Palestine Polytechnic University

Deanship of Graduate Studies and Scientific Research

Master of Architecture – Sustainable Design

A Comparative Thermal-Performance Study of Cladding Systems in Commercial Buildings in Palestine: Samples from Hebron City

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”Thesis submitted in partial fulfillment of requirements of the degree Master ofArchitecture- Sustainable Design”

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Sireen A. Idkaidek

ABSTRACT

The cladding system is an important and effective part of the building. As it is known the main goal of cladding is to protect the quality of interior spaces from extreme climatic conditions and natural forces. High performance cladding systems provide designers and engineers with more functional solutions to improve the quality of the indoor environment. High performance cladding systems can be used to create interior spaces with high thermal comfort conditions.

Recently, new cladding materials such as different types of composite panels have been used in the design of cladding systems for commercial buildings in Hebron-Palestine. Therefore, this study aims to evaluate the modern cladding systems of commercial buildings in Hebron-Palestine and compare the systems to utilize these different new materials and layers. It also aims to improve the design of the exterior wall using these materials in order to obtain the appropriate thermal performance for the system in summer and winter. In addition, the research aims to provide some recommendations for the design of façade systems that can be followed and considered by architects and designers in the early design phases or in the retrofit phase in the development of façade systems for commercial projects in Hebron-Palestine.

The methodology of this study is based on analyzing the cases and then evaluating the proposed materials and layers for each case using the Hourly Analysis Program (HAP) and comparing between the systems to find the most effective façade design to improve the thermal performance of the building. The study simulates some possibilities of façade system models by changing the wall layers, layout, thickness, air cavity, insulation thickness, and glass types. The study obtained useful results with energy savings of 10 to 40% in the assumed modified scenarios, depending on the different circumstances and if the designers define and test the envelope-related parameters at an early stage of the modification of the exterior wall design of the building.

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دراسة مقارنة الأداء الحراري لأنظمة التكسية في المباني التجارية في فلسطين:

عينات من مدينة الخليل

سرين أمين ادكيدك

المستخلص

نظام الكسوة هو جزء مهم وفعال من المبنى. فإن الهدف الوظيفي الرئيسي للكسوة هو الحفاظ على جودة البيئة الداخلية من المناخ والقوى الطبيعية. توفر تقنيات نظام الكسوة عالية الأداء للمصممين والمهندسين المزيد من الحلول الوظيفية لتحسين جودة البيئة الداخلية. يمكن للكسوة عالية الأداء تطوير المساحات الداخلية ذات ظروف الراحة الحرارية .

في الآونة الأخيرة ، ظهر تصميم أنظمة الكسوة في المباني التجارية في الخليل - فلسطين بمواد تكسية جديدة مثل أنواع الألواح المركبة المختلفة. ومع ذلك ، لا توجد دراسات محلية حول تأثير هذه الأنظمة على الأداء الحراري للمبنى. لذلك تهدف هذه الدراسة إلى تقييم أنظمة الكسوة الحديثة للمباني التجارية في الخليل - فلسطين ومقارنة الأنظمة لاستغلال هذه المواد والطبقات الجديدة المختلفة. كذلك لتحسين تصميم الجدار الخارجي باستخدام هذه المواد للمحافظة على الأداء الحراري المناسب للنظام في فصلي الصيف والشتاء. واخيرا ، يهدف البحث إلى استخلاص بعض التوصيات الخاصة بتصميمات أنظمة الكسوة التي يمكن للمهندسين المعماريين والمصممين اتباعها ودراستها في مراحل التصميم الأولى أو مراحل التعديل التحديثي لتطوير أنظمة الكسوة في المشاريع التجارية في الخليل - فلسطين.

تعتمد منهجية هذا البحث على تحليل الحالات ثم تقييم المواد والطبقات المقترحة لكل حالة باستخدام برنامج التحليل الساعي (HAP) والمقارنة بين الأنظمة لتوفير تصميم الكسوة الأكثر فاعلية لتحسين الأداء الحراري للمبنى. يحاكي البحث بعض الاحتمالات لنماذج أنظمة التكسية من خلال تغيير طبقات الجدران والسماكات وتجويف الهواء و العزل وأنواع الزجاج. حققت الدراسة نتائج قابلة للتطبيق مع توفير 10 إلى 40٪ في الطاقة في السيناريوهات المعدلة المعتمدة اعتمادًا على ظروف مختلفة وإذا قام المصممون بتحديد واختبار المعلمات ذات الصلة بالمغلف في مرحلة مبكرة من تعديل تصميم الجدار الخارجي للمبنى.

DECLARATION

I declare that the Master Thesis entitled" A Comparative Thermal-Performance Study of Cladding Systems in Commercial Buildings in Palestine: Samples from Hebron City" is my own original work, and hereby certify that unless stated, all work contained within this thesis is my own independent research and has not been submitted for the award of any other degree at any institution, except where due acknowledgement is made in the text.

Student Name…………………………………….

Signature:.................................. Date:................................

DEDICATION

I dedicate this work to my family, my great husband Arch. Amjad Da'na, for being my ever Proponent who always has been by my side, and encouraged me up. To my darling parents Who devoted their lives to educating their children as best as they could. To my sisters and brother, to my tutors and colleagues at Palestine Polytechnic University.

Thank you

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List of Abbreviations

ACP	Aluminum composite panel
WPC	Wood plastic composite panel
HAP	Hourly analysis program
WWR%	Window to Wall Ratio
SHGC	Solar Heat Gain Coefficient
U –Value	Transmittance Value
ASHRAE	the American Society of Heating, Refrigerating and Air-Conditioning Engineers
HVAC	Heating, ventilating, and air conditioning
HDPE	High-density polyethylene
PP	Polypropylene

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Chapter 1 Introduction

1.1 Preface

The cladding system is an important part of a building. Cladding must meet esthetic, economic and social aspects. Therefore, the design of cladding systems is a process that combines art, science and profession to study the desired objectives of the system. The main goal of cladding is to separate the interior environment from the exterior in a way that maintains the thermal satisfaction of the occupants in the interior spaces. It acts as a filter for the interior. As a result, building components have a major impact on building performance. The thermal properties of the building components affect the properties of the building envelope. Each material has a different ability to absorb, store, transfer and release heat. Designers must have a thorough understanding of the properties of the materials they are selecting, including the thermal conductivity of the material, its density, and how it is affected by heat. The impact of building materials on energy consumption and thermal performance of the building is considered significant.

In recent times, the field of advanced materials and technologies has developed. In the architectural field, particularly in building cladding, the use of synthetic solvent composites for building and cladding systems is being used as an alternative to traditional components and technologies(Martini, 2014). The implications of this development need to be explored by designers and architects to achieve the appropriate design that maintains a high-quality indoor environment.

1.2 Research Significance

From an architectural point of view, the facade of a building is closely related to the extent of technological and aesthetic progress, as it expresses the extent of development, change and time. The prevalence of facades with new and varied cladding materials aims at aesthetics and change, but arbitrariness and the non-use of the most suitable materials for the design of the walls of the external facades have a negative impact on the thermal performance of the building and the extent of its energy consumption.

In Palestine, there is a great need to study the thermal performance of building envelopes, to solve the problem of high energy consumption, especially in residential and commercial buildings. This study contributes to improving the thermal performance of exterior walls, which consist of multiple layers, in a specific climatic region in order to reduce the energy consumption of annual heating and cooling loads. In addition, this study focuses on proposing a group of exterior wall designs for commercial buildings in the city of Hebron based on thermal simulations by adding different material layers to modify the wall design in order to verify the effects of these layers on the thermal performance of the building and energy consumption and compare the results.

In the study of Husameddin M Dawoud in Gaza, two different techniques for available building materials were compared to improve thermal performance and reduce energy consumption. In this study, Ecotect software was used to simulate the two different constructions. The results have shown that the presence of a 5 cm air gap in the exterior walls saves 50% of the energy demand of the building(Husameddin M Dawoud, 2014) . However, the climate in Gaza City is different from that in Hebron. The materials used in the wall layers are not the same as in Hebron city, and there is no similar study for Hebron city.

On the other hand, the study by Al-Qadi et al. estimated the amount of heating energy consumption in the residential sector of the city of Hebron. It was found that the heated area during the winter season does not exceed 9.2% of the total area of the houses(Al Qadi et al., 2018). This study was limited to residential buildings in Hebron city and did not consider commercial buildings. Commercial buildings in the city of Hebron are characterized by the presence of central air conditioning, but residential buildings have almost no such system, and only a small percentage of the house area is heated, unlike the fully heated commercial buildings. This study is limited to the winter season only; the summer season was not considered.

The study by Lazzeroni et al. aimed to assess the extent of the expected reduction in energy consumption at the level of the city of Hebron in Palestine if work is done on energy retrofitting of the city's buildings. This is because the largest share of energy consumption, 35%, was accounted for by meeting heating and cooling needs through air conditioning and heating systems in the buildings of the city of Hebron. This study relied on the improvement of the opaque wall and the transparent wall, as well as the installation of high-efficiency air conditioning systems instead of the existing ones(Lazzeroni et al., 2017) .However, the study did not clarify which layers were added with new cladding materials that could increase the efficiency of the thermal performance of the walls in addition to the added insulation materials.

In addition, the study (Eskin and Türkmen, 2008) estimated the total heating and cooling load (energy demand) using building simulation technology (Energy Plus) for office buildings in different climatic zones of Turkey. A base model was created for a group of office buildings and then the building design was developed to study, compare and analyze it instead of creating a general case. If the wall is insulated with a thickness of 75 mm from the inside, there is a maximum annual saving of 19.67% of the energy needed for cooling and 34.4% of the energy needed for heating in the temperate climate of Istanbul. The percentage varies depending on the prevailing climate in each city. The maximum savings in the required loads for the building were also compared when using double glazing and double clear glazing. In addition, the annual heating and cooling capacity increases significantly as the amount of glazing increases and is compared to smaller glazing areas.

A simulation environment was developed to assist in the design and operation of buildings. This simulation environment was used to learn how to design building envelopes and HVAC systems in five US cities. This study aims to reduce annual energy costs and life cycle costs of buildings while maintaining internal thermal comfort. It then compares the different building envelope and HVAC system improvement scenarios to achieve a simulated high-value environment by designing high-performance buildings and low energy costs. This could be achieved by first determining the building envelope characteristics and then improving the HVAC system options (Bichiou and Krarti, 2011) .Other studies can apply simulation technology to different types of buildings. It can be used as a valuable tool in the design and operation of high-performance buildings.

Modifying the design of the existing building aims to increase the thermal performance of the building, thus reducing energy consumption. It also improves the internal thermal environment, leading to a reduction in carbon dioxide emissions. The designer must be able to identify the most feasible strategies to achieve assessments of annual reduction of building consumption and improve the characteristics of internal thermal as well as access to good investment/return analysis (Güçyeter and Günaydın, 2012). This study only deals with the improvement of energy efficiency by changing the exterior facades of the building. The simulation approach helps to target and evaluate the contribution of modifying the building facades to reduce the annual energy consumption and increase the thermal performance of the existing building by using different material layers and thicknesses.

These various studies have proven that the modification of buildings suffering from a lack of thermal insulation and ineffective heating and cooling systems in the Middle East reduces the overall energy consumption of the city, thus solving the problem of high consumption and great pressure on electricity in the city, as is the case in the city of Hebron. Therefore, this comprehensive study was carried out for all the layers on the exterior walls of the commercial buildings in the city of Hebron, to make the best use of them because of the great development in the use of new materials.

1.3 Research Problem

In Palestine, buildings suffer from unawareness of the choice of building materials. They are not studied by the engineers to improve the performance of the building or to protect the environment. This has resulted in buildings that do not provide comfort to the users, leading to high energy consumption and environmental degradation in the region.

Residential and commercial buildings account for the largest share of energy consumption in Palestine, as they consume 70% of the total energy source("PCBS | Statistics," 2017). Commercial establishments consume the largest share of energy compared to all other establishments, especially in the city of Hebron. Hebron is considered the commercial capital of Palestine. There are a large number of commercial buildings. The number of commercial buildings reached 12,393, which is 22% of the operational facilities in the West Bank in the field of economic activities, which is the highest percentage among the Palestinian governorates after Gaza City("PCBS | Statistics," 2017) .

In addition, Palestine suffers particularly from not being able to control its energy resources because of the Israeli occupation of its land. It is supplied with electricity, gas, and fuel by the occupiers. The extensive dependence on traditional energy leads to significant environmental risks. The significant increase in energy consumption as population density increases makes it urgent to find new methods, technologies, and building materials that will help reduce consumption and protect the environment.

The new cladding techniques and materials are used to improve the performance of the building. There are buildings with stone and concrete walls that do not contain insulation materials, and then new materials are added, especially in commercial buildings. There is a great need for knowledge on how to optimize the use of new building materials and layers to improve the thermal performance of buildings. The stone material is not studied in this study to take advantage of the new cladding materials that have appeared in modern times, as these materials have been added to the esthetics of buildings, such as aluminum composite panels, wood composite panels, and wood panels.

1.4 Research Objectives

The main objective of this research is to use new facade materials to improve the performance of buildings, especially commercial buildings in Palestine. It aims to investigate new materials using simulation programs based on parameters that help architects to find the best façade design for a building to improve its thermal performance and reduce energy consumption.

To achieve the main goal, there are a number of objectives that should also be realized, such as:

- ✓ Improving the thermal performance of commercial centers in Palestine.
- ✓ Investigating and determining the impact of using different materials in the design of building facades on the energy consumption of buildings in Palestine.
- ✓ Recommendations for the designer on how to improve the modification of existing buildings to make them more energy-efficient.
- ✓ To assist the designer in selecting the best materials for the design of building walls in order to improve their thermal performance.
- ✓ Clarify the relationship between high-efficiency thermal wall performance and the initial and operating costs of the building.

1.5 Research Questions

Problem identification has raised the main question: How can façade cladding be used to improve the thermal performance of the building and thus change the design of the building walls to make them more energy efficient?

The research sub-questions are:

1. How does building envelope design affect thermal performance and energy consumption?
2. What are the effective strategies and alternatives to improve the performance of building facades and reduce the energy consumption of commercial buildings in Palestine?

1.6 Research Limits and Limitations

The scope of the study will be limited to the following:

1. A commercial center (retail sales) with an average area of 300-800 square meters with the main facades and other facades of the building is common in the context of Palestinian commercial construction.
2. The climate zone in the city of Hebron in Palestine: a Mediterranean climate, with hot summers and rainy winters.
3. The first floor of the case studies, where cooling and heating units are located, is studied to verify the impact of the thermal characteristics of the building facades on energy consumption.

However, in carrying out the research we encountered several obstacles, namely:

A. The limited time available for the research led to an inventory of the type of buildings covered by the study, the number of study cases, the parts of the buildings studied, and the orientation of the cases.

B. Barriers to accessing some study cases and the inability to gather sufficient information about them.

1.7 Research Organization

The overall structure of the study takes the form of five chapters including this chapter which focuses on the research approach.

- Chapter 2 includes the literature review. It defined the cladding systems. Besides, the design principles of facade claddings and the relationship between the cladding system and thermal comfort are studied. In addition, cladding system materials and technologies are studied. The construction systems in the study context.
- Chapter 3 deals with the thermal performance of commercial buildings, the impact of different building parameters on energy consumption, and the analysis of energy

consumption in Palestine. Finally, the strategies to minimize energy consumption in buildings were discussed.

- Chapter 4 began with a brief overview of the study methodology. Thereafter, it illustrated the cases study selection criteria. The method of cases analysis will be explained. The variables that were studied in the simulation process and the changes that were constant during the simulation stage were identified. Finally, it elucidated the way used in the simulation process in each of the cases-study.
- Chapter 5 addressed the simulation results of modified exterior wall materials on each case at the two stages. Moreover, the difference in cooling and heating loads result at each modification was determined to show how the design of the facade, with its different orientation, affects the thermal performance of the building and energy consumption.
- Chapter 6 a conclusion and summary of the findings and main results was manifested. In addition, a discussion of some recommendations and some suggestions for future research was manifested.

Chapter 2 Cladding Systems Overview

2.1 Preface

The construction sector is the fastest-growing sector in the world. The building consists of a group of integrated elements that work together to achieve its goal. There are systems that are integrated into the building design and perform their function, namely the active system and the passive system, to meet the necessary needs of the occupants and achieve comfort. The active system performs its function with the help of electrical and mechanical systems. Passive systems rely heavily on the use of their materials and items.

The building envelope is the link between the interior and the exterior. It is responsible for controlling energy consumption to ensure the comfort of the occupants in the building. Indoor energy consumption is of great importance to the public and private sectors worldwide. The reason for this is the high prices of non-renewable energy sources(Turrin et al., 2012) .Recently, the world is looking for strategies to rationalize energy consumption and is relying heavily on renewable energy sources

Buildings of the new generation consume more energy than buildings of earlier eras. The traditional building is a building that provides thermal comfort to its occupants in the summer and winter months, but it is not suitable for the requirements of the modern era(Al-Naghi et al., 2020). The modern era saw the emergence of building systems that lacked insulating materials, which led to an increase in the transfer of thermal energy through the building envelope, resulting in high energy consumption.

The optimal use of energy is one of the most important strategic goals that governments strive to achieve. The Palestinian Authority for Energy and Natural Resources is making great efforts to develop national action plans to reduce energy consumption in Palestine. These plans aim to save energy, but the laws and regulations governing Palestinian construction and buildings are not yet comprehensive enough to achieve this goal.

2.2 Definition of Cladding Systems

The Dictionary of Architecture and Construction defines cladding as "the finished covering of an exterior wall of a frame building; the cladding may consist of cladding material such as wood, aluminum, or asbestos cement (but not masonry) applied vertically or horizontally" (Harris, 1999).

The cladding system is a part of the building that protects people from extreme climatic conditions, animals or natural disasters. Thus, the main objective of cladding is to separate the interior and exterior spaces in such a way that the quality of the interior spaces can be maintained under appropriate conditions for the building's occupants(Neto and Brito, 2011) . However, according to Linda Brock, the term cladding "refers to the visible materials on the exterior of the wall. Cladding serves as a primary barrier and is therefore sometimes referred to as a rain screen. Some claddings, such as insulating glass units, perform all the functions of the wall"(Brock, 2005) .

The facade cladding is the outer part of the exterior wall, which is not load-bearing and protects the interior from natural forces such as heat, cold, sun, wind and rain. It also fulfills aesthetic, safety and economic aspects of the buildings. With the advent of new building materials and strict control of the building's interior space requirements and the improvement of energy efficiency, the construction of the building envelope has evolved significantly, so architects should bear a great responsibility for the optimal design of the building envelope(Çıkış, 2007). In addition, the façade system defined by Hunt is a general term that refers to the façade elements sealant between panels, links that connect the panels to the structure, and the system of glazed openings(Hunter et al., 2014).

2.3 Design Principles of Façade Claddings

The main purpose of building cladding is to separate the interior and protect it from the outside world. The design principles of facade cladding consist of a series of integrated elements to fulfill this purpose. These elements form the exterior wall, roof and other components such as openings, windows and doors. The function of the building envelope provides an appropriate interior environment for occupants by

- Controlling airflow,

- Controlling heat flow,

- Controlling sunlight penetration and other forms of radiant energy,

- Controlling the amount of moisture and water vapor entering the building(Çıkış, 2007).

One of the most important functions of façade systems is to regulate the flow of radiant heat from the sun to protect the inside of the wall from radioactive discomfort. Heat is transferred from the outdoor environment to the indoor environment in one of the following ways: conduction, convection, or radiation. Heat transfer from the sun's rays through the building envelope to the interior surface of the building heats the air that comes in contact with the surface, raising the temperature of the interior environment and wasting more energy to cool the air. On the other hand, solar radiation affects the thermal expansion and contraction of the components of the building exterior wall, especially the cladding layer. The difference between daily and seasonal temperatures causes the materials to expand or contract, and this effect varies with the materials in the layers of the cladding system(Quirouette, 1982) .

In addition, building cladding must control the amount of sunlight that enters the interior through the exterior wall. Sunlight is useful to some extent because it provides enough natural light that it is not blinding inside the building, and it is also necessary to raise indoor temperatures in winter. However, sunlight contains destructive ultraviolet wavelengths that are harmful to human health and the building's interior materials. Building cladding systems must keep these wavelengths away from people and interior materials. Building cladding contains windows that can control solar radiation. In addition, some shading devices can be installed to protect the building from harmful solar radiation(Allen and Iano, 2004) .

2.4 The relationship between building cladding systems and indoor thermal comfort

Thermal comfort is ranked as the most important by building occupants compared to visual, acoustic comfort, and air quality. It also has the greatest impact on the quality of the indoor environment compared to other conditions(Frontczak and Wargocki, 2011) .

The most important component of thermal comfort factors are heat gain and heat loss, which are directly influenced by thermal wall properties, mainly thermal resistance (U-value)(Chirarattananon et al., 2012) .The R-value depends on the materials of the wall layers and insulation, which affect the indoor temperature and thus the energy consumption for air conditioning and heating(Aditya et al., 2017) .

Heat conduction is energy transferred between spaces at different temperatures through interfaces and air cavities. The extent of heat conduction depends on physical and chemical properties, humidity, temperature, and atmospheric pressure.

2.4.1 Thermal Conduction Process

The process of heat conduction through the wall is time-dependent and can be illustrated with a heat cycle diagram (Figure 2.1). The process of heat balancing, which includes the study of heat flux, internal surface temperature, and external surface temperature, is an effective solution to the problem of heat conduction(Adrian, 2012) .

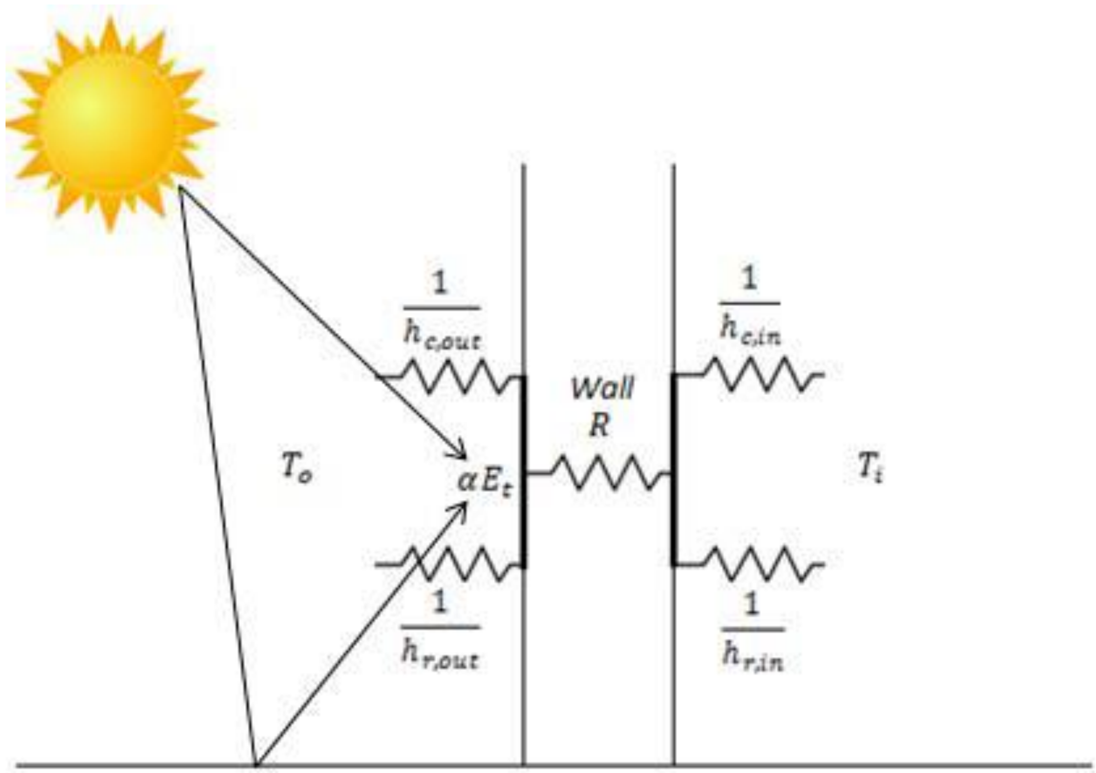


Figure 2.1The thermal conduction through wall process(Adrian, 2012)

2.4.2 Sol-air Temperature

Sol-air temperature defined as "the outdoor air temperature that is in the absence of all radiation changes gives the same rate of heat entry into the surface as would the combination of incident solar ration, radiant energy exchange with the sky and other outdoor surroundings, and convective heat exchange with outdoor air"(American Society of Heating, Refrigerating and Air-Conditioning Engineers, 2009).

