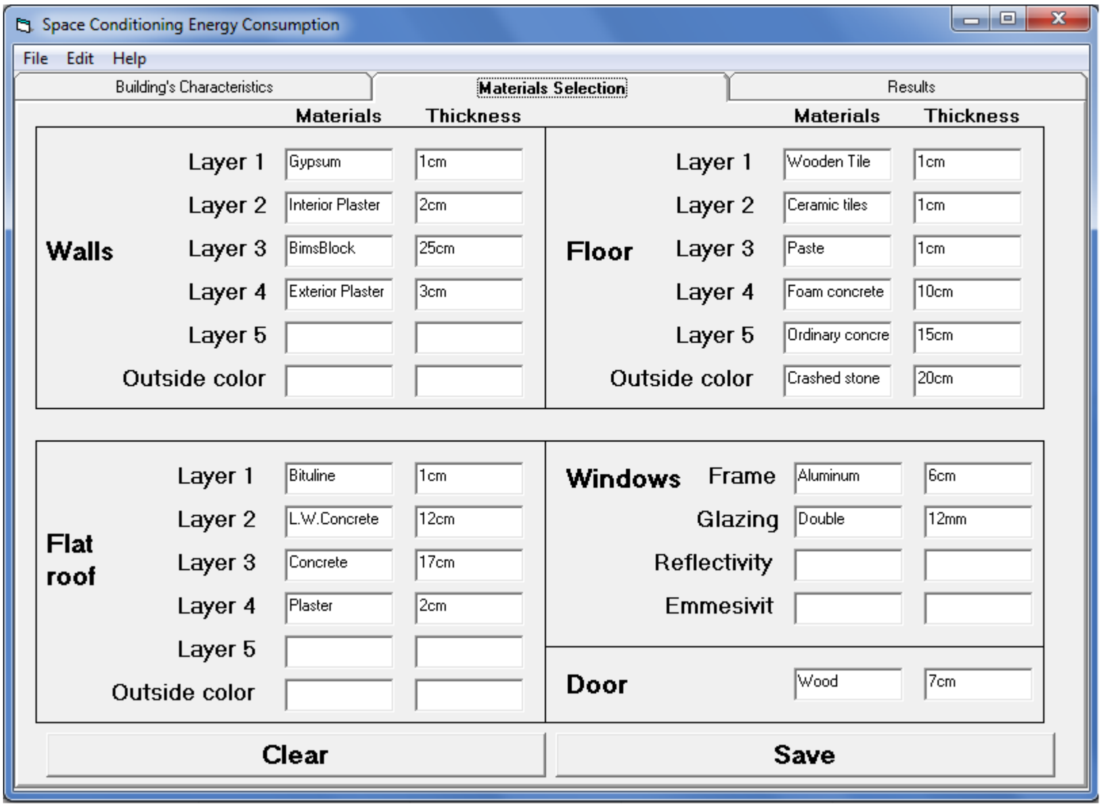
APPENDICES

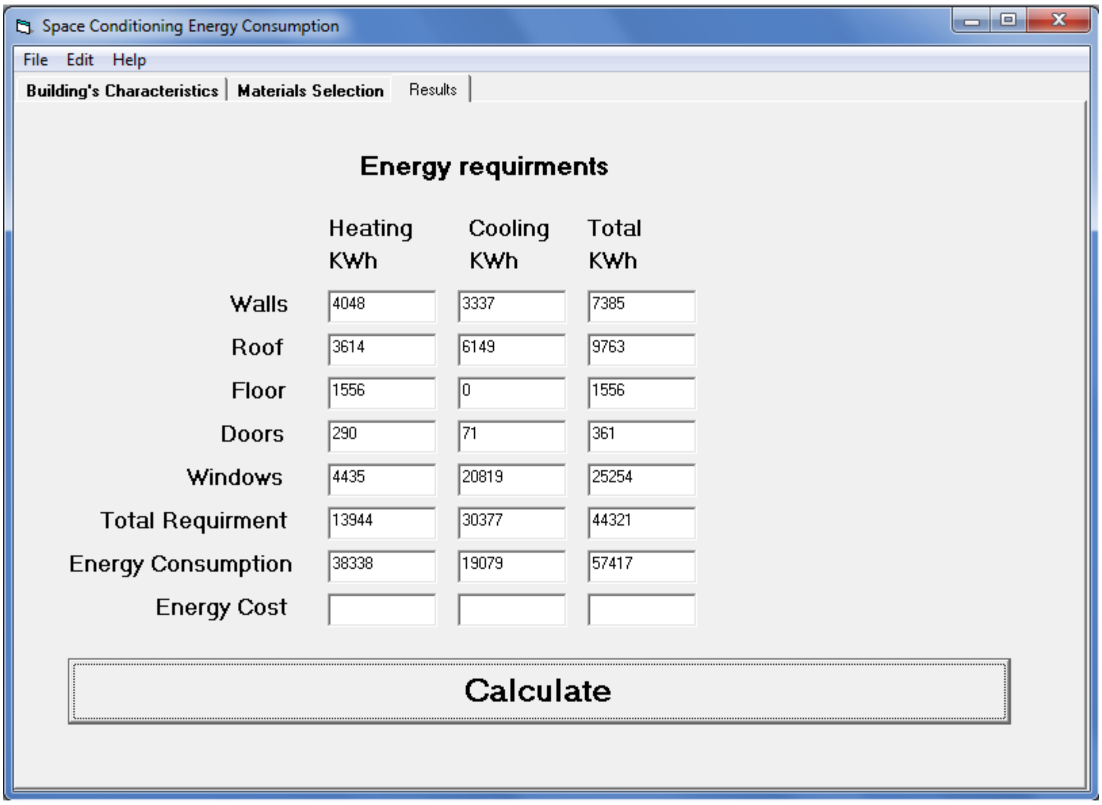
Appendix A.1: Lower Level of the House

Appendix A.2: Upper Level of the House

Appendix B: The Interface of the Developed Program






Space Conditioning Energy Consumption
File Edit Help
Building's Characteristics
Materials Selection
Results
Energy requirments
Heating KWh
Cooling KWh
Total KWh
Walls 4048 3337 7385
Roof 3614 6149 9763
Floor 1556 0 1556
Doors 290 71 361
Windows 4435 20819 25254
Total Requirment 13944 30377 44321
Energy Consumption 38338 19079 57417
Energy Cost
Calculate