2.4.3 Solar Radiation through Windows

- The clear days of winter are the most difficult conditions to maintain indoor thermal comfort and control air conditions. This is because the climate has low air temperature and high solar radiation. A room with a large glazed area and a low thermal insulation value is more susceptible to indoor thermal variations, while a room with a small glazed area and a higher thermal insulation value creates more comfortable conditions and is less affected by the outdoor climate(Tzempelikos et al., 2010) .
- Glazing

The glass surfaces in building facades have the greatest impact on cooling and heating load requirements, and thus on the thermal comfort of the building's occupants. The type of glass directly affects the difference in heat and light loads (Siddhartha et al., 2015). The choice of the appropriate glass type depends on several factors, including U-value, solar heat gain coefficient (SHGC), and visible transmittance(Hassouneh et al., 2010) .The best-insulated glass, which has a low U-value, is preferred to save energy. The triple glass with high solar control and low E glass and the triple glass with low solar control and low E glass (which have the lowest U-value). They are considered to have the least impact on the heating and cooling load value. Since increasing the glazing area increases the impact on cooling and heating load requirements, a WWR of 10% on all facades is considered to be the optimal size for cooling and heating loads. However, this percentage has a negative impact on the natural lighting entering the building, thus increasing the energy consumption for industrial lighting. The low WWR percentage also has disadvantages for the visual communication between inside and outside, especially for commercial buildings. It is necessary to maintain a high percentage of visual communication between inside and outside(Muhaisen and Dabboor, 2015) . Reflective double glazing is ideal in a hot climate, but is not preferred in a cold climate because direct sunlight is important for increasing the indoor temperature. Therefore, triple clear glass is the perfect type in cold climates (Buelow-Huebe, 1998).

The use of windows with low thermal transmittance is suitable for winter if accompanied by high transmittance of the sun. However, the high solar energy transmittance leads to a significant deterioration in summer performance. As a result, suitable shading systems must be installed to improve performance in summer without affecting performance in winter (Gasparella et al., 2011).

In commercial buildings, many types of openings are found in different sizes and orientations, small, large, long horizontal openings and long vertical ones. Care must be taken to ensure that the glass surfaces are well-positioned, aligned and large in order to make the best use of sunlight in the winter season and to avoid a high indoor temperature in the summer. The different types of glass in Palestine can be summarized in (Table 2.1). Clear double glazing is the most commonly used glass in Palestine for windows and curtain walls. There is a wide variety in the ratio of WWR in commercial buildings, ranging from 30-35% for small areas to 50-70% of the wall ratio. Interior louvres are used as shading devices to mitigate the effects of sunlight entering through these glass facades. Different types of glass have different U-values and also differ in SHGC and VT. The heat transmission coefficient (SHGC) is the portion of solar radiation that passes through the glass surface into the building interior, either by direct transmission or absorption. Light transmission is the ratio of the natural light transmission of the glazing surface. Clear glass allows the most sunlight to pass through and is therefore popular in areas where sunlight must be used.

Table 2.1: Physical Characteristics of Windows Available in the Palestinian Market

Type	Visible Transmittance	Solar Heat Gain Coefficient(SHGC)	U-Value
Clear- double glass	81%	76%	2.73
Tinted- double glass	61%	63%	2.7
Reflective- double glass	8%	63%	2.73
Double-high solar gain – low E Glass	78%	26%	1.99
Double- low solar gain- low E Glass	64%	26%	1.7
Triple- high solar Gain- low E Glass	69%	55%	1.42
Triple- Low Solar Gain Low E Glass	63%	38%	1.02

2.4.3 Parameters Affecting Envelope Thermal Performance

The amount of heat lost or gained through the building envelope depends on various parameters (U-value, window-to-wall ratio, emissivity and reflectivity of the material, the ratio of envelope area to volume, etc.) in addition to the characteristics of the envelope. Environmental conditions include external and internal conditions. The external conditions are influenced by the various external gains, the surrounding urban morphology, including the amount of green space, the height of the buildings, and the shading areas. Internal conditions are assessed by the internal gain resources and set point temperature(Adrian, 2012).

2.5 Materials in Cladding systems

High-performance cladding materials are on the rise to provide architects and engineers with more solutions to the problems associated with cladding systems. In addition to the functions of protection from rain, wind and solar radiation, cladding materials also have an aesthetic function that determines the appearance of the building. When different types of materials are used for exterior cladding of commercial buildings on a larger scale, the thermal performance of this system, indoor thermal comfort and energy efficiency need to be studied.

The most commonly used materials for exterior cladding is stone, artificial stone, wood-based panels, concrete panels, terra-ceramic panels, etc. The panels made of these materials are combined with glass elements in aluminum frames.

The cladding system gives the visual impression of the building walls. This system hides the structural, visual and construction defects that occur on the internal components of the building. The material properties of the cladding system are different and so are the properties of the systems (Babajanyan, 2019).

The building materials used vary from country to country and are often due to the availability of local materials, their suitability for the environment, and the local climate in the region. Material preferences and material properties need to be understood by policymakers, architects, engineers, and construction companies to create a more sustainable building environment in the future (Høibø et al., 2015; Vasanen, 2012).

Many factors influence the use of building materials. The local sources in the region make the buildings rich in these materials. The other factor is related to the type of building and the social and cultural values of the people in the region. Cost and financial aspects also play a role. Prescribed laws and standards for the use of materials to fight fire, earthquake, etc. are also important.

- Stone

Stone is considered one of the oldest materials used for cladding buildings. The stone mainly depends on the support systems behind it to maintain its structural integrity and to ensure the thermal and moisture integrity of the cladding system (Çıkış, 2007).

It is known as a common building material for cladding the exterior facades of buildings in Palestine, especially in the central and southern regions and in urban and semi-urban areas. Stone is an important resource that is quarried in large blocks in the Palestinian territories and then cut and shaped into various small pieces suitable for the desired design. The stone blocks available in the Palestinian market vary in thickness from 2 to 7 cm and in length from 25 to 80 cm, but the height varies from 25 to 50 cm.

The Palestinian Territories are rich in different types of natural stone, characterized by durability. The stone is named after the areas from which it is extracted.

In this study, the stone material is not investigated in order to use new cladding materials that have appeared in modern times, especially in commercial buildings in Palestine, such as aluminum composite panels, wood composite panels and wood panels, since these materials contribute to the aesthetics of the buildings

- Composite Panels

Nowadays, aluminum and stainless steel are the most commonly used metal materials for cladding systems. There are various forms, sandwich panels and fluffy metal panels.

1. Aluminum Composite Panels (ACP)

Aluminum composite panels are panels consisting of more than one layer of aluminum with a core of polyethylene. Aluminum composite panels are an energy-saving and environmentally friendly curtain wall decoration material, and are widely used for curtain walls, exterior cladding, retrofitting of old buildings and other applications. In recent years, the demand for aluminum panels has grown rapidly, indicating that it is a third generation of decorative building materials. (figure 2.2)(Mohaney and Soni, 2018; Zhao et al., 2017).

Table 2.2: Physical properties of aluminum composite panels(Mohaney and Soni, 2018)

Item	Unit	Thickness		
		3mM	4mm	6mm
Density	g/cm3	0.52	.37	.22
Weight	Kg for m2	.55	.48	.34
Thermal expansion	10-6/0c	2	4	5

There are two common typologies of aluminum panels

- Honeycomb laminated: Plastic, aluminum or tough paper is used to increase the toughness of the aluminum. This typology is useful when the thermal properties of the structure need to be increased, but the system requires more detail.
- Aluminum composite panels (Alucaboned): advanced with the brand Alucaboned, developed in the 1970s by Alcon in North America. This typology can be designed in curves, is easier to install, and is less expensive than other aluminum panels(Çıkış, 2007).

The aluminum panels, which are approximately 50 mm thick, are coated with aluminum, steel, or zinc sheet. The panels are available with heights up to 10 m and curved shapes (figure 2.2)(Çıkış, 2007).

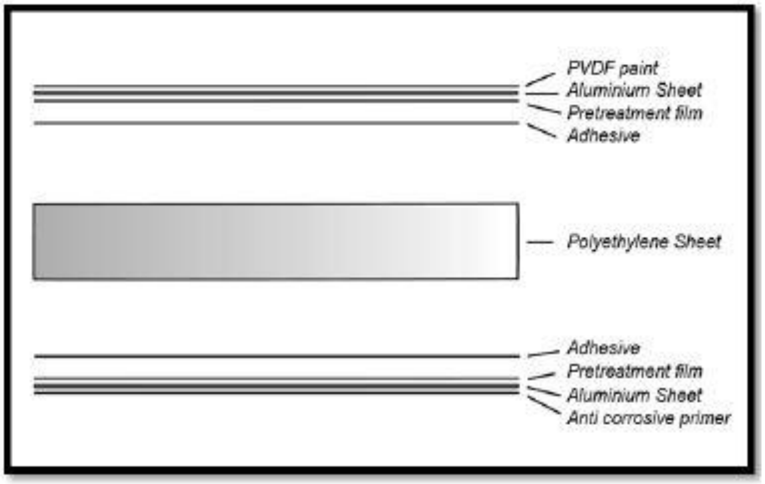


Figure 2.2: Composition of aluminium composite panels(Mohaney and Soni, 2018)

In this research the advantages and disadvantages of aluminum composite panels are shown in the (table 2.2).

Table 2.3: Advantages and disadvantages of aluminum panels

Advantages	Disadvantages
aluminum protects itself against corrosion(Çıkış, 2007)	as the material is highly conductive of heat, cladding components must be thermally broken (Çıkış, 2007)
various surface treatments can be applied to the material including color, texture, brightness etc.(Zhao et al., 2017)	High impact on environment with high GHG emission respectively through life cycle assessment(Rezaei et al., 2019).
it can be fabricated economically into elaborately detailed shapes by means of process of extrusion	
its light weight(Zhao et al., 2017)	
simple connections(Çıkış, 2007)	
Little waste or pollution is associated with the process(Çıkış, 2007)	
equipped with strong wind resistance, bending	

strength(Zhao et al., 2017)	
This type of cladding seldom needs maintenance, lasts for a long time	
can be recycled when a building is demolished(Zhao et al., 2017)	
easy to be constructed or cleaned(Mohaney and Soni, 2018)	

There are a number of mounting systems designed to facilitate the installation of aluminum composite panels. Most of these systems are based on fixing the panels to a steel mesh with a substructure consisting of separate angle joints and ribbed tubes arranged to facilitate the installation of the panels on it. Sometimes between the joints and the vertical panels is placed insulation made of gaskets. (“Technical documents archivos,” 2021)(figure 2.3).

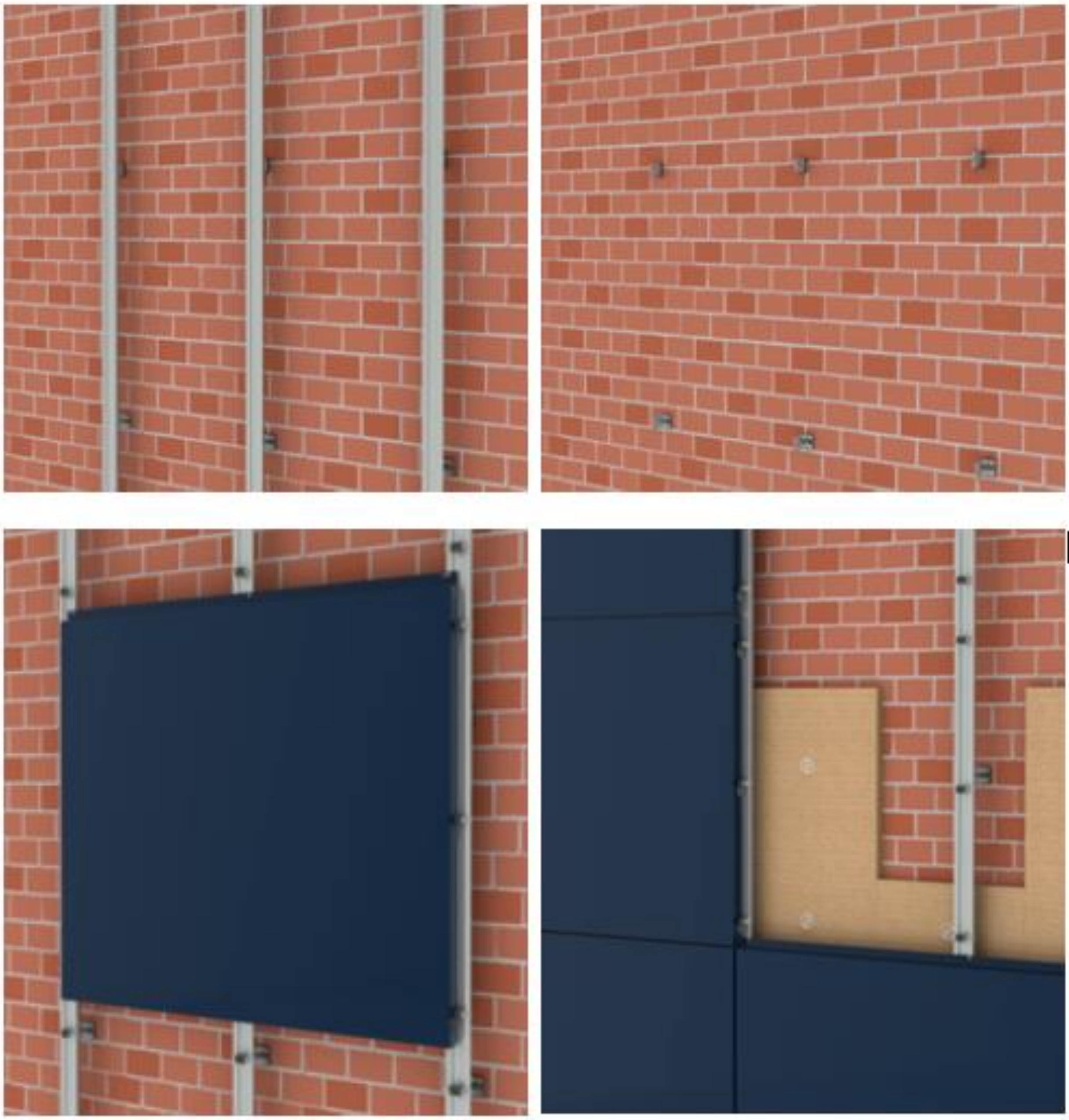


Figure 2.3The stages of installing aluminum composite panels

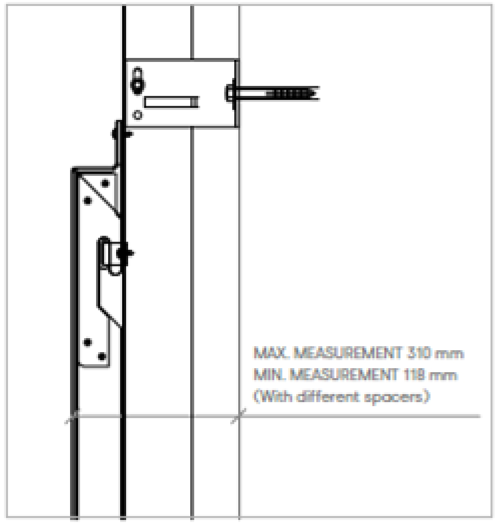


Figure 2.4 Vertical cross-section for installing aluminum panels

An example of aluminum panels will be added from a catalogue of a manufacturer (figure 2.5) to illustrate the most important characteristics that are attached when purchasing panels see (Appendix B).

Figure 2.5 An example of manufactured aluminum composite panels(“Technical documents archivos,” 2021)

Figure 2.6: the use of Alucobond material as an external layer in Hebron commercial building

2. Stainless Steel Panels:

Stainless steel is a durable material that allows for thinner and more durable buildings with more cost-effective features that can be used in a wide range of construction applications (Figure 2.6). There are several types of stainless steel cladding, including embossed, smooth, reflective, and non-reflective surfaces that are also rigid, adaptable, and recyclable. The process of light interference gives deep shades of color to stainless steel("Architectural Metals," 1995; Baddoo, 2008).

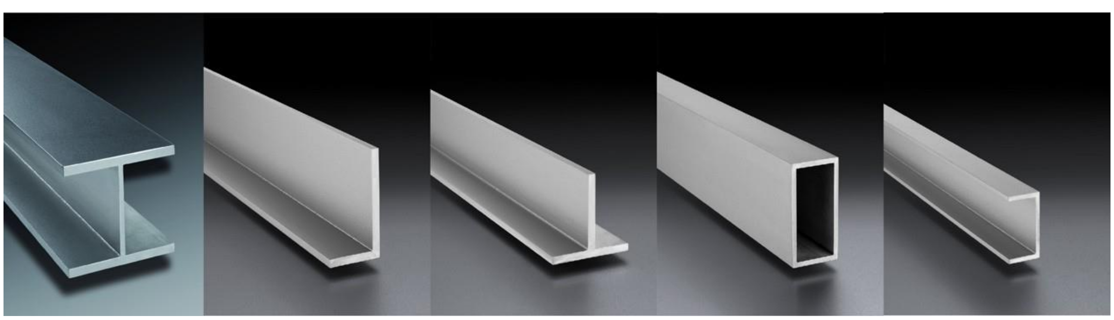


Figure 2.7: stainless steel panels sections(Baddoo, 2008)

The annual growth rate of stainless steel consumption has increased by 5% in the last period, surpassing other materials. Stainless steel differs from carbon steel in having better properties in the stress-strain curves for tension and compression. The joining of stainless steel with other materials should be studied to avoid abrasion between the different materials and to maintain the surface finish, especially when welding is problematic.(Baddoo, 2008). The analyzed of stainless-steel advantages and disadvantages are shown in (table 2.3).

Table 2.4: Advantages and disadvantages of stainless-steel panels

Advantages	Disadvantages
corrosion-resistant(Çıkış, 2007)	High impact on environment with high GHG emission respectively through life cycle assessment(Rezaei et al., 2019)
long-lasting(Çıkış, 2007)	
Making thinner and more durable structures possible (Baddoo, 2008).	
It presents architects with many possibilities of shape, color and form, whilst at the same time being tough, hygienic, adaptable and recyclable(Baddoo, 2008)	
be specified for even greater protection in coastal areas or areas with high pollution levels(Çıkış, 2007)	

3. Wood plastic composite (WPCs)

Wood-plastic composite (WPC) is a lightweight material composed of softwood flour, two types of thermoplastics, high-density polyethylene (HDPE) or polypropylene (PP). There are different concentrations of softwood (10, 20, 30). These types of panels are used as an alternative to aluminum composite panels (Alucobond) (Figures 2.7, 2.8). WPC panels can be made from wood waste and recycled plastics and are therefore environmentally friendly materials. The presence of wood as part of the components improves the thermo physical and mechanical properties of the composite panels (table 2.4)(Mahmood Mussa et al., 2020). These panels are characterized by a low cost compared to traditional panels due to the waste materials that are used in them.

Figure 2.8: Wood plastic composite (WPCs) Source (“WPC Products | Composite products | Rusdecking,” 2021)

Figure 2.9 An example of manufactured Wood plastic composite panels(“China exterior wall Panel made of wood plastic composite is called WPC wall cladding – welcome,” 2020)

Table 2.5: Thermal Properties of WPCs type(Mahmood Mussa et al., 2020)

WPCs type	Thickness(mm)	Thermal conductivity(W/m.k)	R-Value
PP (Alucobondcore)	4mm	0.24	0.016667
	6mm	0.23	0.026087
	8mm	0.22	0.036364
PP+PW10%	4mm	0.235	0.017021
	6mm	0.22	0.027273
	8mm	0.20	0.04
PP+PW20%	4mm	0.21	0.019048
	6mm	0.205	0.029268
	8mm	0.20	0.04
PP+PW30%	4mm	0.20	0.02
	6mm	0.195	0.030769
	8mm	0.192	0.041667
HDPE(Alucobond core)	4mm	0.52	0.007692
	6mm	0.50	0.012
	8mm	0.48	0.016667
HDPE+PW10%	4mm	0.48	0.008333
	6mm	0.46	0.013043
	8mm	0.44	0.018182
HDPE+PW20%	4mm	0.44	0.009091
	6mm	0.43	0.013953
	8mm	0.42	0.019048
HDPE+PW30%	4mm	0.39	0.010256
	6mm	0.385	0.015584
	8mm	0.38	0.021053

The wood-plastic composite panels are installed through a series of steps. An internal steel grid, consisting of a series of longitudinal and transverse bars, is used to arrange the panels one by one and fasten them with a set of stainless nails, drilling holes in the existing wall with a drill bit (figure 2.9)(“WPC Products,” 2021).

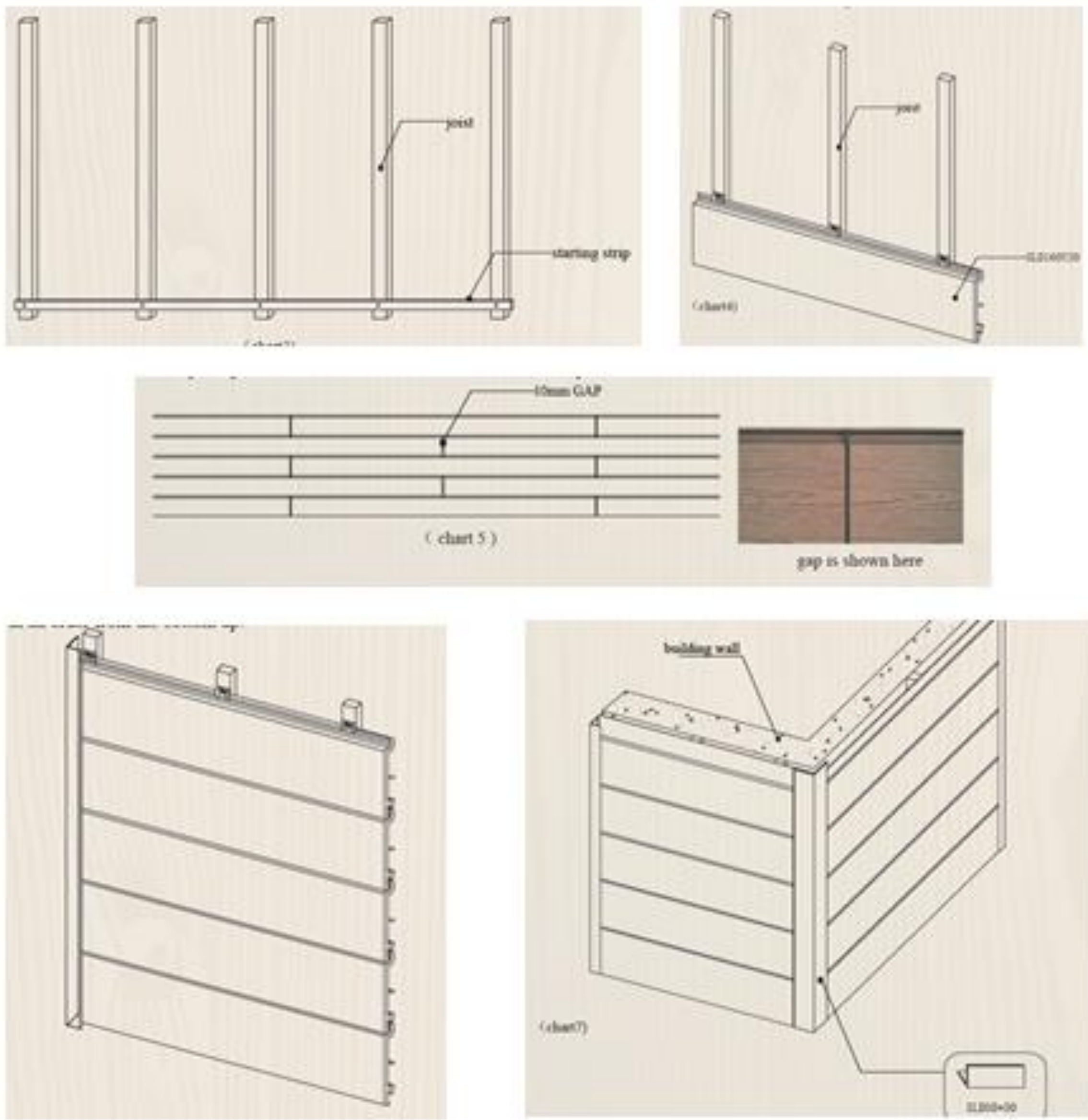


Figure 2.10The stages of installing wood plastic composite panels (“WPC Products | Composite products | Rusdecking,” 2021)

Wood-plastic composite panels usually replace natural wood to solve the problems of wood panels. The wood panels are made by adding insulating materials to achieve better thermal performance. The study (Zhang et al., 2021)dealt with the calculation of the thermal transmittance of a single-layer frame wall clad with a layer of 20 mm thick WPC panels. When calculating the heat transfer coefficient of the two-layer frame wall clad with 50 mm thick WPC panels, the result was that the heat transfer coefficient was lower by half. A value that meets the standard for the thermal level of walls in very cold areas.

Modification of wood-plastic composite panel components is carried out in several studies. In the study (Ayrilmis and Jarusombuti, 2011), the physical and chemical properties of WPC made from PP mixed rubber wood fiber powder formulations were evaluated. In this study, the rubber wood fibers were mixed in different proportions, namely 40%, 50%, 60% with the dry mixed-rubber wood powder PP without and grafted with 3% maleic anhydride PP (MAPP). The result showed that increasing the percentage of wood fiber has a negative effect on the water-resistance of the panels. However, increasing the wood fiber content increases the elastic modulus of the boards. In addition, increasing the fiber content decreases the strength of the internal bonding and the resistance to screw pulling. On the other hand, increasing the percentage of maleic anhydride (polymer) increases the strength and resistance of the boards to water. The study recommends the use of a 50/50 composition of rubber wood fibers and polypropylene as a scientific option, as it has higher water resistance and greater adhesion strength for various applications of wood-plastic composite panels.

The (Foti et al., 2022) study also has demonstrated the success of manufacturing single-layer composite wood panels made of wood dust and recycled polystyrene. 89% of the dust particles used was less than 1 mm. The physical properties, water absorption, rupture modulus, parallel shear strength and swelling of sheet thickness were significantly improved when the percentage of recycled polystyrene content was increased from 15% to 30%. The production of these panels using this waste from raw materials such as recycled polystyrene and wood dust works to get rid of these wastes in a way that provides environmentally friendly wood panels.

The analyzed of wood composite plastic panels advantages and disadvantages are shown in (table 2.5).

Table 2.6 Advantages and disadvantages of WPCs(Mahmood Mussa et al., 2020) (Zhang et al., 2021)

Advantages	Disadvantages
Water-Resistant	The increase in the proportion of wood fiber negatively affects the water-resistance of the panels
The panels are treated with thermal and mechanical physical properties (the presence of insulating materials, air cavity inside the panels)	Increasing the percentage of fiber negatively affects the resistance to pulling the screw in the panels
Environmentally friendly panels	
Longer durability than wood panels and less maintenance	

- Wood

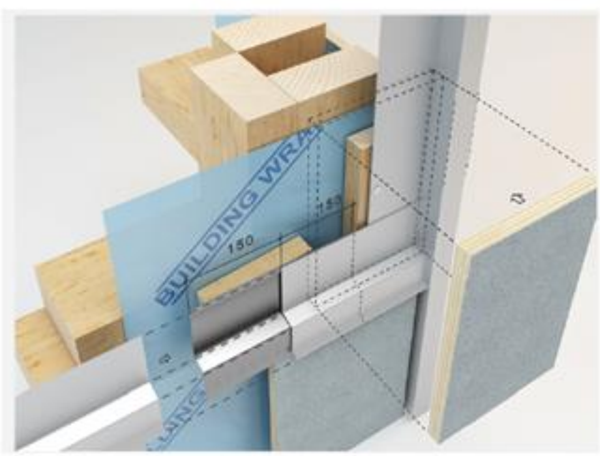
Wood is a hygroscopic material that can exchange moisture with the outside air. Some mechanical properties of wood are affected by the change in moisture content when the fibers are saturated. It is generally known that wood is an environmentally friendly material. Wood is treated with preservatives to protect it from external weather conditions (Pelaz et al., 2017). When it is used as an external layer for the building wall, it is necessary to use materials with a high reinforcing capacity of wood to protect it and provide greater durability (Pajchrowski et al., 2014). Several advantages make wood a popular material, but also some disadvantages, which are summarized below (table 2.5):

Table 2.7: the advantages and disadvantages of wood materials,(Aydin et al., 2006) (Pelaz et al., 2017)

Advantages	Disadvantages
it has a good thermal conductivity coefficient,	flammable
it is a good acoustic insulation ,	Low endurance
it is light and mechanically strong	Great influence on humidity
It presents architects with many	it is affected by amnesty and fungi

possibilities of shape, color and form,	
It is adds a warmth feeling	
Its dimensions does not change with the change in temperature in summer and winter	
It is resistant to destructive chemical effects	
It absorbs moisture if it is available in small quantities and releases it in dry weather, which positively affects the surrounding atmosphere.	
It absorbs moisture if it is available in small quantities and releases it in dry weather, which positively affects the surrounding atmosphere	

The wooden panels are fixed on a grid of longitudinal and transverse stainless-steel bars. A set of stainless nails assists in mounting the panels to the existing wall (figure2.12) ("Shadowclad® Exterior Plywood » Plywood NZ," 2021). Panels are manufactured in various dimensions and specifications. Manufacturers are interested in producing panels of varying quality to meet all requirements. We have included a number of examples from one manufacturer's catalogue (see Appendix B) to familiarise you with the way the product is represented and its specifications are displayed to help you select the most appropriate product for each project (figure 2.10).



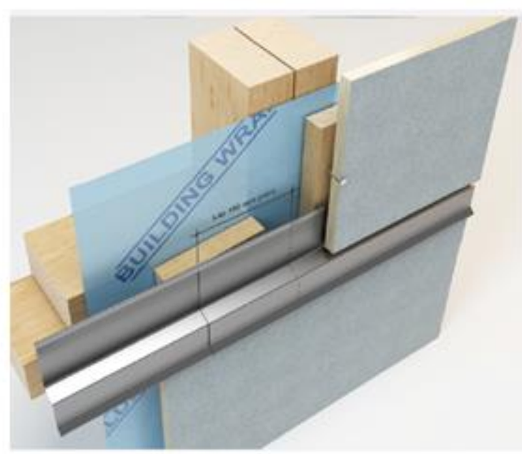


Figure 2.11 Illustrations of installing wood panels for facade cladding ("Shadowclad® Exterior Plywood » Plywood NZ," 2021)

A set of examples has been attached from the catalogue of a manufacturer of wood panels that cover the exterior facades of the building (figure 2.11) see Appendix B.

Figure 2.12An example of natural wood exterior cladding (“S-P-00975 - HPL boards with natural wood finish - Facade and Wet Internal,” 2020)

According to studies, there are practical and proven ways to overcome the disadvantages of wood to use it as an exterior material for the outer wall of the building. There are materials that are treated to overcome the fungal attack and moisture faced by the fibers of the wood material (Pelaz et al., 2017). The prices of wood can also be based on where it is available. When it is available in large quantities, its price decreases, but the lack of availability in the study area, for example, makes it a high-priced material.

2.6 Construction Systems in Hebron

Palestinian building construction consists of a concrete structure with different cladding materials and flat roofs (Husameddin M Dawoud, 2014).

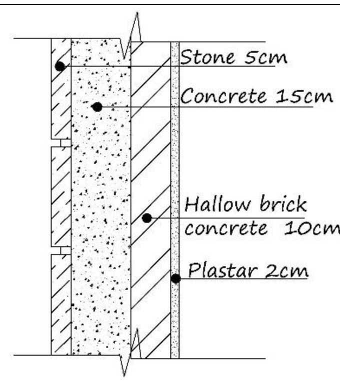
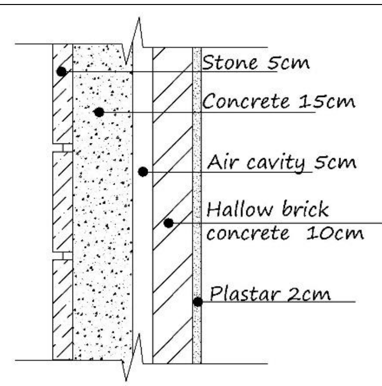
The diversity of exterior walls depends on the diversity of local sources, geographical topology and climatic zone. In addition, economic and social factors also contribute to what type of exterior facade should be used.

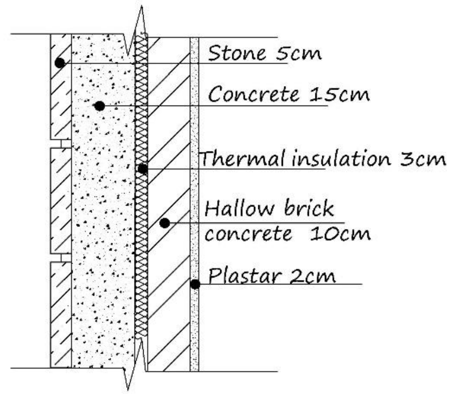
- Exterior concrete walls
  In some areas of Palestine where there is no source of stone material, exterior walls of

concrete are widely used, whether an exterior wall of concrete or hollow blocks of concrete with exterior plaster.

1. Concrete with stone exterior wall Stone exterior walls are one of the most popular building facades in Palestine. There are many types and systems of exterior stone walls with different details and thicknesses depending on the different interior wall layers and insulation (Table 2.7).
   Different internal layers and insulation affect the heat flow through the wall. Therefore, the layers and thicknesses of the façade need to be studied in order to design a suitable insulated façade for the climate of Palestine in hot summer and cold winter

Table 2.8 Stone-concrete wall types

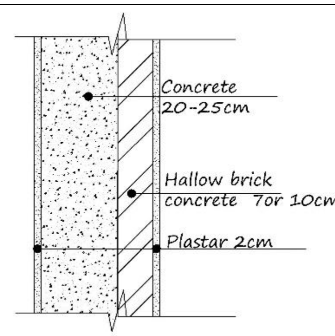
Description	Wall section
1. 5cm exterior stone layer, 15-20 cm of concrete layer, another inner layer of hollow concrete block wall 7 or 10 cm with 2cm cement plaster.	
2. 5cm exterior stone layer, 15-20 cm of concrete layer, 5cm of air cavity, and another inner layer of hollow concrete block wall 7 or 10 cm with 2cm cement plaster.	

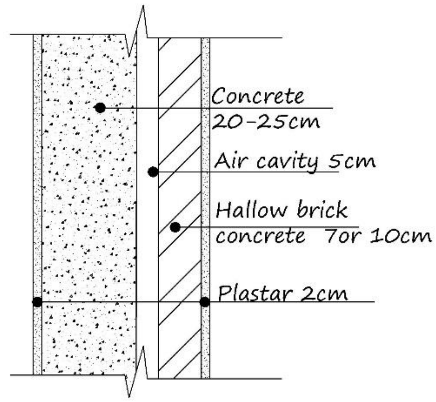
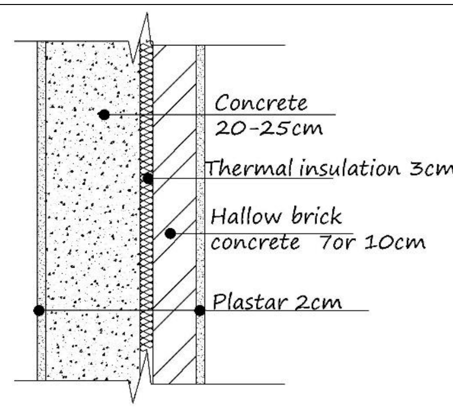
3. 5cm exterior stone layer, 15-20 cm of concrete layer, 3cm of thermal insulation layer, and another inner layer of hollow concrete block wall 7 or 10 cm with 2cm cement plaster.	

2. Concrete with external plaster

Concrete used in the external facade could by ready-mixed concrete or precast concrete. The ready-mixed concrete is the most common types with the reinforced concrete column (table 2.9)

Table 2.9: Concrete Wall types

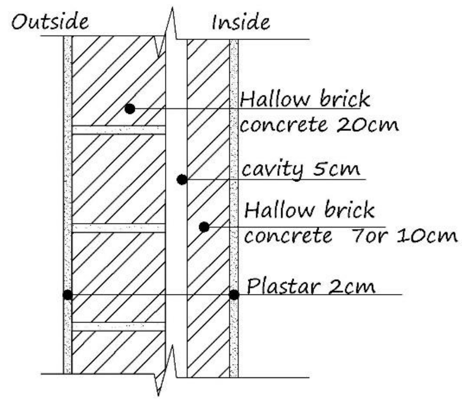
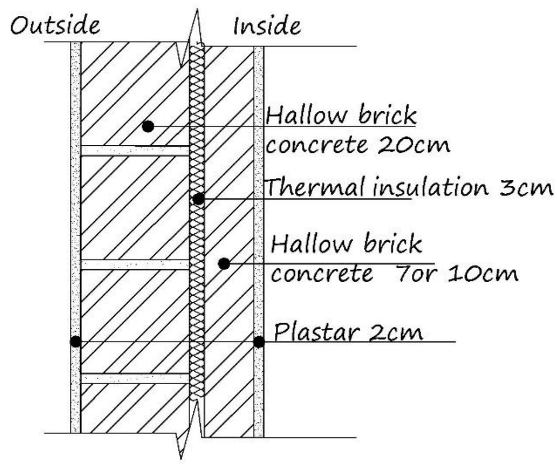
Description	Wall section
1. External concrete wall 20-25cm with 2cm layer of cement plaster then another hollow concrete block 7 or 10 cm to increase the wall insulation.	

2. External concrete wall 20-25cm with 2cm layer of cement plaster, 5cm air cavity, then another hollow concrete block 7 or 10 cm for more insulation.	
3. External concrete wall 20-25cm with 2cm layer of cement plaster, 3cm thermal insulation layer, then another hollow concrete block 7 or 10 cm with 2cm plaster for more insulation.	

3. External Hollow Concrete Block Walls

Hollow concrete blocks are widely used in Palestinian camps. This type is cheaper than stone. There are three types of concrete blocks used in Palestine: hollow load-bearing, non-load-bearing, and solid load-bearing (table 2.10).

Table 2.10: Hallow concrete block wall types

Description	Wall section
1. Hollow concrete block 20 cm built from outside then air cavity 5cm and another layer of 7 or 10 cm hollow concrete from the inner side.	
2. Hollow concrete block 20 cm built from outside then thermal insulation layer 3cm and another layer of 7 or 10 cm hollow concrete from the inner side.	

Concrete is a mixture of Portland cement, aggregates and water. A chemical reaction takes place between the concrete components to produce the desired mixture. The proportions of mix components that directly affect the properties of concrete vary (Table 2.11). Typically, 10 to 15 percent cement, 60 to 75 percent aggregates are mixed with 15 to 20 percent water. Water with cement is a wet mixture mixed with aggregates that vary according to the type and size of concrete desired. The mixture is homogenized and poured to the desired location before it becomes stiff. (Hadid, 2002).

Table 2.11: Thermal Properties of Light Weight Aggregate Concrete(Hadid, 2002)

Density (Kg/m3)	Thermal Conductivity (W/m.Co)	Specific Heat Capacity (KJ/Kg/C)
800	39	97
900	44	97
1000	49	97
1100	55	97
1200	62	97
1300	70	97
1400	79	97
1500	89	97
1600	1.00	97
1800	1.30	97
2000	1.60	97

- Insulations

Insulation materials are applied to the exterior wall of a building to improve the insulation of the walls between the exterior and interior spaces. There are different types and forms of insulation materials used in Palestine. The most common types are:

1. Polyurethane and polystyrene foams

Polystyrene is a material derived from petroleum. It is produced in the form of sheets that resist natural conditions such as moisture and water. Polystyrene is produced in the form of sheets with thickness of (12.7, 19.05, 25.4, 38.1, 50.8, 76.2, 101.6) mm and width of (0.406, 0.610, 1.219) m. Polystyrene is produced in three types (figure 2.13)(Salameh, 2012).

- Extruded polystyrene.
- Low and medium density expanded polystyrene.
- High density expanded polystyrene.

2. Rock wool panels (RWP)

Rock wool is an insulating material in the form of a board containing bonded fibers bonded with a thermal binder. Rock wool is produced in various densities and thicknesses - rigid and semi-rigid. (Salameh, 2012)

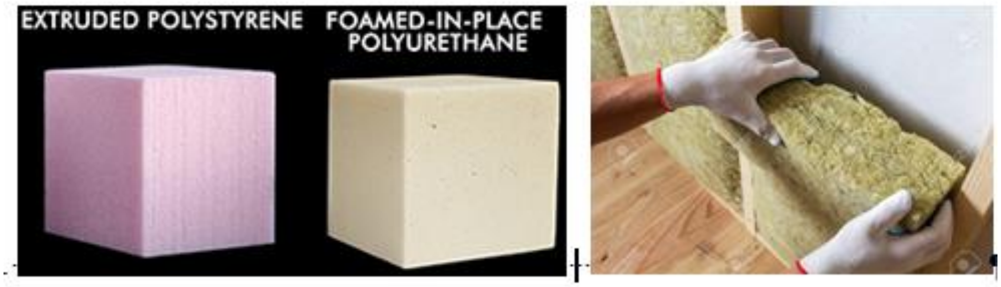


Figure 2.13: insulation materials (Shannon, 2009)

Asfour's study demonstrated that the use of thermal insulation in the walls and ceilings of buildings in Gaza City can directly reduce unwanted heat gains and losses from the building envelope. The presence of insulation in the ceilings and walls reduces human discomfort by 17% throughout the year. The study also recommended that the use of the air cavity as thermal insulation in the double wall has greater effectiveness than the use of polystyrene thermal insulation (Asfour and Kandeel, 2014).

A few years ago, people in Palestine shied away from using thermal insulation because the cost was too high and people were unaware of the benefits. Recently, Palestinians have become aware of the importance of insulating walls (Alsayed, 2019).

Nowadays, various cladding systems are used on commercial buildings in Palestine to attract people and as a kind of exterior decoration of the building. These systems include various materials such as aluminum (ALUCOBOND), wood- plastic composite panels and wood panels in various colors and shapes. However, there are no local studies to determine the impact of these cladding systems on indoor thermal performance.

In the last two decades, advanced materials and technologies have improved, especially in the field of cladding systems. Architects and civil engineers now use composite materials as an alternative to traditional techniques. The concept of composites refers to new materials made from two or more different compositions, which may be natural or synthetic components. The composites have higher quality physical and mechanical properties than single raw materials, such as high performance, fire resistance, stiffness, lightness and tensile strength, etc. In addition, the innovative materials and construction technologies in cladding systems reduce energy consumption.(Martini, 2014).

2.7 Summary

This chapter has focused on the discussion of the main issues and definitions related to the research objective:

1. The definition of the cladding system and its objectives, and the relationship between the systems and the internal environment of the building

2. A study of the main materials used for building cladding and the advantages and disadvantages of each material. It was concluded that composite panels have several advantages depending on the materials used.

3. The generally accepted building systems in Palestine were studied.

Chapter 3 Commercial Buildings and Energy Consumption

3.1 Preface

Construction and building design have changed dramatically in the Palestinian Territories in the last century. There has been a great development in new materials and construction technologies that have transformed buildings into walls and ceilings of varying thickness. Thermal insulation has replaced the thick walls and vaulted ceilings of older buildings. However, new buildings have a higher demand for cooling, heating and ventilation systems, which increases energy consumption.

In recent days, there is a tendency in the Palestinian territories to look for alternatives that increase the efficiency of buildings. There is an increased focus on highly efficient insulation materials and new construction techniques and methods that reduce heat gain in the summer and heat loss in the winter. In this way, energy consumption in buildings is reduced and occupants are provided with greater comfort and a better environment.

3.2 Commercial buildings

The commercial building (shop) is an evolution of the multifunctional building, where the lower floors are apartments or offices. This type of building is considered the most popular investment building in Hebron Palestine. According to the Palestinian Building Law, these buildings are allowed to be built in many areas, such as commercial areas, main roads and production areas. The height of the stores varies from 3 m to 8 m with a mezzanine floor on the first floor, while the upper floors themselves have a design and height with living spaces that can be converted into offices.(Hadid, 2002).

There are two types of a commercial building:

1. Linear-shop building:

   This type of shop is a lower floor with a height of up to 8 m and in most cases with a mezzanine. The building design follows the street line, forming a chain of stores on the main streets and in the commercial areas (Figure 3.1) (Hadid, 2002).

Figure 3.1: Linear shop building in Hebron

2. Commercial Center (Mall):

Commercial buildings have many shapes and designs; some have a courtyard in the center of the building whose upper opening is covered by a skylight that provides light for all floors, others have a portion of the courtyard on the lower floors that is then covered to be used as interior space, and still others have no courtyard at all. Horizontal movement is through corridors and vertical movement is through stairwells and elevators leading to stores, offices and other facilities. (figure 3.2) (Hadid, 2002).

Figure 3.2 Hebron center mall

3.3 Thermal Performance in Commercial Buildings

The thermal performance of commercial buildings is the performance of the building due to the flow of heat between the external environment and the interior spaces. The quality of the building's thermal performance depends on the physical thermal properties of the building envelope components: Walls, openings, windows, ceilings, as well as the orientation of the building. The building materials that make up the building components control the amount of heat flow through them. Commercial buildings are buildings that are operated over a long period of time to buy and sell. These buildings contain equipment and appliances in addition to the occupants who require thermal comfort. Energy is consumed by the operation of the corresponding air conditioning systems to achieve the desired comfort during working hours3.4

3.4 The Relationship between Thermal Performance and Energy Consumption

The intensification of energy consumption in heating, ventilation and air conditioning systems is essential in parallel with the increase in demand for thermal comfort, a luxury that spread not so long ago. This has led to significant energy consumption in all building sectors. Thermal comfort is defined as 'that condition of mind which expresses satisfaction with the thermal environment' (International Organization for Standardization et al., 1994). Predicting average temperatures to achieve comfort depends on cultural influences, including environmental and personal factors (Taleghani et al., 2013).

3.5 Impact of Different Parameters on Building on Energy consumption

There are a set of factors that affect energy consumption in buildings, such as designs, new materials and the use of passive design strategies. The strategies are taking into account the building orientation, window-to-wall ratio, insulation, building shape, the use of high-efficiency glazing, in addition to air movement and ventilation in the building. The electrical loads resulting from improving the quality of the internal environment consume a large amount of the total energy of the building.

The design of the building envelope has a major impact on the energy consumption of the building and thus on the thermal comfort for the occupants as well as on the indoor air quality (Ge et al., 2013). Proper selection of building materials reduces the energy consumption of the building. Materials with low thermal conductivity help reduce heat gain and loss from the building envelope, thereby reducing associated peak heating and cooling loads (Robati et al., 2017).

Innovative technologies and strategies for energy efficiency measures are now widely available, and the main problem is determining which technology is most effective for a given building and sustainable in the long term. Various building energy efficiency measures aim to meet occupant needs. Building energy improvement scenarios are determined by an energy expert and then evaluated primarily through simulations. Where energy is first analyzed, the strategies studied and developed are then implemented. These scenarios differ depending on the characteristics of the building, its type and use, and climatic and other conditions (Diakaki et al., 2008).

3.6 Energy Consumption in Palestine

In the Palestinian Territories, energy consumption amounted to 75,178 TJ in 2018. Of this, electricity accounted for about 28%, imported and manufactured energy for 58%, and renewable energy for about 12%.

In 2008, the residential sector accounted for 45% of final energy consumption, the transportation sector for 38%, and the commercial, industrial, and agricultural sectors for the remainder (*West Bank and Gaza Energy Efficiency Action Plan 2020-2030*, 2016).). The commercial sector reached 10%, the agricultural sector reached 6%, and the agricultural sector reached 1%, according to the figures (3.3, 3.4).

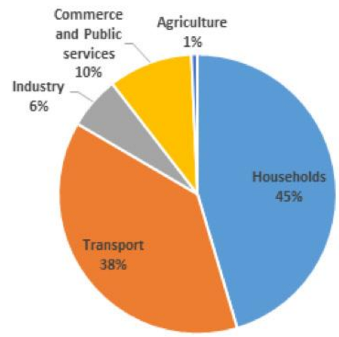


Figure 3.3: Energy Consumption in Palestine by sectors (*West Bank and Gaza Energy Efficiency Action Plan 2020-2030*, 2016)

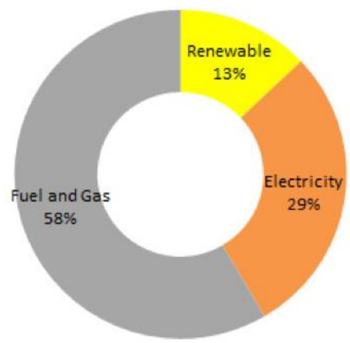


Figure 3.4: energy consumption in Palestine 2018 (*West Bank and Gaza Energy Efficiency Action Plan 2020-2030*, 2016)

Energy consumption in commercial buildings and public services has doubled in value; in the early years from 2010 to 2011, the value was even higher. However, this doubling has declined significantly in recent years. The reason for the doubling of energy consumption is the extensive switch to the use of electric air conditioning in these buildings (table 3.1).

Table 3.1: Electricity Consumption in commercial and public services Buildings in Palestine (*West Bank and Gaza Energy Efficiency Action Plan 2020-2030*, 2016)

Flows	Electricity (GWh)2010	Electricity (GWh)2011	Electricity (GWh)2012	Electricity (GWh)2013	Electricity (GWh)2014	Electricity (GWh)2015	Electricity (GWh)2016	Electricity (GWh)2017	Electricity (GWh)2018	Electricity (GWh)2019
Commerce & public services	523	1024	1624	1174	1098	1296	1346	1349	1473	1827.8

3.7 Strategies to Minimizing Energy Consumption in Buildings

Strategies for minimizing energy consumption in buildings can be divided into two different levels. The first level is the decision level. Here, there are regulations and laws from the Department of Energy and the Department of Buildings that affect construction. They prescribe certain standards that aim to reduce energy consumption in the design, implementation, and operation phases of the building (Turrin et al., 2012). The second level refers to the extent to which the design phases of the building are modeled using computer simulations and developments for the design of the building, which increases the performance of the building, thus reducing energy consumption and finding appropriate solutions in the early design phases. Multiple computer programs allow design engineers from all disciplines to help and collaborate to develop an integrated design for buildings that reduces energy consumption.

CFD (Computational Fluid Dynamics) used for modeling, this environment provides simultaneous visualization of heat transfer, airflow movement, and pollutant ratio (Zhai and McNeill, 2014). This tool helped in evaluating the building and developing strategies for energy efficient cooling and heating. However, this tool requires a high level of skill in working, calculating, and carefully following the steps.

3.7 Summary

This chapter has focused on discussing the major issues related to thermal performance and energy consumption:

1. residential and commercial buildings account for the largest electricity consumption, and Hebron is the West Bank city with the largest number of commercial buildings.
2. strategies to reduce electricity consumption are summarized in laws and regulations issued by the government authority for the main standards to which buildings must be designed, in addition to a strategy for the design and simulation of the building before its implementation, in order to study all possible options and achieve the most energy-efficient design.

Chapter 4 Research Methodology

4.1 Preface

This chapter examines how the design of exterior walls affects the thermal performance of a building and tests the new cladding materials used in commercial buildings in Palestine. The thermal performance of buildings can be affected by many parameters. The building materials used for the building envelope have the greatest impact on building performance and energy consumption.

The great development in building materials technology has led to the emergence of new cladding materials and construction techniques, neglecting the impact of these materials on the thermal performance of the building or their proper use to improve the performance and energy consumption of the building.

The research deals with a certain method of comparison between new cladding materials to achieve the best design for exterior cladding of buildings with different variables and factors. The objective of determining the research methodology is to identify how the research objectives can be achieved in a logical manner (figure 4.1).

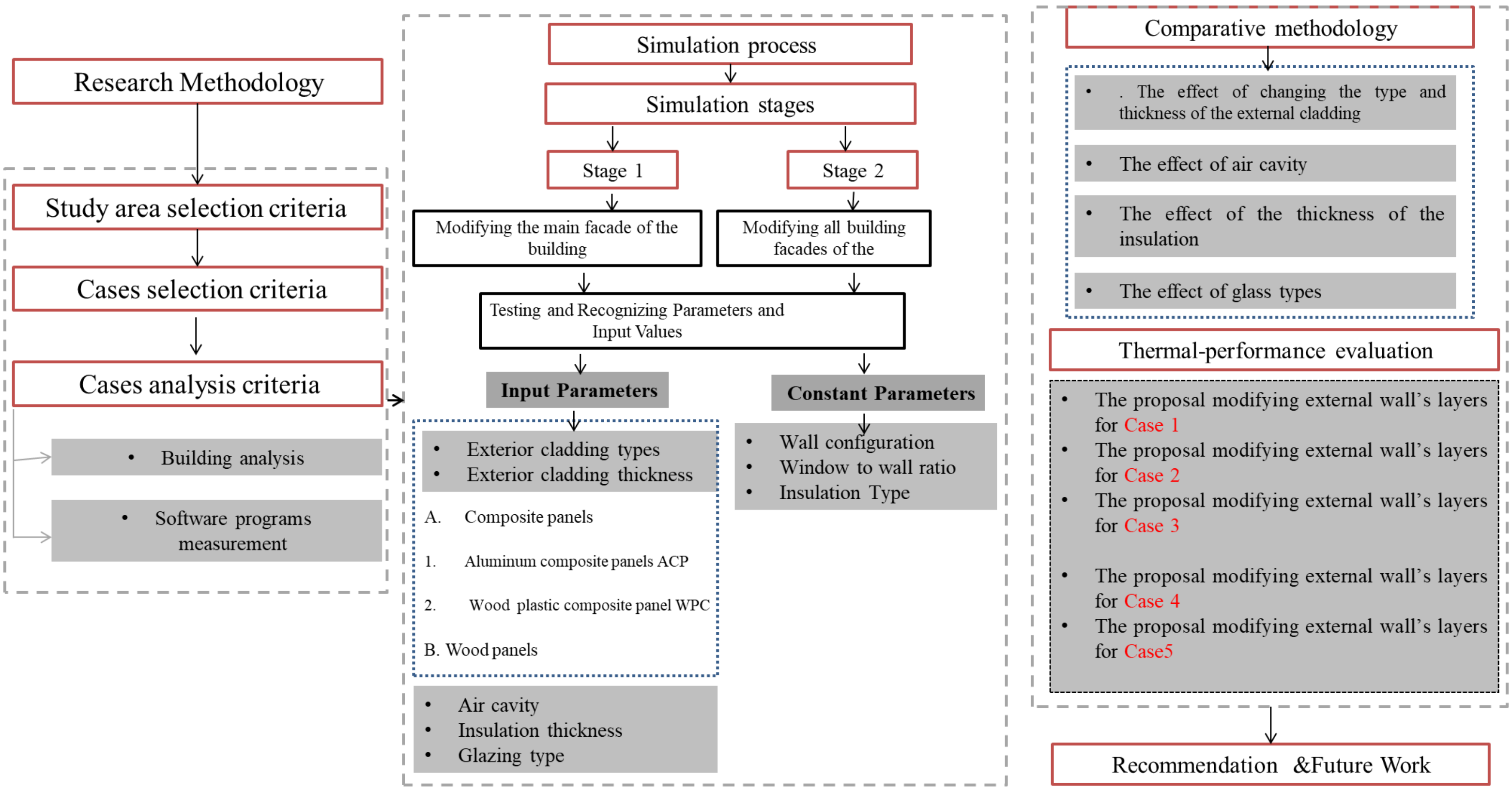


Figure 4.1: the sequence of the research methodology

Both qualitative and quantitative methods were used in the data collection and simulations. These processes provide a systematic framework to obtain a comparative evaluation of the thermal performance of cladding systems in commercial centers. Interviews were conducted to assess the thermal satisfaction of commercial centers owners to ensure that the problem exists and that a solution needs to be found. A representative sample of case studies of commercial buildings was selected to provide a systematic modeling framework to compare all possible cases and then arrive at reasonable results that help create a matrix of the best designs of façade systems in commercial centers for the Mediterranean climate with a variety of variable parameters such as orientations and exterior wall layers. The matrix can be extracted after a lengthy discussion of the results and by summarizing the various design parameters.

4.2 Study Area Selection Criteria

The selected area for the research work is considered one of the Palestinian cities where the problem exists. Hebron is considered the commercial capital of the West Bank, Palestine.

According to the Palestinian Statistics Center, it registers the highest number of commercial buildings. Therefore, a wide variety of new cladding materials, especially for the main facades, is a common phenomenon in Hebron. It is a great phenomenon because the commercial buildings have a great variety of new cladding materials for the main facades.

4.3 Cases Selection Criteria

The case study method is applied to study the contemporary phenomenon of new facade design. There are many cases of modern facade technology as this trend is increasing day by day in Hebron, Palestine. A large number of commercial buildings were randomly selected from the study area (see Figure 4.6). Certain criteria were followed:

1. The selection considers cases that are commercial projects (retail type).
2. Cases with different main façade orientations are considered in order to focus on the study of the fourth main orientation.
3. The selection considers the commercial projects that have exterior wall layers of new cladding materials.
4. The cases that have stone and concrete wall configuration are also included in the selection.

It is important to know the details of each case study, i.e., the areas, types, and numbers of each floor. This will facilitate the analysis of energy consumption and the calculation of cooling and heating loads. It is also necessary to know the activities and applications carried out. The five selected cases were listed as follows (table 4.1)

Table 4.1: The selected cases of commercial buildings

No	Project Name	Location	Use	Cases selection
1.	Sbitany I store	Alsalam st.	Retail sales	 Figure 4.2 Case1 Sbitany I Store

2.	AL-Bayed center	Al haouz st.	Retail sales	 Figure 4.3 Case 2 AL-Bayed Center
3.	Home Plaza	Mafraq al-algama' st.	Retail sales	 Figure 4.4 Case 3 Home Plaza
4.	LC WAKIKI	Al-haras st.	Retail sales	 Figure 4.5 Case 4 LC WAKIKI
5.	Alsalam center	Alsalam st.	Retail sales	 Figure 4.6 Case 5 Al-Salam Center

In this research, the five selected commercial constructions were chosen as typical cases for comparison and discussion, while the research was conducted in the initial phase of the study. In the first and second cases, the south façade was studied, which is the main façade of the commercial center, since it is considered the most critical façade that is exposed to direct sunlight for a long time in summer. In addition, the third case study examined the impact of the changes to the north façade (the main façade). This façade is not exposed to sunlight and is therefore considered the critical façade in the Mediterranean buildings that needs special treatment in winter. The fourth case study concerns the main facade in the west and the fifth case study was selected to study the design of the east facade.

4.4 Cases Analysis Criteria

The selected cases were analyzed based on documentation collected both directly and indirectly through surveys, interviews, and observations. The analysis criteria have a specific method that includes two parts:

A. Building analysis: tabular data, including building location, main façade orientation, exterior cladding materials, etc. (Table 4.2).

Table 4.2: analysis tabulated data

Building Location:	Street- city	No. of windows	1, 2, 3…10.
The orientation of the main façade	orientation	No. of floors	1, 2, 3…10.
Exterior cladding materials	Materials type	No. of doors	1, 2, 3…10.
WWR	10, 20,100%	Cooling and heating systems	Conditioning type

B. Measurement of the software programs: In order to complete the analysis process for the selected cases, measurements were taken for different parts, e.g., building area, window-to-wall ratio, main facade area, etc. In order to simulate the building accurately, software programs were used (table 4.3).

Table 4.3: Tabulated data measurements

Building floor area	In square meter	Building activity	Building type
The area of the main façade	In square meter	the work hours	1, 2, 3 …, 24.

4.5 Simulation Process

In this study, changes in exterior wall layers and glass types that affect thermal performance and energy consumption were analyzed using HAP version 4.9 software to determine the value of the building's heating and cooling loads during the summer and winter seasons. The hourly analysis program is a commercial software for hourly calculation of cooling and heating loads that provides high quality results. The program uses the ASHRAE Transmit Task process for load calculations and Energy Simulation Method 8.780 hour-by-hour for energy use analysis. The goal of this program is to help engineers know the annual energy. This annual energy is used to design heating, ventilation, and air conditioning systems for all types of buildings (Zaphar and Sheworke, 2018). The program works on scaling commercial air conditioning systems and simulates the energy performance of the building. In addition, it facilitates effective daily work in estimating loads, sizing systems, and evaluating building energy performance by using input data, and then the results of direct design calculations from studies and energy(Crawley et al., 2008).

Energy analysis is performed in the hourly analysis program during the design phase of the project through a series of steps that begin with the collection of complete data on the building, the environment, and the types of heating, cooling, ventilation, and other HVAC design system requirements. The main information that must be collected and included in the program:

- Complete climate data for the building area.

- General information about the building, including building dimensions, size, shape, floor plan, number of stories, and floor area

- General information about the type of material layers to be used for exterior walls, windows, doors, and ceilings.

- General information about the use of the building, its hours of operation, population density, and the level of use of equipment, machinery, and lighting.

- General information about air systems, equipment and devices needed for the air conditioning system.(Carrier, 2016)

Afterwards, the general information about the project was collected and entered into the hour analysis program. Then it proceeded to the output of the results in the form of simulation reports containing estimates of the annual loads of the building, in order to arrive at the design of the appropriate air conditioning system for the building(Carrier, 2016).

A discussion was held with an engineer working in the Palestinian market to estimate the different building loads. In addition, one of the main objectives was to provide guidance and to highlight the effectiveness of the hourly analysis program in estimating annual cooling and heating loads and determining the required size of HVAC equipment.

This program provides accurate results proven by real use of building load in many different cases in the market.

Categorizing Parameters

As referenced in the literature review in Chapter 2, the set of parameters are constant, variable parameters and confounding variables (table 4.4).

Table 4.4: Categorizing Parameters

Input Parameters	Constant Parameters	Confounding variables
• Insulation thickness • Glazing type • Exterior cladding types • Exterior cladding thickness	• Wall configuration • Window to wall ratio • Insulation Type	• Occupancy • Lighting • Appliances

4.5.1 Simulation stages

1. In the first phase of the simulation, the main building facade was changed in case 1 and 2 (south facade), case 3 (north facade), case 4 (west facade) and case 5 (east facade). In addition, the rest of the building facades remain unchanged, i.e., they are made of stone and concrete, with

no insulation applied to the wall (Table 3.5).
2. The second phase of the simulation was modified on all facades of the building by adding insulation for all facades and each case separately to achieve the best design of the facades of the building (table 4.5).

Table 4.5: Simulation process in stages

Cases		Simulation process
Case 1	Stage 1	• Modifying the south and east façade (new cladding material, stone, concrete, insulated and concrete block)
	Stage 2	• Modify the north and west façade (stone, concrete, insulated and concrete block)
Case 2	Stage 1	• Modifying the south façade (new cladding material, stone, concrete, insulated and concrete block)
	Stage 2	• Modifying the north, east and west façade (stone, concrete, insulated and concrete block)
Case 3	Stage 1	• Modifying the north and east façade (new cladding material, stone, concrete, insulated and concrete block)
	Stage 2	• Modifying the south and west façade (stone, concrete, insulated and concrete block)
Case 4	Stage 1	• Modifying the west (new cladding material, stone, concrete, insulated and concrete block)
	Stage 2	• Modifying the south and north and east façade (stone, concrete, insulated and concrete block)
Case 5	Stage 1	• Modifying the east, north and south facades (new cladding material, stone, concrete, insulated and concrete block)
	Stage 2	• Modifying the west façade (stone, concrete, insulated and concrete block

The process of developing and modifying the outer wall of the study cases took place in both phases according to a specific algorithm, which is a series of parametric commands within well-defined constants and variables, as follows:

1. Simulating the building as it is in reality, without any change
2. Stage 1: simulating the effect of changing the main facades in each case with the following steps:
   A. Simulating the effect of adding different types of cladding material on the building performance.
   B. Verification of the impact of different cladding material thicknesses on the main facades of the cases.
   C. Simulating the effects of adding thermal air cavity layer and a 10 cm thick hollow concrete brick to the main facades.
   D. Replacement of the thermal air cavity with an insulating material (expanded polystyrene)
   E. Review of the effects of different insulation thicknesses on building performance.
   F. Application of different glazing properties in glazing areas and doors to check their effects on the building performance.
3. Stage 2: Application of all the previous steps of the first stage in this stage, they were applied to the main facades of the building with the average insulation thickness of the other building facades.
4. The application of a horizontal shading device to reduce the impact of direct solar radiation on the south facades, if the south facade has a glass surface.

4.5.2 Testing and Recognizing Parameters and Input Values

All interfaces were studied in the previous cases. The simulation was carried out in the presence of a group of parameters that affect the internal temperature of the building and change the cooling and heating load. While the facades of the building were studied, focusing on the treatment of the main facades, the usual wall was installed in the area composed of stone and concrete, and finally the variables studied were added. The types and thickness of the outer layer of the cladding system were studied and different insulation thicknesses of the wall were added. In addition, the types of glass used were studied without changing the glass surfaces, except in the first case windows were added. The study of the materials that make up the roof was neglected, since the simulation was carried out on the first floor of the building.

1. Exterior wall layer

- Composite panels

a) Aluminum composite panels ACP: The thickness of the aluminum composite panels was determined to be 4, 6 and 8 mm during the study (Figures 4.8, 4.11) (Table 4.6). These are the most widely used panels in the Palestinian market.

b) Wood-plastic composite panel: simulations were performed for the study cases by changing the types of wood composite panels and their thicknesses of 4, 6 and 8 mm. The different types of panels were selected according to the different percentage of wood in the mass of the panels (10, 20 and 30%). They were used as external cladding of the building wall on the main façade, which was studied in the first simulation phase. Then, in the second simulation phase, they were applied to the two main facades to achieve the optimal condition of thermal optimization for the exterior of the building. In the simulation, 50.8 mm thick insulation, 10 cm hollow concrete brick and Double-High Solar Gain - Low E Glass type were used. The cross section of the wall (figures 4.9, 4.12) (table 4.6).

- Wood panels: the type of wood material changed and the simulation worked for the two types of plywood with a thickness of 13, 16 and 19 mm (Figure 4.5), in addition to the wood boards with a thickness of 15, 20 and 25 mm (figures 4.10, 4.13) (table 4.6).

Table 4.6: the types and thickness of the cladding to be studied

<table>
<tr><td colspan="4">Types</td><td>Thickness</td></tr>
<tr><td rowspan="4">composite panels</td><td colspan="3">Aluminum composite panels ACP</td><td>4,6,8 mm</td></tr>
<tr><td rowspan="3">Wood composite panel</td><td rowspan="3"></td><td>PP (Alucobond core)</td><td rowspan="3">4,6,8 mm</td></tr>
<tr><td>PP+PW10%</td></tr>
<tr><td>PP+PW20%</td></tr>
</table>

			PP+PW30%	
			HDPE(Alucobond core)	4,6,8 mm
			HDPE10%	
			HDPE20%	
			HDPE30%	
Wood panels	Plywood			13,16,19mm
	Wood boards			15,20,25mm

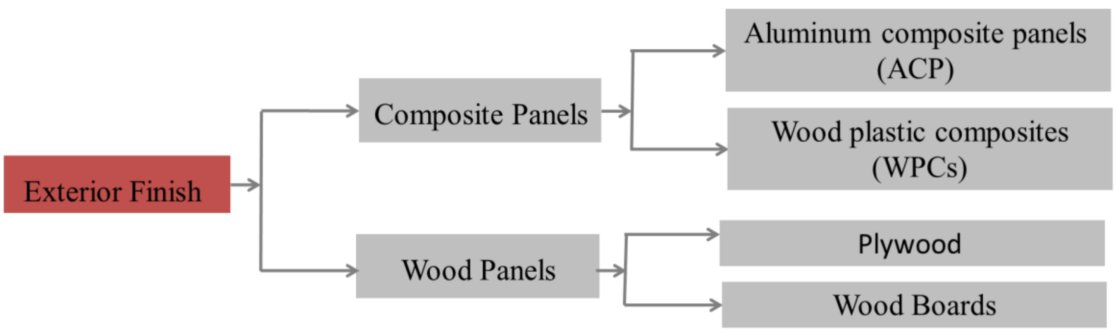


Figure 4.7: The cladding materials included in the study

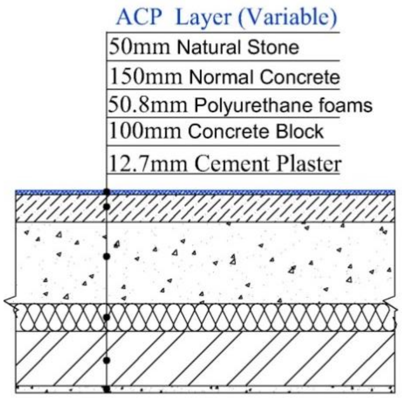


Figure 4.8: Cross section for studying ACP layer

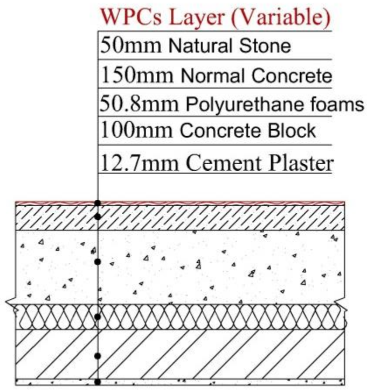


Figure 4.9: Cross section for studying WPCs layer

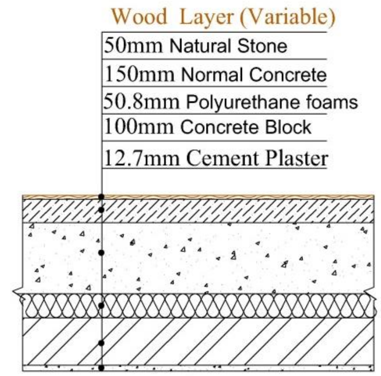


Figure 4.10: Cross section for studying Wood layer

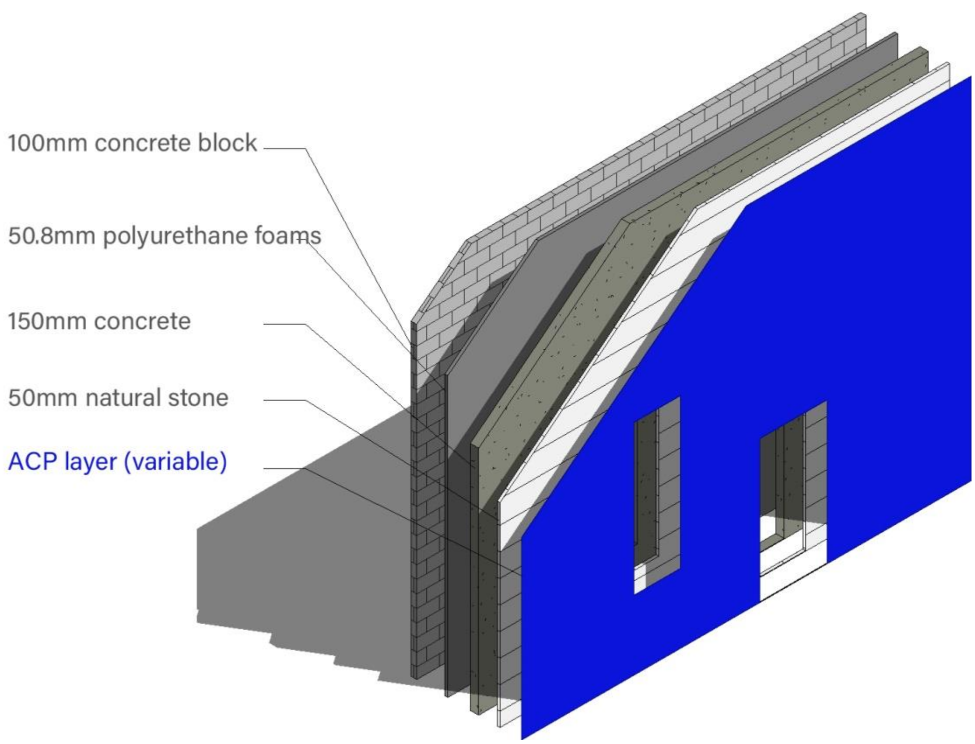


Figure 4.11: Detailed section of ACP wall layers

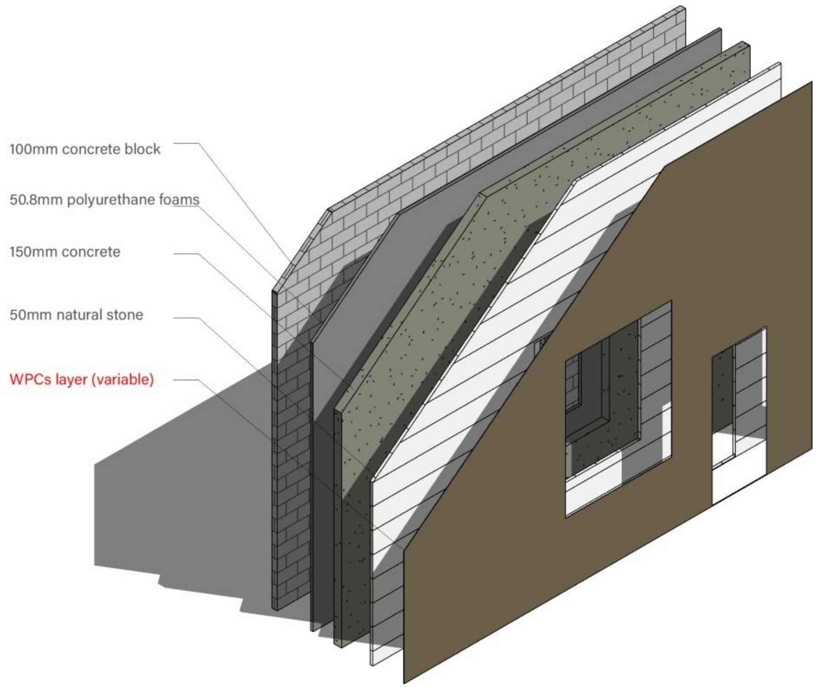


Figure 4.12 Detailed section of WCP wall layers

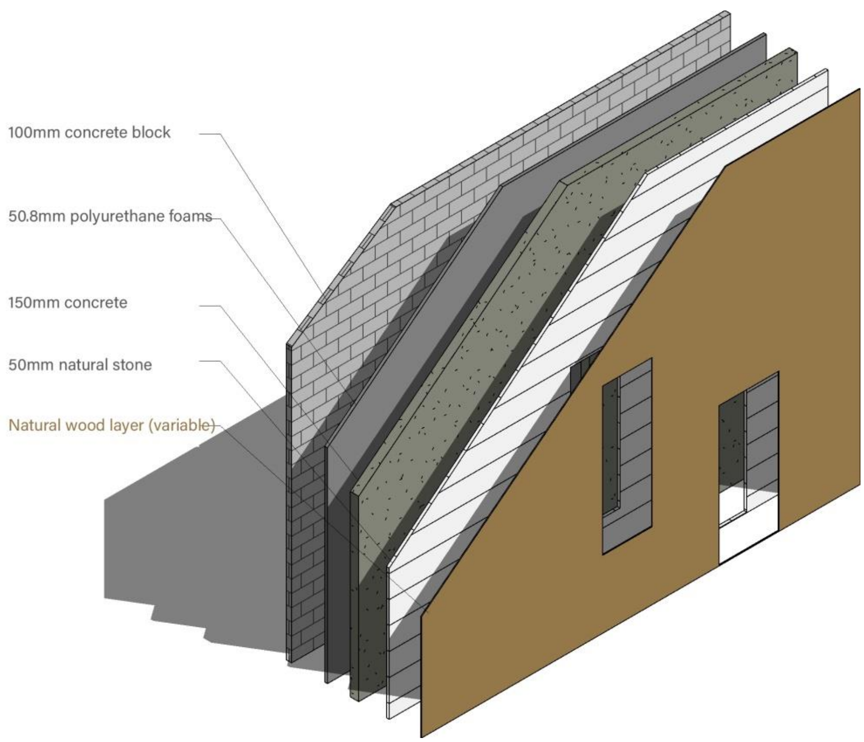


Figure 4.13 Detailed section of Natural wood wall layers

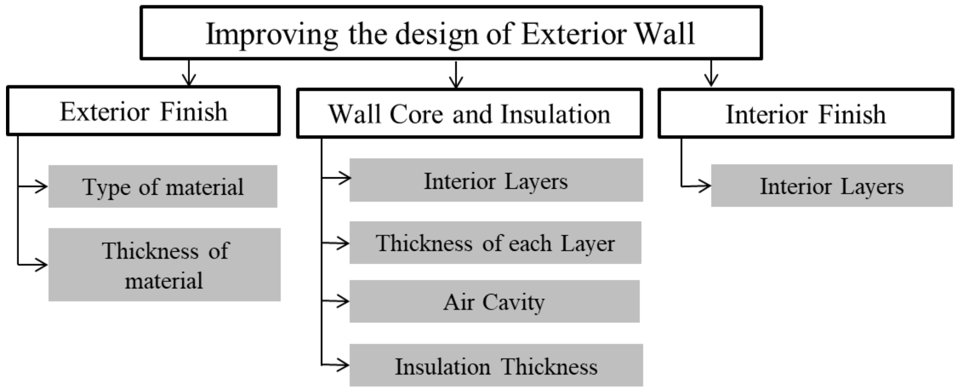


Figure 4.14: improving the design of the exterior wall layers

2. Air cavity

Evaluating the effect of 5cm air cavity with 10cm of bricks on the main facades in stage 1, afterwards adding it to all facades of the building in stage 2 for all cases.

3. Wall insulation

Wall insulation is directly affected by wall orientation. As the R-value of a building's exterior wall increases, the building becomes more efficient. This scientific fact has led researchers to develop high-performance insulation technologies. The R-value of a building wall is directly related to the season, building type, location and orientation of the building.

- The insulation thicknesses tested in this study are the most common dimensions available in the Palestinian market (12.7, 19.05, 25.4, 38.1, 50.8, 76.2, and 101.6 mm) (Figure 4.15). The simulations were performed during the months of January-December 2021. The HVAC system was turned on at a heating setpoint temperature of 21 C° and a cooling setpoint temperature of 23 C° to calculate the heating and cooling loads.

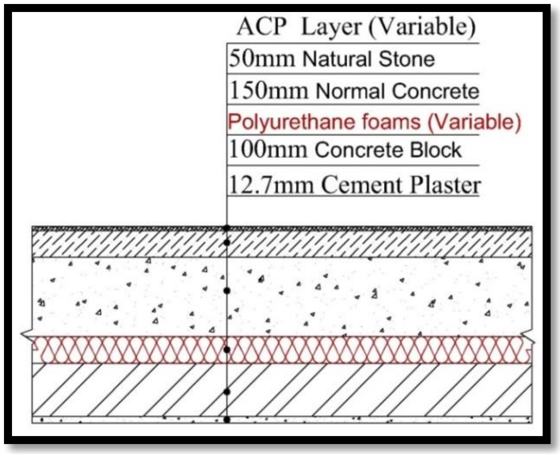


Figure 4.15: Cross section for studying insulation thickness

4. Glass type

The presence of glazed areas strongly affects the thermal performance of the building wall. Therefore, a simulation of the building was carried out by changing the types of glass on the main facade of the case study. The glass types available in the Palestinian market were used with their types, thicknesses and thermal properties as described in chapter two. In building case A, there are no glass surfaces except for the glass doors. Windows were added to 35% of the wall area to introduce adequate natural lighting and then simulate the cooling and heating loads.

5. Testing the Shading of the South Façade

The case 1 and case 2 that have the main southern facade were provided with a horizontal shading device. The horizontal shading device on the south facade does not block the view of the glass facades of the commercial center. Otherwise, it was added to the variables that gave the best value of cooling and heating loads to see how well they improved the simulation results. The west and east facades are exposed to horizontal sunlight and need a vertical shading device to block these rays, but these vertical shading devices block the view of the business centers, so movable internal vertical blinds are used in the morning and evening hours.

4.6 Cost of Materials Studied

When comparing the efficiency of the materials used to see how much they contribute to energy savings with their cost efficiency, the comparisons were on the side of cost in terms of cooling and heating loads. Prices were obtained for all materials used in the exterior wall layers. The prices were determined by talking to contractors, local distributors, and engineers. Pricing will be discussed later in the results chapter

4.7 Evaluation Criteria

There is no specific value used to evaluate the thermal performance and energy consumption of a building. The evaluation was based on a comparative approach between the different cases. The comparative process was performed separately for each phase. The different variables of the case were compared with each other and then compared with the other cases. The effect of changing the type and thickness of the exterior cladding, the thickness of the insulation and the types of glass on the performance of the building was evaluated, with the result that gives better performance and lower energy consumption being preferred and recommended.

4.8 Summary

This chapter contains an explanation of the methods that were followed and applied in each step of this research. The main steps that were clarified:

1. the explanation of the criteria by which the study area was selected.
2. the explanation of the criteria for the selection of the different study cases on which the study will work.
3. The explanation of the case study analysis sheet, which contains all the important information about the cases and their use in the simulation process.
4. The explanation of the different phases of the simulation process and the constant parameters, variable parameters and confounding variables.
5. The explanation of the process of testing parameters and the definition of the properties of the parameters used, such as the type and thickness of the layers.

These steps were explained to achieve the desired results.

Chapter 5 Research Results

5.1 Field Work

Field visits revealed that commercial buildings in Hebron, as throughout the West Bank, are frequently clad in a variety of materials. The facades are clad with new material over the existing stone material. These claddings are applied indiscriminately without using these materials to improve the thermal performance of the building.

5.2 Case Study Area: Hebron

Hebron is a Palestinian city in the southern West Bank; it is 930m above sea level (Figure 5.1)("mstkShf," 2020). It is the commercial capital of the West Bank. Hebron governorate is the largest governorate in Palestine.

Figure 5.1: Hebron city location according to the West Bank. ("mstkShf," 2020)

Hebron has a typical Mediterranean climate with hot, dry summers from mid-May to mid-September and cold, wet winters from November to mid-March. In January and February - the coldest months of the year - average temperatures reach 14°C and the average low temperature 8°C. In July and August - the hottest months of the year - average temperatures reach 29°C and the average high temperature 32°C. The average annual rainfall is 589 mm.("Hebron Climate, Weather By Month, Average Temperature (Palestinian Territories) - Weather Spark," 2021).

The average temperature, average precipitation, average sunshine duration and wind data of Hebron city were presented in Figures 5.2, 5.3, 5.4, 5.5, 5.6 and 5.7, respectively. Table 5.1 shows the average annual weather parameters in Hebron. The warmest months are July and August. The coldest months are January and February. The sunniest day of the year is June 21 with an average radiation of 8.6 kWh/m2 and an average daylight duration of 14 hours. In Hebron, the average hourly wind speed is subject to smooth seasonal variations throughout the year. From August 31 to November 19, the wind blows most strongly from the north. From

November 19 to August 31, the wind blows strongest from the west.(“Hebron Climate, Weather By Month, Average Temperature (Palestinian Territories) - Weather Spark,” 2021).

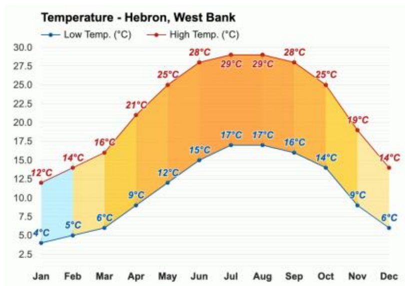


Figure 5.2: Average temperatures Hebron, West Bank. Weather atlas: https://www.weather-atlas.com/en/west-bank/hebron-climate

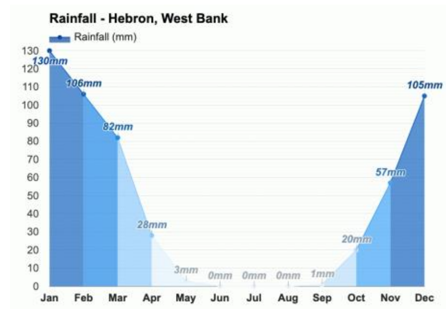


Figure 5.3: Average rainfalls Hebron, West Bank. Weather atlas: https://www.weather-atlas.com/en/west-bank/hebron-climate

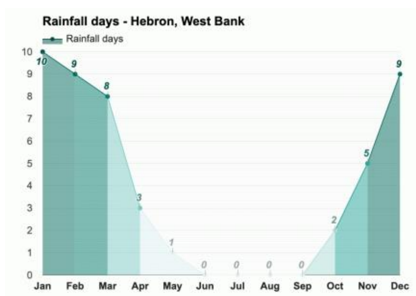


Figure 5.4: Average rainfall days Hebron, West Bank. Weather. Weather atlas: https://www.weather-atlas.com/en/west-bank/hebron-climate

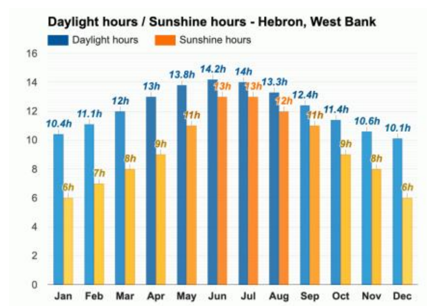


Figure 5.5: Average daylight / Average sunshine Hebron, West Bank. Weather atlas: https://www.weather-atlas.com/en/west-bank/hebron-climate

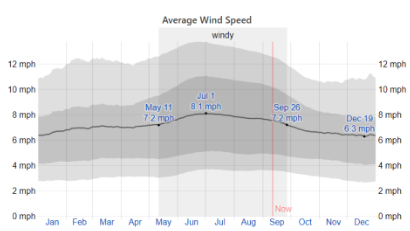


Figure 5.6: The average of mean hourly wind. Weather spark: https://weatherspark.com/y/98840/Average-Weather-in-Hebron-Palestinian-Territories-Year-Round

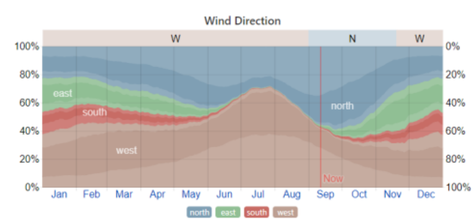


Figure 5.7: The mean wind direction. Weather https://weatherspark.com/y/98840/Average-Weather-in-Hebron-Palestinian-Territories-Year-Round

Table 5.1: Average annual weather parameters in Hebron, West Bank

Weather data	Months	Average high temperature	Average low temperature	Weather data	Months	Average sunshine
The warmest months	July, August	29 °C	17 °C	Months with most sunshine	June, July	13h
The coldest months	January, February	12 °C	4 °C	Months with least sunshine	January, December	6h
Weather data	Months	Average daylight		Weather data		Rainfall
Longest days	June	14.2h		Wettest month	January	130mm
Shortest days	December	10.1h		Driest months	June, July, August	0mm

5.3 Observation and interviews Results

The main purpose was to investigate the general condition in the selected cases. The questionnaire was completed by the staff in the five buildings. The results of the field research were summarized in Tables 5.2, 5.3, 5.4, 5.5, 5.6.

Table 5.2: Case studies datasheet. Case.1: Sbitany I store.

Case 1: Sbitany I store								
Structured information								
Building location	Al-Salam street- Hebron					Ground floor area		715 m^2,
Floors numbers	3					Main façade orientation		South , East and south-east
Material of Cladding system	Alucobond					Building use:		Retail sales
						Sales type		Electrical devices
No. of windows	Two windows have been added with 35% WWR					 Figure 5.8: Sbitany I store		
No. of doors	2							
Area of door	3.2 m2							
Cooling and heating systems	VRF System							
Facades	N	E	SE	S	W			
WWR %	0	35%	35%	35%	0			
Schedules	9:00am-10:00pm							

Table 5.3: Case studies datasheet. Case.2: AL-Bayed center.

<table>
<tr><td colspan="7">Case 2: AL-Bayed center</td></tr>
<tr><td colspan="7">Structured information</td></tr>
<tr><td>Building location</td><td colspan="4">AL- Haouz street</td><td>Ground floor area</td><td>350 (m^2)</td></tr>
<tr><td>Floors numbers</td><td colspan="4">2</td><td>Main elevation orientation</td><td>South</td></tr>
<tr><td rowspan="2">Material of Cladding system</td><td colspan="4" rowspan="2">Alucobond</td><td>Building use:</td><td>Retail sales</td></tr>
<tr><td>Sales type</td><td>sanitary sales</td></tr>
<tr><td>No. of windows</td><td colspan="4">1</td><td colspan="2" rowspan="8">
Figure 5.9: AL-Bayed center</td></tr>
<tr><td>No. of doors</td><td colspan="4">2</td></tr>
<tr><td>Area of door</td><td colspan="4">22.5m2</td></tr>
<tr><td>Cooling and heating systems</td><td colspan="4">VRF System</td></tr>
<tr><td>Facades</td><td>North</td><td>South</td><td>West</td><td>East</td></tr>
<tr><td>WWR %</td><td>0</td><td>65%</td><td>0</td><td>0</td></tr>
<tr><td>Schedules</td><td colspan="4">9:00am-10:00pm</td></tr>
</table>

Table 5.4: Case studies datasheet. Case.3: Home Plaza.

<table>
<tr><td colspan="7">Case 3: Home Plaza</td></tr>
<tr><td colspan="7">Building location</td></tr>
<tr><td>Building location</td><td colspan="4">Mafraq al-algama' street</td><td>Ground floor area</td><td>350 (m^2)</td></tr>
<tr><td>Material of Cladding system</td><td colspan="4">Alucobond- stone</td><td>Main elevation orientation</td><td>North and west</td></tr>
<tr><td rowspan="2">Floors numbers</td><td colspan="4" rowspan="2">5</td><td>Building use:</td><td>Retail sales</td></tr>
<tr><td>Sales type</td><td>Electrical devices</td></tr>
<tr><td>No. of windows</td><td colspan="4">5</td><td colspan="2" rowspan="7">
Figure 5.10: Home Plaza</td></tr>
<tr><td>No. of doors</td><td colspan="4">1</td></tr>
<tr><td>Area of door</td><td colspan="4">12 m2</td></tr>
<tr><td>Cooling and heating systems</td><td colspan="4">VRF System</td></tr>
<tr><td>Facade</td><td>N</td><td>S</td><td>W</td><td>E</td></tr>
<tr><td>WWR %</td><td>50%</td><td>0</td><td>53%</td><td>0</td></tr>
<tr><td>Schedules</td><td colspan="4">8:00am-11:00pm</td></tr>
</table>

Table 5.5: Case studies datasheet. Case.4: LC WAKIKI.

Case 4: LC WAKIKI				
Structured information				
Building location	Al-haras street		Ground floor area	390 m^2,
Floors numbers	2		Main elevation orientation	West
Material of Cladding system	Alucobond		Building use:	Retail sales
			Sales type	Clothing store
No. of windows	2			
No. of doors	1			
Area od door	9 m2			
Cooling and heating systems	VRF System			
Facades	North	South	West	East
WWR %	0	0	55%	0
Schedules	8:00am-10:00pm			

Figure 5.11: LC WAKIKI

Table 5.6: Case studies datasheet. Case.5: Alsalam center.

Case 5: Alsalam center				
Structured information				
Building location	Al-Salam street		Ground floor area	700 m^2
Floors numbers	2		Main elevation orientation	East
Material of Cladding system	Alucobond		Building use:	Retail sales
			Sales type	Cars sales
No. of windows	3			
No. of doors	1			
Cooling and heating systems	VRF System			
Facades	North	South	Wes t	East
WWR %	15%	15%	0	52%
Schedules	9:00am-11:00pm			

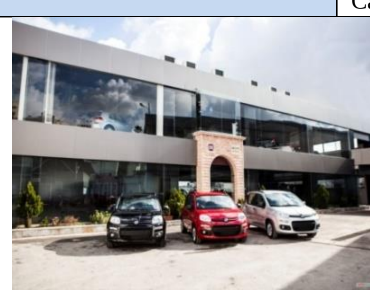


Figure 5.12: Alsalam center.

5.3 Base Model's Simulation

After analyzing the cases, a basic model was developed to match the data sheets. For this purpose, the program Hourly Analysis was used, a simulation of the current situation of each building, to compare it with the changes to be studied (table 5.7).

Table 5.7: Base model's cooling and heating result

Simulation result	Case 1	Case 2	Case 3	Case 4	Case 5
Cooling loads (kWh)	71468.16	46899.84	50111.04	52073.28	79091.52
Heating loads (kWh)	73345.92	59488.32	55537.92	62507.52	71248.32

5.4 Modify Scenarios Results

Depending on the simulation results and following the predefined methodology, the results are described in the following figures.

5.4.1 Testing of Cladding Materials

In this section of the study, the results of the simulation process for different types of exterior cladding for the building wall are presented in two stages, where in the first stage the exterior cladding is applied to the main facade of the building without changing the other building facades, and in the second stage the exterior cladding is applied to the main facades of the building and the other facades are insulated with 50.8 mm insulation (see Appendix). Then the simulation results were compared for the different types of cladding according to the building orientation.

1. Editing the main facades (stage1)

a) Composite panels

- Aluminum composite panel ACP

If you change the thickness of the ACP panels for each case of the main facade, you can see different variations in the required cooling and heating loads in all cases. Composite panels with a thickness of 4 mm provided the best simulation results for the heating load in the first, fourth and fifth cases, then the result of the ACP with 8 mm thickness was very close to the results of 4 mm. The 6 mm thick ACP gave the best results for cooling load, but the worst result for heating load in most cases, except for the case with the main north facade. ACP 8mm is the panel with the best results in summer and winter seasons (Table 5.8).

Table 5.8: comparison between different thicknesses of A.C.P. of each case- stage 1

Cladding material	A.C.P	Case 1	Case 2	Case 3	Case 4	Case 5	results
A.C.P	4mm						0 case
							3case
	6mm						3cases
							1 case
	8mm						2 cases
							3 cases

The lowest cooling load result   The lowest Heating load result

- Wood plastic composite panel

When the exterior cladding was wood-plastic composite panels, the results of the cooling and heating simulations were close due to the convergence of the U-values of the panel types and thicknesses (see Appendix A).

1. In case1 - satge1, when cladding the south facade with wood composite panels, the lowest cooling load that the building required was when PP +PW 20% with a thickness of 4mm was used, then PP +PW 30% with a thickness of 4mm. The heating load the building required was lower when PP +PW 30% with a thickness of 8mm was used. For HPDE, the cooling load of the building was the lowest when HPDE 10% with a thickness of 8mm was used, and the heating load when HPDE 20% with a thickness of 8mm was used (Table 5.9).
2. In Case 2 - Stage 1, the use of HPDE cladding (Alucobond core) with a thickness of 8 mm resulted in the building requiring the least cooling and heating loads. As for the material PP, the lowest cooling load resulted for the type PP (Alucobond core) with a thickness of 4mm and the lowest heating load for PP + PW 20% 6mm thickness(table 5.9).
3. In case3 - stage1, the north facade with a cladding of PP +PW 30% with a thickness of 4mm had the lowest value for the cooling load. As for the heating load, the results of the two types PP +PW 10% with a thickness of 8mm and PP +PW 20% with a thickness of 8mm were the same and showed the lowest value for the heating load. The material HPDE 30% with a thickness of 4mm had the lowest cooling load. The heating load was

lowest for HPDE 20% with a thickness of 8mm and HPDE 30% with a thickness of 8mm. (table 5.9).

4. For Case 5 - Stage 1, the cladding of the east façade with PP +PW 30% 8mm thickness had the lowest value for cooling load, while the heating load was less valuable when using PP +PW 30% thickness 6mm. In the simulation of HDPE material types, the lowest value for the cooling load and the heating load was for the cladding of the facade with HDPE 30% thickness 4mm (table 5.9).

Table 5.9: comparison between different types and thicknesses of WPCs of each case- stage 1

Cladding material				Case 1	Case 2	Case 3	Case 4	Case 5	results	
		PP (Alucobond core)	4mm						1	1
									0	
			6mm						0	0
									0	
			8mm						0	1
									1	
		PP+PW10%	4mm						1	1
									0	
			6mm						0	0
									0	
			8mm						0	1
									1	
		PP+PW20%	4mm						1	1
									0	
			6mm						0	1
									1	
			8mm						0	1
									1	
		PP+PW30%	4mm						1	2
									1	
			6mm						1	2
									1	
			8mm						1	2
									1	
	HPDE	HDPE(Alucobond core)	4mm						0	0
									0	
			6mm						0	0
									0	

			8mm						1	2
									1	
		HDPE10%	4mm						0	0
									0	
			6mm						0	0
									0	
			8mm						0	0
									0	
		HDPE20%	4mm						0	0
									0	
			6mm						0	0
									0	
			8mm						1	3
									2	
		HDPE30%	4mm						3	5
									2	
			6mm						0	1
									1	
			8mm						2	4
									2	

The lowest cooling load result   The lowest Heating load result

- Wood panel

1. In Case 1 - Stage 1, cladding the south façade with 16 mm thick plywood resulted in the lowest cooling load for the building, while the heating load was less valuable when using 10 mm thick plywood. As for the material of the wood panels, it was less valuable for the cooling and heating load when the facade was clad with a thickness of 15 mm. (table 5.10).
2. In case 2 - stage2, the south facade was also clad with 16 mm thick plywood, which gave the best value for the cooling load, while the heating load was less valuable when using the material with a thickness of 13 mm and then 16 mm. In addition, the material of the wooden panels, the cooling load was better when using a thickness of 15mm, and the heating load was better when using the panels with a thickness of 25mm (table 5.10).
3. The cladding of the north facade in case3 - stage1 with plywood panels of thickness 13 mm gave the lowest value for the cooling load, while the heating load was less valuable with a thickness of 16 mm. The material made of wooden panels with a thickness of 15

mm gave the best cooling load, while the heating load with a thickness of 25 mm showed the best value. (Table 5.10).

4. Case 4 - Stage 1 Cladding the west façade with 10 mm thick plywood resulted in the lowest cooling and heating load requirements for the building. As for the material of the wood panels, the building had the lowest cooling and heating requirements when clad with a thickness of 15 mm. (table 5.10).
5. For Case 5 - Stage 1, cladding the east façade with 13 mm thick plywood gave the best value for cooling and heating load, while cladding the east façade with 19 mm thick wood panels gave the best value for cooling and heating load (table 5.10).

Table 5.10: comparison between different types and thicknesses of Wood material of each case- stage 1

Cladding material		thickness	Case 1	Case 2	Case 3	Case 4	Case 5	results	
Wood material	Plywood	10mm						1	3
								2	
		13mm						2	5
								3	
		16mm						2	3
								1	
	Wood board	15mm						4	6
								2	
		19mm						1	2
								1	
		25mm						0	2
								2	

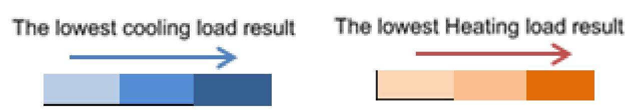
The lowest cooling load result The lowest Heating load result

Although the cases were oriented differently, the results for the exterior cladding were close to the best cooling and heating loads. (Table 5.11). Shows the heating and cooling loads for each case, the case1 - stage1 with the main southern facade, the lowest value for the cooling load was for HDPE and the heating load was for wood panels and then HDPE (Figure 5.13). In Case2 - Stage1 with the main south facade, the HDPE material also has a lower value for cooling loads and heating loads (Figure 5.14). In case3 - stage1, the main northern facade, the best result in the simulation of the cooling load was for the HDPE material, while the heating load for the wood boards material was (figure 5.15).

In Case4 - Stage1 of the west façade, the PP material gave the best cooling loads and the HPDE material, while the wood panels gave the best heating loads (Figure 5.16). In case5 - stage1, with the main eastern facade, the cooling load of the ACP material and the heating load of the HDPE material were less valuable (figure 5.13).

Table 5.11: Cladding material simulation result of each case-stage1

Stage 1			Case 1	Case 2	Case 3	Case 4	Case 5
ACP		Cooling loads (kWh)	67978.56	43640.6	44015.0	49758.7	72380.1
		Heating loads (kWh)	67113.6	56074.5	52390.0	61080.9	66779.5
WPCs	Pp+PW	Cooling loads (kWh)	67311.36	43765.4	44072.6	49446.7	72438.7
		Heating loads (kWh)	67265.28	55200.9	52097.2	60288.9	65038.0
	HPDE	Cooling loads (kWh)	67154.88	43534.0	43795.2	49662.7	72525.1
		Heating loads (kWh)	66918.72	55106.8	52149.1	60275.5	64787.5
Wood material	plywood	Cooling loads (kWh)	67764.48	43653.1	44348.1	49735.6	73080.9
		Heating loads (kWh)	.68373.12	56080.3	52090.5	59918.4	65472
	Wood boards	Cooling loads (kWh)	67816.32	43762.5	44011.2	49837.4	72951.3
		Heating loads (kWh)	66260.16	55428.4	51911.0	60020.1	65439.3



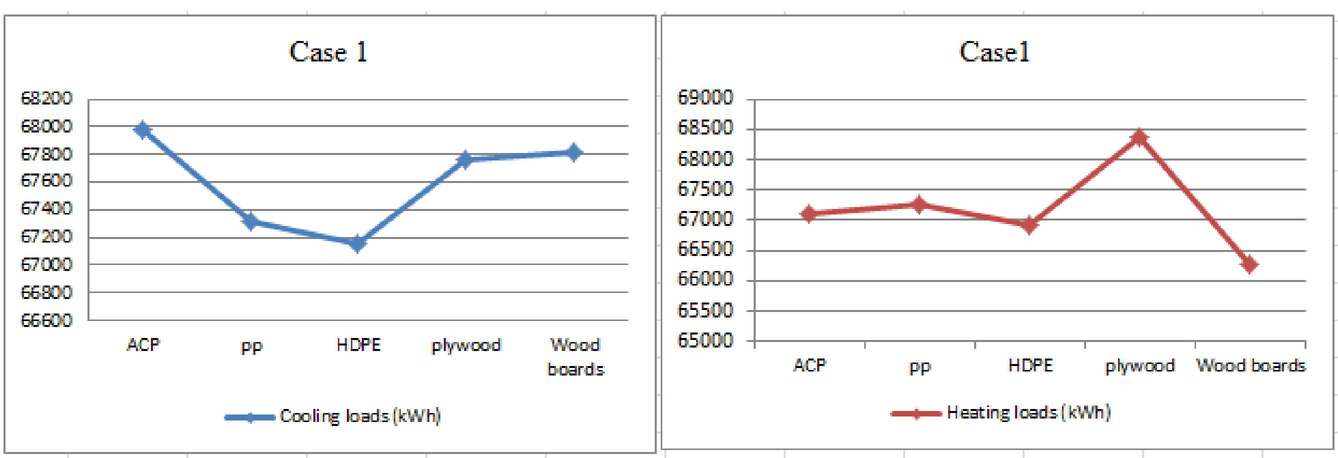


Figure 5.13 comparison between the various cladding materials on the simulation results of case 1- stage 1

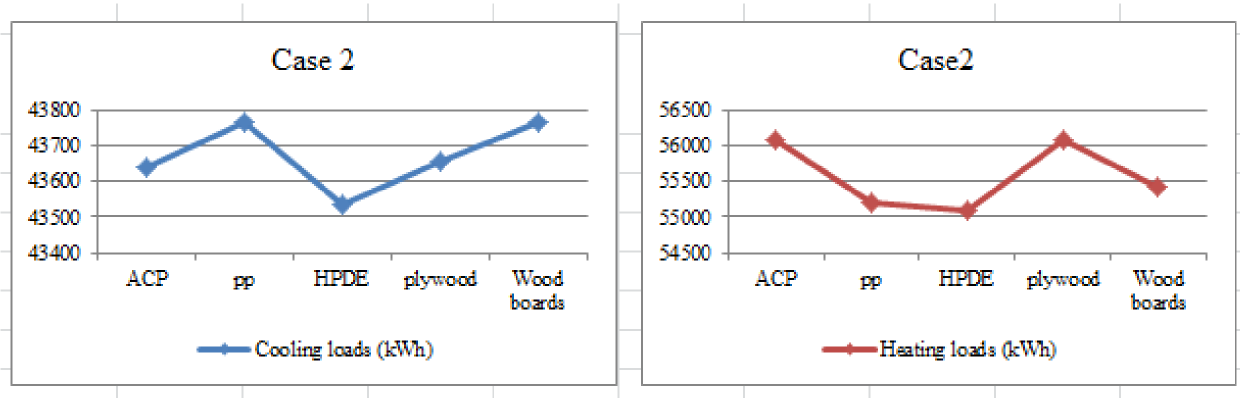


Figure 5.14 comparisons between the various cladding materials on the simulation results of case 2- stage 1

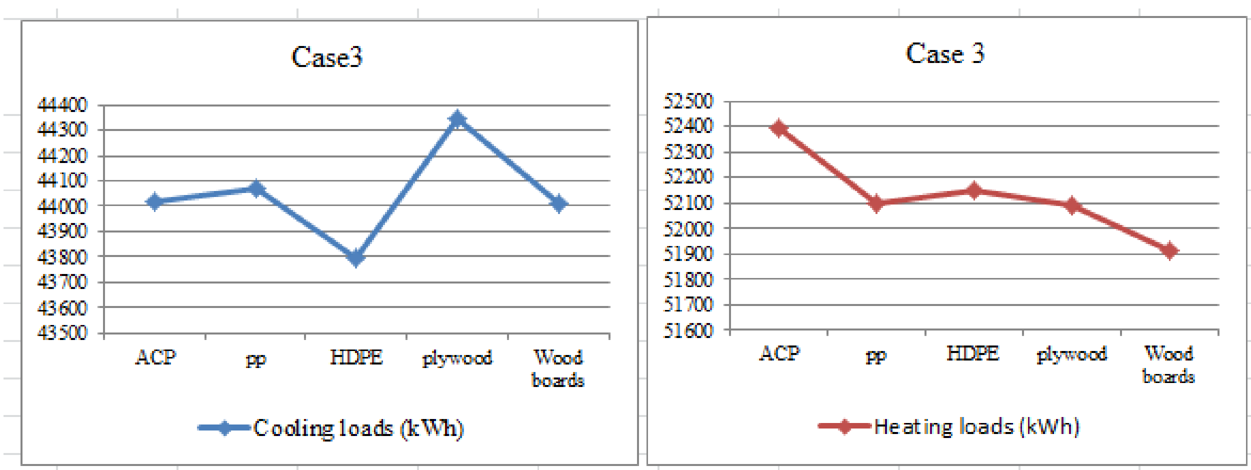


Figure 5.15 comparison between the various cladding materials on the simulation results of case 3- stage 1

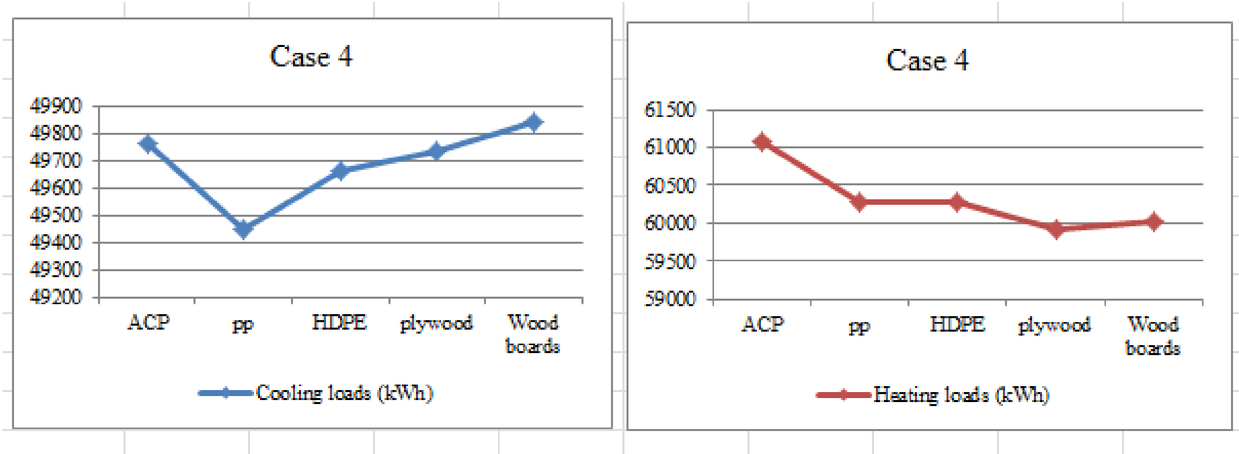


Figure 5.16 comparison between the various cladding materials on the simulation results of case 4- stage 1

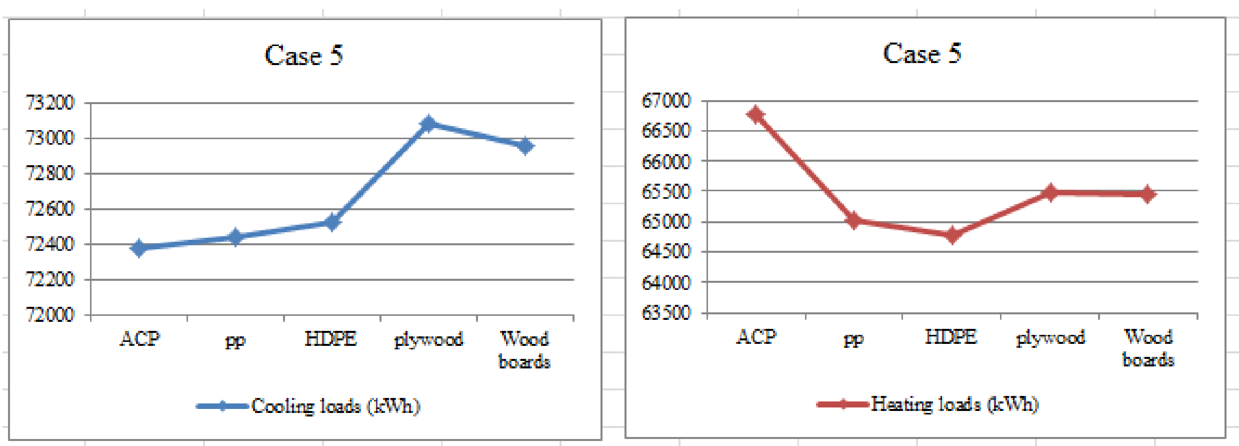


Figure 5.17 comparison between the various cladding materials on the simulation results of case 5- stage 1

2. Editing all facades (stage 2)

- Aluminum composite panel ACP

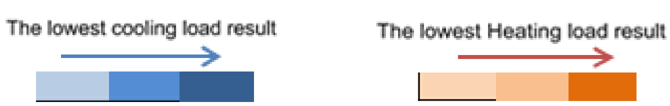
    1. In Case 1 - Stage 2, the south and east facades (the two main facades) were clad with ACP and all facades were insulated with a thickness of 50.8 mm. The results for the cooling load were close between the different thicknesses, and the lowest value was obtained for the thickness of the panels of 6 mm. For the heating load, the differences in the results were greater than for the cooling load and less valuable for a panel thickness of 4 mm.

2. In the case2 - stage2, cladding the main southern facade with ACP and insulating all facades, the results of the cooling load were all close, and the lowest value was for panels with a thickness of 6mm, and the lowest heating load was for panels with a thickness of 4mm (the same results as the first case) (see appendix A).

3. Case 3 - Stage 2, cladding the north and west facades (the two main facades) with ACP and insulating all facades gave the best cooling load for panels 8 mm thick, and the results were close. The heating load was less valuable when using 8 mm thick panels. (see appendix A).
4. Case4 - Stage2 is the cladding of the western facade with ACP and the insulation of all facades. The results of the cooling load were similar and less valuable when panels with a thickness of 4 mm were used. The heating load was lower when 8 mm thick panels were used than when 4 mm thick panels were used, and the results were similar.
5. The case5 - stage2: the main facades with composite panels and insulation of all facades had the lowest value for the cooling load with 8mm panels, while the heating load had the lowest value for 4mm panels (see appendix A) (table 5.12)

Table 5.12: comparison between different thicknesses of A.C.P of each case- stage 2

Cladding material	A.C.P	Case 1	Case 2	Case 3	Case 4	Case 5	results	
A.C.P	4mm						2	5
							3	
	6mm						3	3
							0	
	8mm						2	4
							2	



- Wood plastic composites

1. In case1 - stage2, the lowest value of cooling load was achieved by PP (Alucobond core) with thickness of 8mm and heating load by PP + Pw 10% with thickness of 4mm. For HDPE, the value of cooling load was lower when HDPE (Alucobond core) with a thickness of 8mm was used, then HDPE 30% with a thickness of 8mm and the heating

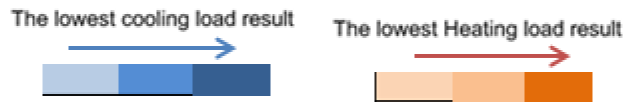
load for HDPE 30% with a thickness of 6mm when the southern and eastern facades were clad with WPCs (table 5.13)..

2. As for case2 - stage2, a south facade with WPCs and insulated walls of the building. The lowest value for the cooling load was at 30% PP + PW with a thickness of 6mm, then with a thickness of 8mm. For heating load at PP + PW 20% with a thickness of 4mm. For HDPE, the lowest value for cooling load when using HDPE was 30% with a thickness of 6mm, and heating load when using HDPE was 40% with a thickness of 4mm (table 5.13).
3. Case3 - Stage2, the north facade and the west facade with WPCs and insulation of all facades with a thickness of 50.8mm, had the lowest value for the cooling load at PP + PW 10% with a thickness of 6mm, then PP + PW 20% with a thickness of 4mm. The heating load is PP +Pw 10% with a thickness of 8mm, then PP +PW 20% with a thickness of 8mm. For HDPE material, the cooling load was lower when HDPE 30% with thickness of 8mm was used, and the heating load when HDPE 20% with thickness of 4mm was used, then HDPE 30% with thickness of 4mm. (table 5.13)..
4. in the case4 - stage2: the west facade with WPCs and insulated facades of the building had the lowest cooling load when using the material PP for the type PP (Alucobond core) with a thickness of 4mm, then for the type PP + PW 30% with a thickness of 8mm, and for the material HDPE the lowest cooling load for the type HDPE 20% with a thickness of 6mm, then for the type HDPE 30% with a thickness of 8mm. As for the heating load of PP when using PP (Alucobond core) with a thickness of 6mm, then PP + PW 20% with a thickness of 6mm. As for the material HDPE, if you use HDPE 10% with a thickness of 4mm, then for the type HDPE 30% with a thickness of 8mm. (table 5.13) (see appendix A).
5. In Case5 - Stage2, when cladding the main facades with WPCs and insulated walls, the cooling and heating load was lower when PP + PW 30% with a thickness of 8mm was used. For HDPE, the cooling load was 20% when HDPE was used with a thickness of 8mm, and the heating load was 30% when HDPE was used with a thickness of 6mm. (table 5.13).

Table 5.13: the comparison between different types and thicknesses of WPCs of each case- stage 2

Cladding material				Case 1	Case 2	Case 3	Case 4	Case 5	results	
			4MM						1	1
									0	
			6MM						0	1
									1	
		PP (Alucobond core)	8mm						1	1
									0	
			4mm						0	1
									1	
			6mm						1	1
									0	
			8mm						0	1
		PP+PW10%							1	
			4mm						1	2
									1	
			6mm						0	1
									1	
			8mm						0	1
		PP+PW20%							1	
			4mm						0	0
									0	
			6mm						1	1
									0	
			8mm						3	4
		PP+PW30%							1	
	HDPE		4mm						0	0
									0	
			6mm						0	0
									0	
		HDPE(Alucobond core)	8mm						1	1
									0	
			4mm						0	1
									1	
			6mm						0	0
									0	
			8mm						0	0
		HDPE10%							0	
		HDPE20%	4mm						0	1

									1	
			6mm						1	1
									0	
			8mm						1	1
									0	
			4mm						1	3
									2	
			6mm						1	3
									2	
			8mm						2	3
		HDPE30%							1	



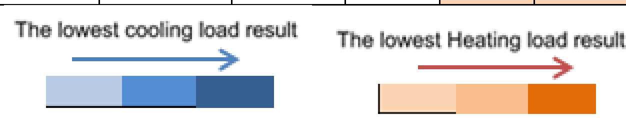
- Wood panel

1. Case1 - Stage2, a south façade and an east façade with a plywood panel with a thickness of 13 mm resulted in the lowest value for the cooling load, while the heating load was less valuable when using plywood panels with a thickness of 16 mm (see Appendix A). The wood panel material had the lowest value for cooling and heating load at 15mm thickness (table 5.14).
2. Case2 - Stage2 with a south façade of 10 mm thick plywood gave the lowest value for the cooling load. The heating load had the lowest value with a thickness of 16 mm. For the wood panels, the best cooling load is at a thickness of 15 mm, while the heating load is at a thickness of 19 mm. (table 5.14).
3. Case3 - Stage2 with the north and west main facades with 10 mm thick plywood cladding resulted in the lowest cooling and heating load. For the wood panels, the lowest value for the cooling load of the building was obtained with a thickness of 19 mm and the lowest value for the heating load was obtained with a thickness of 25 mm (table 5.14).
4. Case4 - Stage2, a west façade with 10 mm thick plywood cladding, resulted in the lowest load for cooling and, with a thickness of 16 mm (see Appendix A), the lowest load for heating. The wood panel material had the lowest value for cooling load with a thickness of 15 mm and the lowest heating load with a thickness of 25 mm (table 5.14).

5. In case5 - stage2, the lowest cooling load using plywood with a thickness of 10 mm and a heating load with a thickness of 16 mm. As for the wood panel material, it is less valuable for the cooling load with a thickness of 19mm and the heating load with a thickness of 15mm (table 5.14).

Table 5.14: Comparison between different types and thicknesses of Wood material of each case- stage 2

Cladding material		thickness	Case 1	Case 2	Case 3	Case 4	Case 5	results	
Wood material	Plywood	10mm						4	5
								1	
		13mm						1	1
								0	
		16mm						0	4
								4	
	Wood board	15mm						3	5
								2	
		19mm						2	3
								1	
		25mm						1	3
								2	

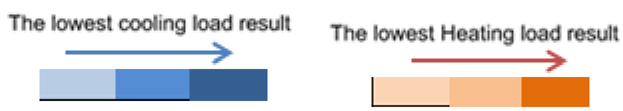


In stage 2 of the simulation, depending on the orientation of the study cases, the results were different when the exterior cladding of the building wall was changed. In cases 1 and 2 with the main southern facades, the cooling load was best when wood boards were used (Figure 5.18, 5.19). The heating load was best in the first case using plywood, while in cases 3, 4 and 5 the best results were obtained using PP (Figures 5.20, 5.21, 5.22). In the third case and the fifth case, cooling was less valuable, even when using PP. In the fourth case, the cooling load was lower when HDPE was used, and in the fifth case, the lowest heating load was obtained (table 5.15).

Table 5.15: Cladding material simulation result of each case

Stage 2				Case 1	Case 2	Case 3	Case 4	Case 5
ACP			Cooling loads (kWh)	55930.5	36696	37403.5	39076.8	63867.8
			Heating loads (kWh)	46365.1	41580.4	42356.1	41592.9	48746.8
WP	Cs	PP	Cooling loads (kWh)	60114.2	36577.9	36912.9	38860.8	63432.9

		Heating loads (kWh)	46416.9	41038.0	41160.9	40811.5	47485.4
	HDPE	Cooling loads (kWh)	60027.8	36207.3	37111.6	38677.4	63958.0
		Heating loads (kWh)	46385.2	41577.6	41363.5	41356.8	47420.1
Wood material	plywood	Cooling loads (kWh)	54685.4	36312.9	37453.4	38973.1	63816
		Heating loads (kWh)	45039.3	41667.8	42114.2	41190.7	48325.4
	Wood boards	Cooling loads (kWh)	54325.4	36096	37061.7	39469.4	63637.4
		Heating loads (kWh)	45796.8	41180.1	42442.5	41578.5	48547.2



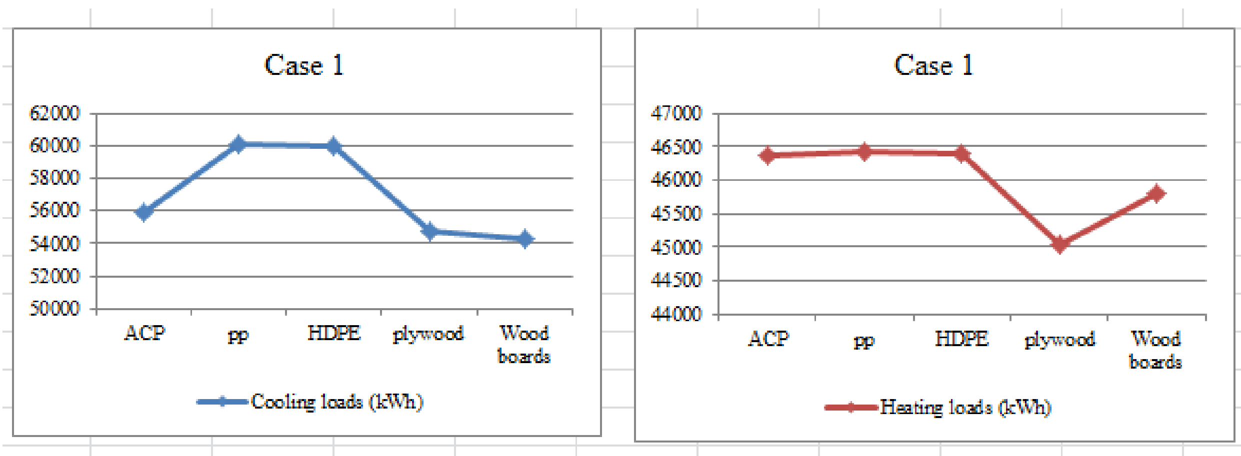


Figure 5.18 Comparison between the various cladding materials on the simulation results of case 1- stage 2

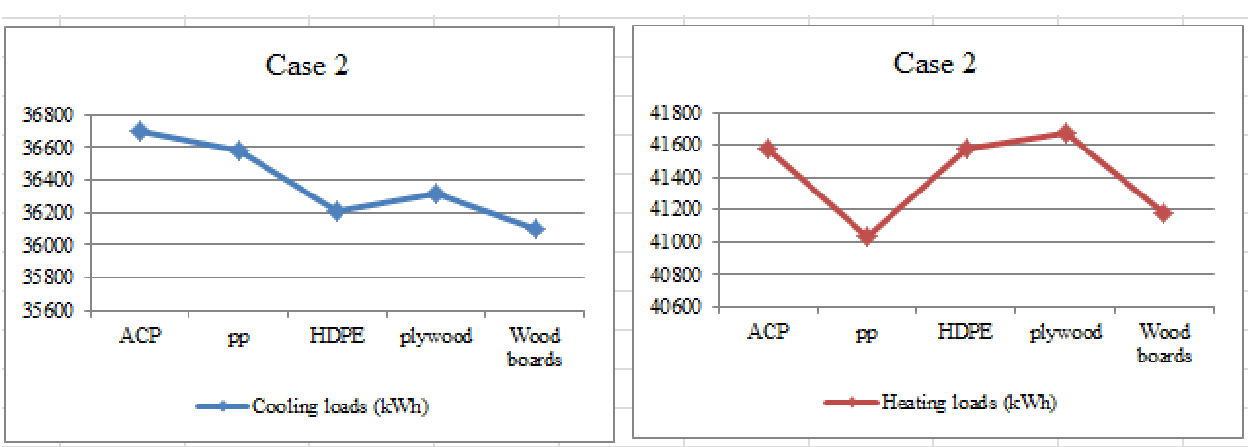


Figure 5.19 Comparison between the various cladding materials on the simulation results of case 2- stage 2

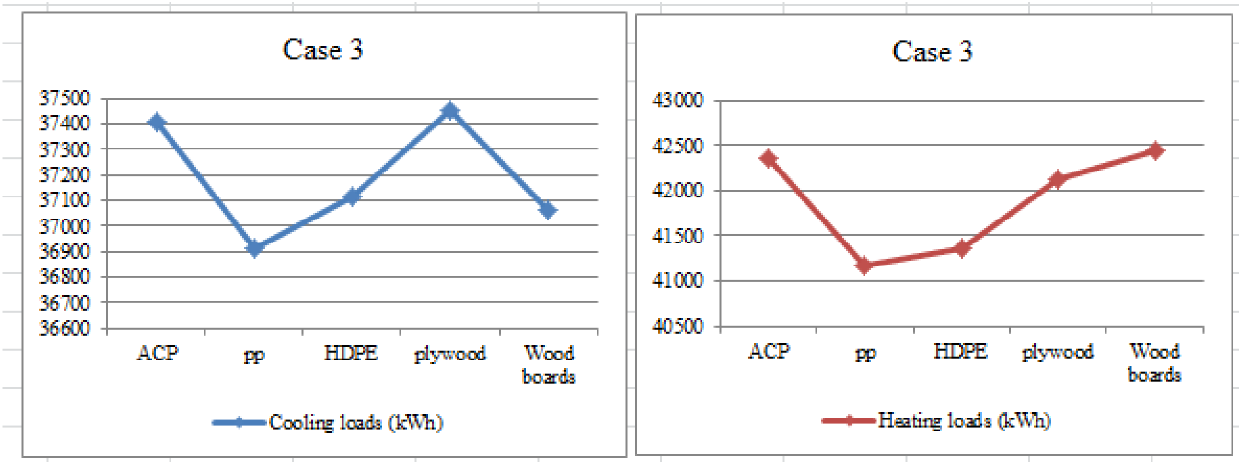


Figure 5.20 Comparison between the various cladding materials on the simulation results of case 3- stage 2

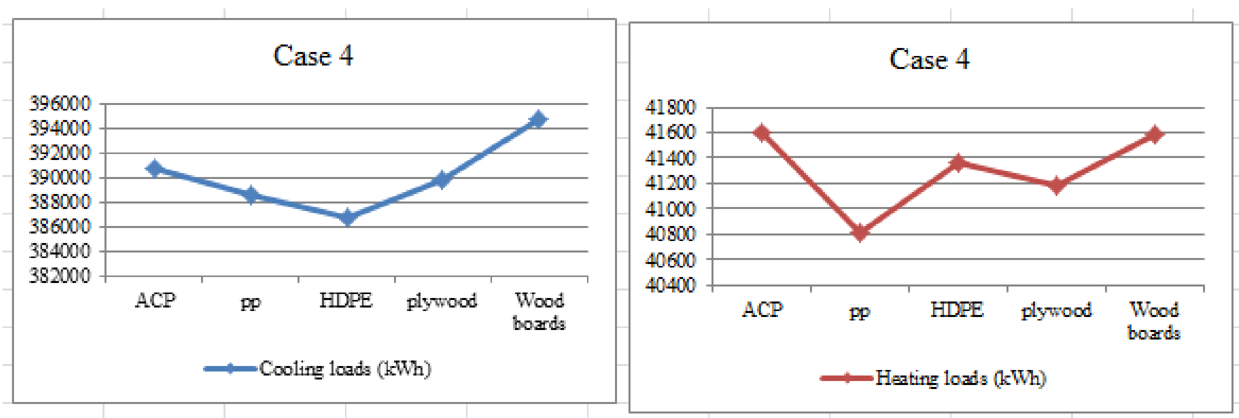
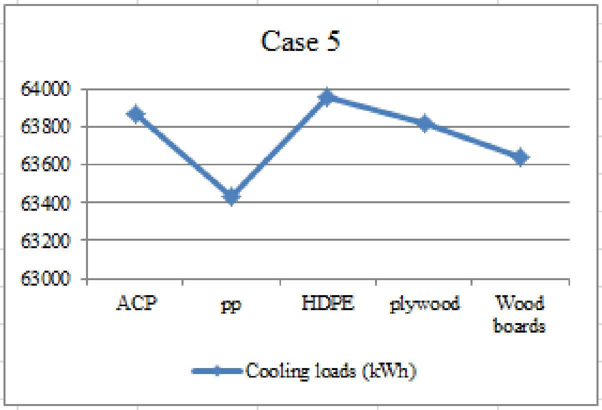


Figure 5.21 Comparison between the various cladding materials on the simulation results of case 4- stage



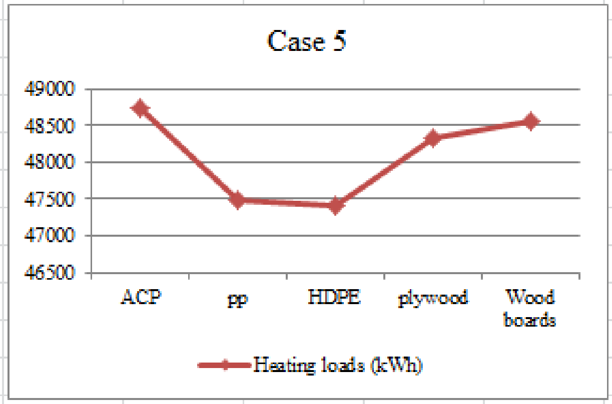


Figure 5.22 Comparison between the various cladding materials on the simulation results of case 5- stage 2

5.3.2 Testing of Wall Insulation

The best type of insulation has the lowest thermal conductivity value, namely expanded high-density polyurethane (U-value =0.02 (W/m.C)). The simulation results of cooling and heating load when testing the same thickness of the two different types of polystyrene and polyurethane. When testing the different thicknesses of insulation available in the Palestinian market, the larger thickness gave the best result (the lowest value in both heating and cooling load), but in the Palestinian society the medium thickness of insulation (50.8 mm) is common due to the high cost of the insulation with the large thickness.

1. Editing the main facades (stage 1)

   A. In Case 1 - Stage 1, the WWR on the south façade was 35%, so changing the thickness of the façade insulation had a large impact on the heating and cooling demand of the building (see Appendix A). Insulating the south façade with a thickness of 76.2 mm and 101.6 mm reduced the building's cooling demand by 3360 kWh and heating demand by 5184 kWh when using the low insulation thickness of 12.7 mm. (table 5.16).

   B. Case2 - Stage1 insulates the main south facade. The effect of increasing the insulation thickness was not large, because the difference in cooling loads when increasing the insulation thickness from 12.7 mm to 76.2mm is 556.8 kWh (Table 5.16).

C. In addition, Case3 - Stage1 with a glass area on the north façade of 60% had the best cooling load for the building when 38.1 mm thick insulation was used (see Appendix A). As for the heating load when a 76.2 mm thick insulation was used (table 5.16).

D. In Case 4 - Stage 1, the cooling load was lowest when insulating the main western façade with a ratio of 60 WWR when 50.8 mm of insulation was used. As for the heating load, when 12.7 mm insulation was used (table 5.16).

E. In Case5 - Stage1, the insulation on the main east façade had the lowest cooling load with a ratio of 60 WWR to a thickness of 76.2. In terms of heating load, the lowest load was for the use of 38.1 mm insulation and 101.6 mm insulation. (Table 5.16).

Table 5.16: comparison between different insulation thicknesses of each case- stage1

Cladding material	thickness	Case 1	Case 2	Case 3	Case 4	Case 5	results	
Insulation materials	12.7						0	1
							1	
	19.05						0	0
							0	
	25.4						1	1
							0	
	38.1						2	2
							0	
	50.8						2	2
							0	
	76.2						3	5
							2	
	101.6						1	3
							2	

2. Editing the all facades (stage 2)

A. In Case1 - Stage2, insulating the building facades (north and west) with a thickness of 50.8mm and the two main facades (south and east) with a thickness of 101.6mm reduced the cooling load by 4320 kWh. The heating load was reduced by 10513 kWh, which is a significant impact on the heating load compared to an insulation thickness of 12.7mm. (See appendix A).

B. Also the case2 - stage2, where the insulation of all facades was applied with a thickness of 50.8mm and the main facade with a thickness of 101.6mm, resulted in the lowest cooling load and was 2688 kWh lower than the cooling load when using a 12.7mm insulation and the heating load was 5.4mm lower (see appendix A)..

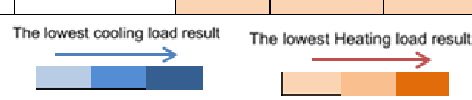
C. In Case3 - Stage2, the insulation of the north and west facades with a thickness of 101.6 mm provided the best cooling and heating performance. The difference in cooling load was 2784 kWh and heating load was 5088 kWh for the loads that were lower than insulation with thickness of 12.7 mm (see appendix A).

D. The case4 - stage2, where all facades are insulated by 50.8 mm and the main western facade by 76.2 mm and 101.6 mm. The building required less cooling load. But the insulation of the main facade with a thickness of 25.4 mm resulted in the fact that the building required the lowest heating load (see appendix A).

E. The case5 - stage2: insulation of the main eastern facade with a thickness of 50.8 mm resulted in the lowest cooling load of the building, but the thickness of 101.6 mm resulted in the lowest heating load, and all facades were insulated with a thickness of 50.8 mm (table 5.17).

Table 5.17: comparison between different insulation thicknesses of each case- stage2

Cladding material	Thickness	Case 1	Case 2	Case 3	Case 4	Case 5	results	
Insulation materials	12.7						0	0
							0	
	19.05						0	0
							0	
	25.4						0	1
							1	
	38.1						0	0
							0	
	50.8						1	1
							0	
	76.2						2	2
							0	
	101.6						5	9
							4	



5.3.3 Testing for air cavity

Insulating all facades with a 5 cm air cavity layer gave better results than adding the air space only on the main facade. The difference is visible in the cooling and heating loads in the first case. The difference was 12480 kWh for cooling load and 18240 kWh for heating load and the differences remain large, so it is preferable to add the air cavity on all facades of the building. (Table 5.18).

In Stage 1, the difference between a 5-cm air cavity layer for the main façade only and insulation with 5.08 cm of polyurethane is not clear (Table 5.19), but in Stage 2, the cooling and heating load results for the walls with 5.08 cm of polyurethane insulation were lower than the results for the walls with a 5-cm air cavity layer (table 5.20).

Table 5.18: comparison between air cavity result on stage 1 and stage 2 of each case

	Case1		Case2		Case3		Case4		Case5	
	stage1	Stage2	stage1	Stage2	stage1	Stage2	stage1	Stage2	stage1	Stage2
Cooling loads (kWh)	71369.28	58510.08	44719.68	38640.96	45112.32	39255.3	52382.4	44595.84	79.394	70899.84
Heating loads (kWh)	71960.64	53544.96	57697.92	50065.92	55072.32	45972.48	61610.88	52315.2	72.701	61702.08

Table 5.19: comparison between 5cm air cavity and 5.08cm of expanded polystyrene on stage 1

	Case 1-stage1		Case 2-stage1		Case 3-stage1		Case 4-stage1		Case 5-stage1	
	5cm air cavity	5.08cm expanded polystyrene	5cm air cavity	5.08cm expanded polystyrene	5cm air cavity	5.08cm expanded polystyrene	5cm air cavity	5.08cm expanded polystyrene	5cm air cavity	5.08cm expanded polystyrene
Cooling loads (kWh)	71369.28	81364.8	44719.68	44738.88	45112.32	45237.12	50337.6	50256.96	76218.24	72486.72
Heating loads(kWh)	71960.64	75546.24	57697.92	57152.64	55072.32	54181.44	61003.2	61408.32	69792.96	66326.4

The lowest cooling load result The lowest Heating load result

Table 5.20: comparison between 5cm air cavity and 5.08cm of expanded polystyrene on stage 2

	Case 1-stage2		Case 2-stage2		Case 3-stage2		Case 4-stage2		Case 5-stage2	
	5cm air cavity	5.08cm expanded polystyrene	5cm air cavity	5.08cm expanded polystyrene	5cm air cavity	5.08cm expanded polystyrene	5cm air cavity	5.08cm expanded polystyrene	5cm air cavity	5.08cm expanded polystyrene

Cooling loads (kWh)	58510.0	59487.36	38640.96	36777.6	39255.36	37403.52	41850.24	39076.8	70899.84	63965.76
Heating loads (kWh)	53544.9	47965.44	50065.92	42631.68	45972.48	43051.2	50302.08	41743.68	61702.08	49991.04

The lowest cooling load result   The lowest Heating load result

5.3.4 Testing for Glass Types

The Reflective-Double-Glass type gave the least results in cooling performance in summer because it reflects the sun's rays. However, these rays are important in winter to increase the indoor temperatures of the building (see appendix A).

1. Editing the main facades

A. In Case1 - Stage1 main south facade, the difference in cooling load between the low solar radiation triple glass type, which has the lowest cooling load value, and the clear double glass, which has the highest cooling load value, is 2571 kWh. As for the heating load, the result was higher for the type of triple high solar gain glass and the lowest value was for the type of reflective double glass and triple low solar gain glass and the difference was 1633 kWh.

B. Case2 - Stage1, with southern exposure, had the lowest cooling load for the Triple-High Solar Gain glass type and the highest value for a Double-Clear Solar Gain glass, and the difference between the two values was 2670 kWh, which is very similar to the difference between the glass types in the first case. As for the heating load, it was the lowest for the triple-high solar gain glass type and triple-low solar gain glass type, and the highest for the tinted double-clear glass type and the difference between them was 2516 kWh.

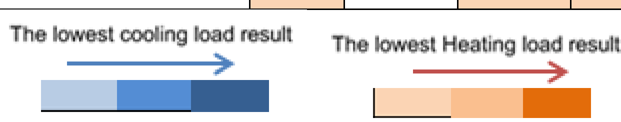
C. Case3 - Stage1 (main northern facade of the building) was strongly affected by a change in the types of glass used, so that the difference in cooling load between the lowest value of the Triple-Low-Solar Gain glass and the Double-Clear glass was about 2880 kWh. In addition, the difference in heating load between the lowest value of the Triple-Low solar gain glass and Triple-Low solar gain glass and the highest value of the reflective Double-Clear glass and Double-high solar gain was about 2880 kWh.

D. In case4 - stage1 the best value for the cooling load demand of the building was when the glass type is triple high solar gain, but the use of double clear glass is higher by 2611 kWh. The heating load demand of the building was lower when triple solar gain glass was used, and the heating load demand was also higher when double glazing was used. The difference between the two is 2362.5 kWh.

E. In Case 5 - Stage 1, the main eastern façade, the difference in cooling and heating loads doubles when the glass types are varied. For the cooling load, the difference between the lowest value of the triple low solar radiation type and the highest value of the double glazing type reached 6714 kWh, and the heating load was between the lowest value when using the triple low solar radiation type and the highest value of the reflective double glazing type, corresponding to 6144 kWh (table 5.21).

Table 5.21: Comparison between different glazing's types simulation of each case- stage1

Cladding material	Thickness	Case 1	Case 2	Case 3	Case 4	Case 5	results	
Glass types	Clear- double glass						0	0
							0	
	Tinted- double glass						0	0
							0	
	Reflective- double glass						4	5
							1	
	Double-high solar gain – low E Glass						0	1
							1	
	Double- low solar gain- low E Glass						0	0
							0	
	Triple- high solar Gain- low E Glass						2	6
							4	
	Triple- Low Solar Gain Low E Glass						3	7
							4	



2. Editing all facades (stage 2)

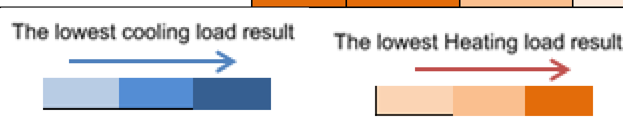
When all building facades are modified and insulated, the results for cooling and heating loads are better for glass types with low thermal conductivity. Insulating the whole building in addition to modifying the glass has a significant impact on improving the indoor climate and adapting to temperatures in summer and winter (table 5.22).

A. In Case1 - Stage2, the cooling load and heating load from installing glass with triple solar shading on the south and east facades were 3840 and 2880 kWh less, respectively, than from using double clear glass.
B. In Case2 - Stage2, when the four building facades were insulated and only the south facade contained glass surfaces, the differences in both the maximum and minimum cooling load results and the mix and minimum heating load results were not large. 1621 kWh for cooling load between using double clear glass (the highest value) and triple glass with high solar gain and reflective double glass (the lowest value). For heating load, the difference was 1655 kWh between using double high solar gain glass, which had the highest value, and triple low solar gain glass.
C. Case3 - Stage2 isolates all facades and the contents of the north and west facades on glass surfaces. The difference in cooling load (highest value and lowest value) was 960 kWh greater than the difference in heating load values. The difference between double clear glass (the highest value) and between triple high solar gain and triple low solar gain is about 3360 kWh. And the difference in heating load between tinted double clear glass (the largest value) and between triple low E solar gain and triple high solar gain is about 2496 kWh.
D. However, in case4 - stage2, the four facades of the building were isolated and only the west facade was provided with a glass surface. The difference between the highest and lowest values of the load was about 1440 kWh greater than the difference between the highest and lowest values of the cooling load. The heating demand of the building is 3168 kWh greater when using the double clear glass type than when using either the triple high solar gain or triple low solar gain types. The cooling demand of the building is about 1440 kWh higher when using double clear glass than when using triple-low e solar gain.

E. In Case5 - Stage2, where the building is fully insulated and contains glazed areas on the east, west and south facades, the effect of using the Triple High Solar Gain and Triple Low Solar Gain types was very large. The difference in cooling load was 6720 kWh when using double clear glass (the highest value). The difference in heating load was 4800 kWh between the use of reflective double glazing (the highest value) and the use of triple-high solar gain.

Table 5.22: Comparison between different glazing's types simulation of each case- stage2

Cladding material	thickness	Case 1	Case 2	Case 3	Case 4	Case 5	results	
Glass types	Clear- double glass							
	Tinted- double glass							
	Reflective- double glass						5	6
							1	
	Double-high solar gain – low E Glass						0	0
							0	
	Double- low solar gain- low E Glass						0	1
							1	
	Triple- high solar Gain- low E Glass						4	8
							4	
	Triple- Low Solar Gain Low E Glass						4	8
							4	

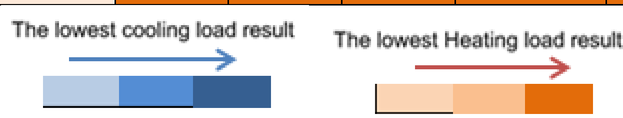


5.3 Shading the South Elevations

When horizontal shading devices were added to the south façade in Case1 and Case2, the second case was affected by a greater proportion of the cooling load due to the larger glazing area on the south façade. The cooling load decreased by an average of 2304 kWh to 7296 kWh (when simulated and using a glass with lower thermal conductivity). In the first case, the cooling load increased from 873.6 kWh to 1598 kWh (on the main façade clad with ACP). Regarding the impact of the building demand on the heating load, in both cases the horizontal shading devices increases the heating load by blocking the important sunlight and increasing the temperatures inside the building. The impact in the first case was greater than in the second case, where the rate of increase of the load in the first case was between 566.4 kWh and 1824 kWh. The second case is between 19.2 and 1536 kWh. (table 5.23).

Table 5.23: comparison between south façade with horizontal shading and without shading on case1and case2-stage2

			Exterior cladding					insulation	Glass type
			ACP	WPCs		Wood material			
				PP	HPDE	PLYWOOD	Wood Boards		
Case 1	without shading	Cooling load (kWh)	55930.5	60114.2	60027.8	54685.44	54325.4	58202.8	59734.08
		Heating load (kWh)	46365.1	46416.9	46385.2	45039.36	45796.8	46066.5	46894.08
	With shading	Cooling load (kWh)	53577.6	54526.0	54217.9	54376.32	53916.4	53949.1	52385.28
		Heating load (kWh)	48210.2	46983.3	47848.3	46783.68	46928.6	46722.2	46775.04
Case 2	without shading	Cooling load (kWh)	36696	36577.9	36207.3	36312.96	36096	35644.8	35513.28
		Heating load (kWh)	41580.4	41038.0	41577.6	41667.84	41180.1	41279.0	40976.64
	With shading	Cooling load (kWh)	350976	35230.0	35366.4	35035.2	35094.7	35557.4	34824.96
		Heating load (kWh)	41561.2	41515.2	42162.2	41929.92	42753.6	42132.4	41312.64



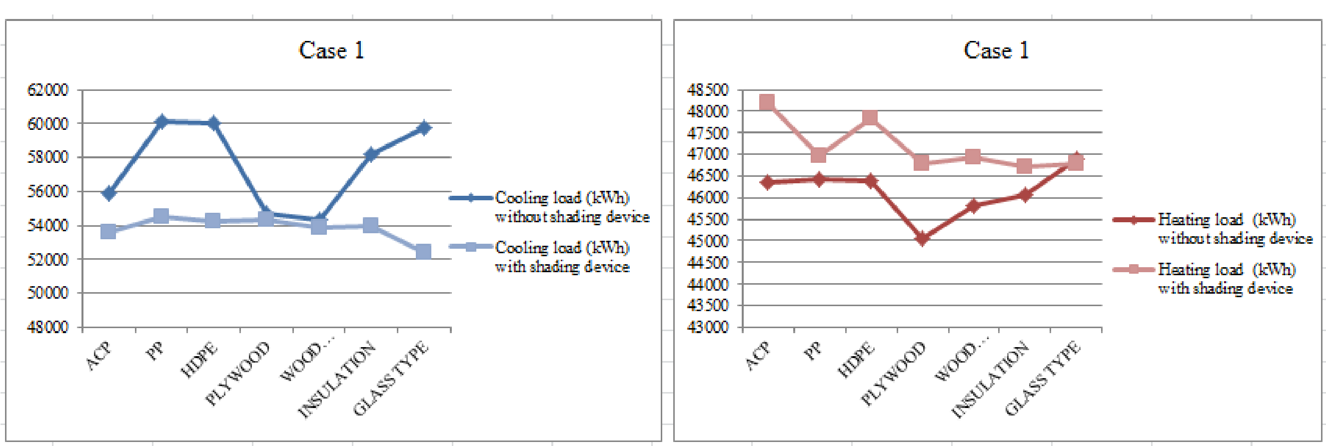
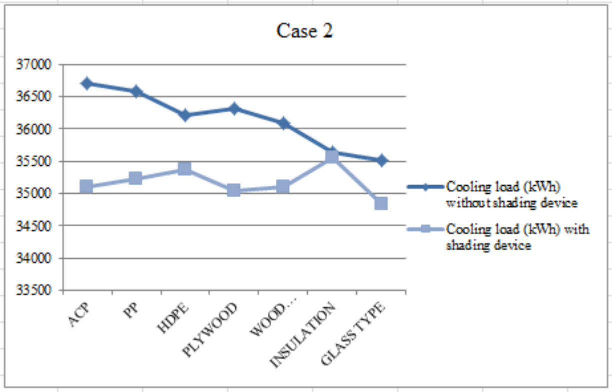


Figure 5.23 the comparison between south façade with horizontal shading and without shading on Case1-stage2



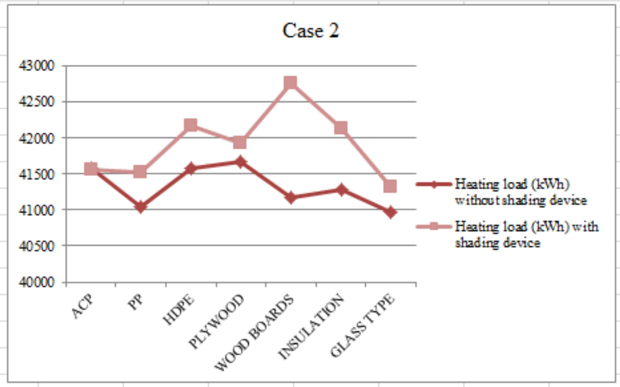


Figure 5.24 comparison between south façade with horizontal shading and without shading on Case2-stage2

The following table shows the simulation results for all cases and how to extract the cooling and heating results for each of the input variables to find out the most effective variables for both summer and winter loads. The variables that have the best effectiveness in more than one study case show the high thermal performance of this material.

Table 5.24 The simulation results of all Cases

Cases			case 1 Isbitany center				case 2 al bayyed center				case 3 home plaza		case 4 LC WAKIKI		case 5 Alsalam center	
Input parameters		Loads	stage 1	stage 2	without shading	with shading devices	stage 1	stage 2	without shading	with shading devices	stage 1	stage 2	Stage 1	stage 2	stage 1	stage 2
exterior cladding	Alucobond	Lowest Cooling load result	6mm	6mm	55930.56 kWh	53577.6 kWh	8mm	6mm	36696 kWh	350976 kWh	6mm	4 & 8mm	6mm	4mmm &6mm	8mm	8mm
		Lowest Heating Loads result	4mm	4mm	46365.12 kWh	48210.24 kWh	8mm	4mm	41580.48 kWh	41561.28 kWh	6mm	8mm	8mm	4mm &6mm	8mm &4mm	4mm
	WPCs	pp Lowest Cooling load result	20% 4mm& 10% 4mm/8 mm	alucab o 8mm	60114.24 kWh	54526.08 kWh	aluc 4mm	30% 6mm&3 0% 8mm	36577.92 kWh	35230.08 kWh	30% 4mm	10% 6mm&20% 8mm	30% 6mm	aluca 4mm & 30%8mm	30% 8mm	30% 8mm
		pp Lowest Heating Loads result	30% 8mm	10% 4mm	46416.96 kWh	46983.36 kWh	20% 6mm	20% 4mm	41038.08 kWh	41515.2kWh	10% 8mm&20% 8mm	10% 8mm & 20% 8mm	aluca 8mm & 30% 6mm	aluca 6mm & 20%6mm	30% 6mm	30% 8mm
		HPDE Lowest Cooling load result	30% 4mm	aluc 8mm+ + 30%8 mm	60027.84 kWh	54217.92 kWh	aluca 8mm	30% 6mm++ 30% 8mm	36207.36 kWh	35366.4 kWh	30% 4mm&30% 8mm	30%8mm	20% 8mm & 30% 8mm	20% 6mm & 30% 4mm	30% 4mm	30% 6mm & 30% 8mm
		HPDE Lowest Heating Loads result	20% 8mm & 30% 4mm	30% 6mm	46385.28 kWh	47848.32 kW	aluca 8mm	30% 4mm	41577.6 kWh	42162.24kWh	20% 8mm & 30% 8mm	20% 4mm& 30% 4mm	30% 6mm & 30% 8mm	10% 4mm &30 % 8mm	30% 4mm	30% 6mm & 30% 8mm
	Wood Material	plywood Lowest Cooling load result	16mm	13mm	54685.44 kWh	54376.32 kWh	16mm	10mm	36312.96 kWh	35035.2 kWh	13mm	10mm	10mm	10mm	13mm	10mm
		plywood Lowest Heating	10mm	16mm	45039.36 kWh	46783.68 kWh	13mm	16mm	41667.84 kWh	41929.92kWh	16mm	10mm	10&13m m	16mm	13mm	16mm

		Loads result														
		Wood Boards Lowest Cooling load result	15mm	15mm	54325.44 kWh	53916.48 kWh	15mm	15mm	36096 kWh	35094.72 kWh	15mm	19mm	15mm	15mm &25mm	19mm	19mm
		Woad Boards Lowest Heating Loads result	15mm	15mm	45796.8 kWh	46928.64 kWh	25mm	19mm	41180.16 kWh	42753.6kWh	25mm	25mm	15mm	25mm& 19mm	19mm	15mm
Wall Insulation	Lowest Cooling load result		76.2&101.6	101.6mm	58202.88 kWh	53949.12 kWh	76.2	101.6	35644.8 kWh	35557.44 kWh	38.1	101.6	50.8& 25.4	76.2& 101.6	76.2& 50.8	50.8& 76.2& 101.6
	Lowest Heating Loads result		101.6	101.6mm	46066.56 kWh	46722.24 kWh	76.2	101.6	41279.04 kWh	42132.48 kWh	76.2	101.6	12.7 mm	25.4	38.1 &101.6	101.6
Glass type	Lowest Cooling load result		triple low solar gain	triple high& triple low solar gain	59734.08 kWh	52385.28 kWh	triple high solar gain& reflective	triple high solar gain& reflective	35513.28 kWh	34824.96 kWh	reflective & triple low solar gain	reflective& triple high solar gain& triple low solar gain	reflective & triple high gain	reflective& triple low solar	reflective & triple low solar gain	reflective& triple low gain
	Lowest Heating Loads result		high solar gain& triple low solar gain	solar gain& triple low solar gain	46894.08 kWh	46775.04 kWh	triple low solar gain& triple high solar gain	&reflective& triple high solar gain	40976.64 kWh	41312.64 kWh	triple high solar gain& triple low solar gain	triple high solar gain& triple low solar gain	triple high gain &triple low	triple high gain & double low	triple low solar & triple high solar gain	triple high solar gain& triple low solar gain

5.4 The Results of Materials Studied Cost

After a comparative evaluation of the contribution of the different wall layers studied to achieve the proposed wall that reduces the consumption of annual heating and cooling loads for each case. Information on the initial cost of each of the layers used was also obtained from the local market of Hebron. In order to compare the prices of materials with different properties and derive a set of recommendations for engineers and designers on the most effective materials with the cost of each of the materials..

Table 5.25 Cost of Aluminum composite panel installation

	Aluminum composite panels installation work	Cost m^2/ Shakel
1	Aluminum composite panel cost	110 shekel / m^2
2	iron grid cost	100 shekel / m^2
3	Iron network installation fee	50 shekel / m^2
4	The fee for lamination of panels	100-150 shekel / m^2

Table 5.26 cost of wood plastic composite panel installation

	Wood Plastic composite panels installation work	Cost m^2/ Shakel
1	Wood Plastic composite panels cost	300-340 shekel / m^2
2	iron grid cost	100 shekel / m^2
3	Iron network installation fee	50 shekel / m^2
4	The fee for lamination of panels	100-150 shekel / m^2

Table 5.27 cost of wood panel installation

	Wood panels installation work	Cost m^2/ Shakel
1	Wood panels cost	200 shekel / m^2
2	iron grid cost	100 shekel / m^2

3	Iron network installation fee	50 shekel / m²
4	The fee for lamination of panels	100-150 shekel / m²

Table 5.28 Cost of Insulation Material

	Insulation material	Cost m^2/ Shakel
1	25.4 mm insulation	5.75 shekel / m²
2	38.1 mm insulation	7 shekel / m²
3	50.8 mm insulation	12 shekel / m²

Table 5.29 Cost of glazing

	Material	Cost / m² in Shekel
1	Clear-Double Glass	130-140 shekel / m²
2	Tinted- Double Glass	130-140 shekel / m²
3	Reflective- Double Glass	190-250 shekel / m²
4	Low Energy Double Glass	450-550 shekel / m²
5	Low Energy Triple Glass	450-550 Shekel / m²

5.5 Summary

The better the building is insulated, the greater the positive impact on the building's cooling and heating needs, and the thicker the insulation, the greater its effectiveness in most cases. In addition the effect of the exterior cladding has also had a positive impact on the building, as the additional material above the stone layer increases the resistance of the exterior wall to weathering and thus increases the effectiveness of the wall in insulating the interior environment of the building. Stage 1 of the simulation examined the effect of the design of the main façade and its modification on the building's internal environment depending on the orientation of the façade. The second stage was to increase the insulation and take control of the building to study the effect of adding insulation to all facades, modifying the main facades by changing the exterior cladding, insulation thicknesses and different types of glass. The new cladding with wood-plastic composites resulted in the lowest values in most cases. This is a modern technology that has increased the effectiveness of the exterior wall of the building when used.

Chapter 6 Conclusion and Recommendations

6.1 Introduction

It has been shown that the design of the exterior walls has a strong influence on the performance of the building. The use of different layers of materials with different thermal properties helps to increase the efficiency of the wall and make the building energy efficient..

6.2 Conclusion

In response to the research objective, this study utilizes the alternative new cladding materials that can be used in the development of exterior wall design of commercial buildings to improve building performance and energy consumption. In addition, the study identifies the importance of insulating the facades of the building rather than insulating only the main facades to minimize energy consumption.

The development and modification of the existing wall involves the selection of thermally modified glass to reduce heat transfer from the inside to the outside or vice versa. This study helps architectural designers looking for new cladding materials for aesthetic purposes by choosing the alternative that improves the performance of the existing building more than other options available on the local market.

The method for performing a simulation to modify the facades of an existing building has been explained. The method is explained in such a way as to help the engineers to refer to it and follow it in order to study any new façade material that appears in the face of the great evolution of the building materials industry, and to make the appropriate decision according to the orientation and characteristics of the building.

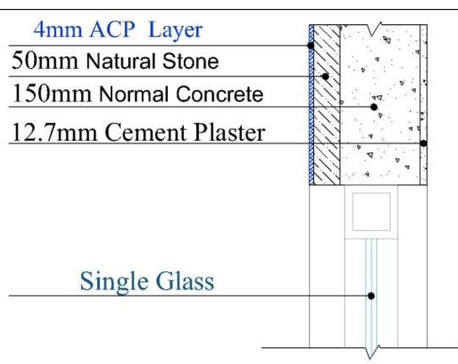
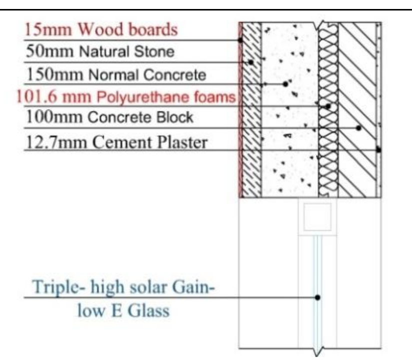
- Case1: The contribution of the modification to the building wall was different in the cases. In case1- stage2, with the presence of shading means, the contribution of the air cavity was 18.1% to the cooling load and 27% to the heating load, which is very close to the contribution of the polyurethane insulation with a thickness of 101.6, since it contributed 18.5% and 37% to the cooling and heating loads, respectively. The least valuable result when adding cladding materials was a wooden boards with a thickness of 15 mm. The contribution to the improvement of the cooling load was 24%, while the heating load was 37.5%, with an average insulation of the walls of 50.8 mm polyurethane and the glass type Double-high solar gain - Low E Glass. In the study of the type of glass that makes a greater contribution to the improvement of building loads, it is triple-high solar gain - low E glass, which corresponds to 16.4% for the cooling load and 36% for the heating load. (table 6.1)

Table 6.1: Comparison of the base model for Case 1 and the contribution of each of the variables studied on stage 2

Case 1	Base model's	50mm Air cavity		101.6mm insulation		Cladding material (15 mm Wood board)		Glass type (Triple- high solar Gain- low E Glass)	
			Contribution to reducing loads (%)	101.6	Contribution to reducing loads (%)		Contribution to reducing loads (%)		Contribution to reducing loads (%)
Cooling load (kWh)	71424	58464	18.1%	58176	18.5%	54240	24%	59712	16.4%
Heating load(kWh)	73344	53472	27%	45984	37.2%	45792	37.5%	46848	36.0%

When simulating the cases with the wall layers that gave the lowest results for the building loads, and combining them into one wall, we then simulated with them. In case1, the contribution was 25.5% for the cooling load and 38.8% for the heating load compared to the base model (table 6.2).

Table 6.2: Comparison between the current situation of Case 1 and the modification of the exterior wall layers to reach a better thermal performance of the building.

Case 1	Case1 Base Model	The proposal modifying external wall layers	The ratio of the contribution of the modification on the layers of the wall to the basic model to the building's loads
External wall layers			

Cooling load kWh	71424	53184	25.5%
Heating load kWh	73344	44832	38.8%

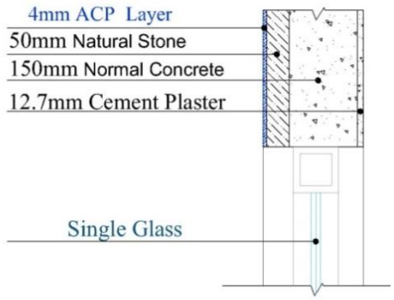
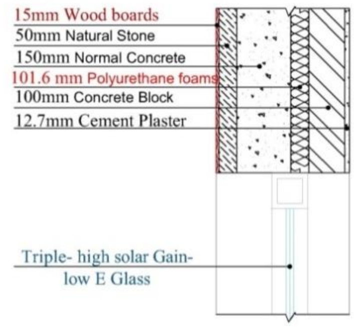
- Case2: The contribution of air cavities to the building load in case2 stage2 with horizontal shading device was 17.6% for cooling load and 15.8 for heating load. Insulation of all facades with a thickness of 101.6 contributes to the reduction of loads by 24% for cooling load and 30.6% for heating load. Cladding the main south façade with a 15 mm thick wood boards contributed to the largest reduction in cooling and heating loads, contributing 23% to the cooling load and 30.7% to the heating load. Triple glazing with high solar radiation and low E content is the glass type that contributes the most to the reduction of building loads: 24.3% in cooling load and 29.1% in heating load (table 6.3).

Table 6.3: Comparison of the base model for Case 2 and the contribution of each of the variables studied on stage 2

Case 2	Base model's	Air cavity		insulation		Cladding material		Glass type Triple- high solar Gain- low E Glass	
				101.6		Wood board			
Cooling load (kWh)	46848	38592	17.6%	35616	24.0%	36096	23.0%	35424	24.3%
Heating load (kWh)	59424	50016	15.8%	41184	30.6%	41088	30.7%	42144	29.1%

In case 2, the combination of layers with lower values of building loads contributed to a 28% reduction in cooling load. As for the heating load, it contributed33.4% to the heating load compared to the base model (table 6.4).

Table 6.4: Comparison between the current situation of Case 2 and the modification of the exterior wall layers to reach a better thermal performance of the building

Case 2	Case1 Base Model	The proposal modifying external wall's layers	The ratio of the contribution of the modification on the layers of the wall to the basic model to the building's loads
External wall layers			
Cooling load(kW)	46848	33696	28%
Heating load(kW)	59424	39648	33.4%

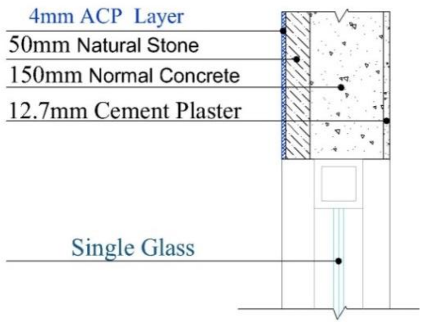
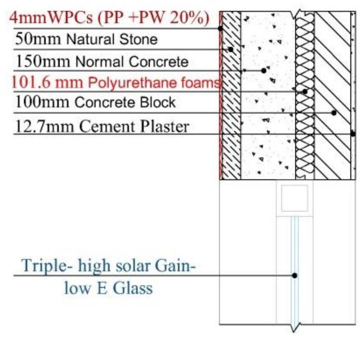
- Case 3: The contribution of the air cavity in Case3- Stage2 was 21.7% for the cooling load and 17.2% for the heating load, which is similar to the contribution of the wall insulation with 101.6 insulation thicknesses, so the contribution was 27.5% for the cooling load and 25.5% for the heating load. The cladding of the main facades with PP 20% 4MM material contributed to the lowest building loads, which was 26.3% for cooling load and 25.9% for heating load. Triple glazing with high solar gain and low E-value contributed to 29% for cooling load and 26.5% for heating load (table 6.5).

Table 6.5: Comparison of the base model for Case 3 and the contribution of each of the variables studied on stage 2

Case 3	Base model's	Air cavity		insulation		Cladding material		Glass type	
						Pp PP 20% 4MM		Triple- high solar Gain- low E Glass	
Cooling load (kWh)	50112	39264	21.7%	36288	27.5%	36864	26.3%	35520	29.0%
Heating load (kWh)	55488	45984	17.2%	41376	25.5%	41088	25.9%	40800	26.5%

In case 3, the proposed wall reduces the cooling load and heating load by 29% (table 5.6).

Table 6.6: Comparison between the current situation of Case 3 and the modification of the exterior wall layers to reach a better thermal performance of the building

Case 3	Case1 Base Model	The proposal modifying external wall's layers	The ratio of the contribution of the modification on the layers of the wall to the basic model to the building's loads
External wall layers			
Cooling load (kWh)	50112	35520	29%
Heating load(kWh)	55488	39456	29%

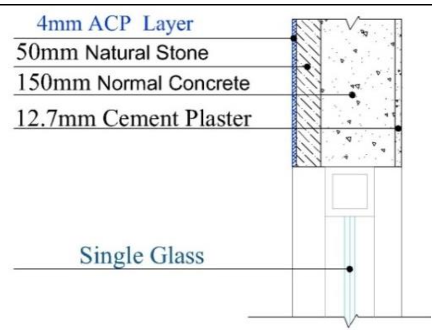
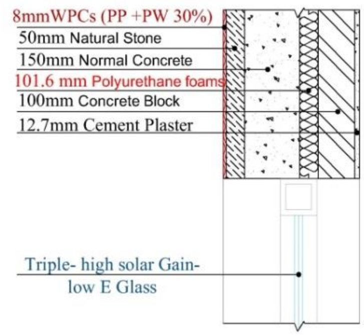
- Case 4: The contribution of the air cavity in Case 4 - Stage 2 was 14.3% for the cooling load and 16.3% for the heating load. The 101.6 insulation thicknesses contributed 25.5% to the cooling load and 31.4% to the heating load. The cladding of the main facades with PP +PW 30% 8MM material contributed to the lowest building loads, 25.4% for cooling load and 34% for heating load. The triple glazing with high solar radiation and low E content contributed 25.8% to the cooling load and 35.1% to the heating load (6.7).

Table 6.7: Comparison of the base model for Case 4 and the contribution of each of the variables studied on stage 2

Case 4	Base model's	Air cavity		insulation		Cladding material		Glass type	
						Pp PP 30% 8MM		Triple- high solar Gain- low E Glass	
Cooling load (kWh)	52032	44544	14.3%	38784	25.5%	38880	25.4%	38592	25.8%
Heating load (kWh)	62496	52320	16.3%	42816	31.4%	40800	34%	40512	35.1%

In Case 4, the PP 30% 8MM outer layer, 101.6 thick insulation, and high solar gain, low E triple glazing contributed to a 27.3% reduction in cooling load and a 36% reduction in heating load. (table 6.8).

Table 6.8: Comparison between the current situation of Case 4 and the modification of the exterior wall layers to reach a better thermal performance of the building

Case 4	Case1 Base Model	The proposal modifying external wall's layers	The ratio of the contribution of the modification on the layers of the wall to the basic model to the building's loads
External wall layers			
Cooling load (kWh)	52032	37824	27.3%
Heating load (kWh)	62496	40032	36%

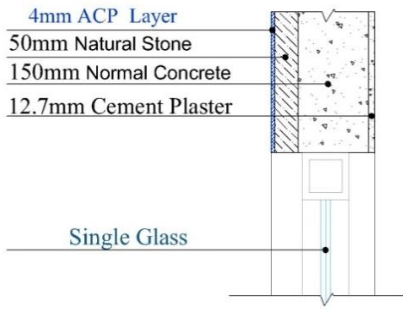
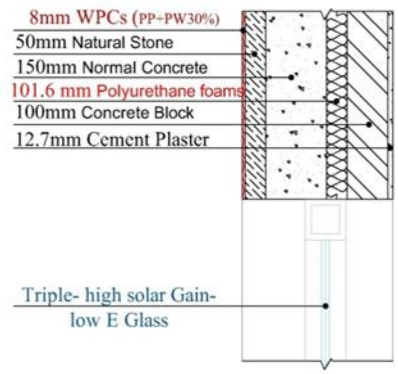
- Case 5: The contribution of the air cavity in case5- stage2 was very low, for cooling load by 10.4% and heating load by 13.4%, while the insulation of the facades with a thickness of 101.6 was 18.7% for cooling load and 34.7% for heating load. The presence of cladding with PP +PW 30% 8MM contributed to 19.8% for the cooling load and 33.3% for the heating load. Triple glazing with high solar gain and low E content reduced the cooling load by 20.8% and the heating load by 33%(table 6.9).

Table 6.9: Comparison of the base model for Case 5 and the contribution of each of the variables studied on stage 2

Case 5	Base model's	Air cavity		insulation		Cladding material		Glass type	
						Pp PP 30% 8MM		Triple- high solar Gain- low E Glass	
Cooling load (kWh)	79104	70848	10.4%	64224	18.7%	63360	19.8%	62592	20.8%
Heating load (kWh)	71232	61728	13.4%	46464	34.7%	47424	33.3%	47616	33.0%

When simulating the proposed wall in case5 with layers that gave low values for the building loads, this wall helped reduce the cooling load by 22.5% and the heating load by 35.4% (table 6.10).

Table 6.10: Comparison between the current situation of Case 5 and the modification of the exterior wall layers to reach a better thermal performance of the building

Case 5	Case1 Base Model	The proposal modifying external wall’s layers	The ratio of the contribution of the modification on the layers of the wall to the basic model to the building's loads
External wall layers			
Cooling load (kWh)	79104	61248	22.5%
Heating load (kWh)	71232	45984	35.4%

6.3 Recommendation

The recommendation we have arrived at in this research can be divided into two phases of the life cycle of a building. The first phase is the preliminary design phase of the building design. It is recommended that each case be studied according to location, orientation, building type, and the services to be provided. The orientation of the building affects the design of the building in ways that avoid large expanses of glass on the eastern and southern orientations, avoid uninsulated facades, and pay attention to the study of cladding materials with thermal properties that increase the thermal performance of the building, as well as other design principles.

The second and central concept of this research refers to the second phase of the life cycle of buildings, that is, to the current modification of existing buildings. In the modification of the building, all analytical data for each case must be taken and studied. Each case has a different analysis than the other cases. The data that must be analyzed include the orientation of the building, the main facades of the building, the glass surfaces and their orientation, the current condition of the building, and the study of the available options in the materials that make up the layers of the building walls to improve the thermal performance of the building and reduce energy consumption depending on the season and temperature. There are many recommendations that can be extended to clarify the comparison of the different wall layer materials studied, such as:

1. Wood-plastic composite panels compared to natural wood panels:
   - A. Composite wood has better thermal properties than natural wood because of the thermoplastics inside. There is a wide range of manufactured wood panels; there are panels that contain thermal insulation and internal air spaces, which can be used for very cold and very hot areas as a highly insulating cladding material.
   - B. The cost is higher than natural wood. The installation cost is the same, but the wood-plastic panels cost 340 shekels per square meter, while the natural wood panels cost 200 shekels per square meter. However, wood-plastic requires less maintenance and is more durable than natural wood. In addition, the wood-plastic panels are treated so that they do not absorb water.
   - C. Wood composite panels are made from recycled wood and plastic. It is an environmentally friendly cladding material that reduces waste by using raw materials.

2. Wood composite panels compared to aluminum composite panels:
   - A. Wood composite panels are more expensive than aluminum composite panels. The price of aluminum panels is about 110 shekels per square meter, but the wood composite panels cost 300-340 shekels per square meter.
   - B. The installation method is similar to the composite panels, a stainless-steel mesh is needed to install them, and it is the same price.
   - C. Wood-based panels have better thermal performance than aluminum composite panels. In the study of the previous cases, the results were better because the natural wood panels and the wood composite panels helped to reduce the heating and cooling loads of the building.
   - D. There is a wide range of colors for aluminum composite panels, and they can also be made in the shape and color of wood material.

3. Comparison between natural wood panels and aluminum panels:

A. Aluminum composite panels are cheaper than natural wood panels. The price of aluminum composite panels is 110 shekels per square meter, while the price of natural wood panels is 200 shekels per square meter.
B. Aluminum composite panels require less maintenance and are more durable. Natural wood requires a lot of maintenance and is less durable than aluminum composite panels because of its water absorption and other problems.
C. There are large shapes and panels for aluminum composite panels, which are made to closely resemble the color and shape of natural wood.

4. In the city of Hebron, there is an upward trend in the use of triple and double low-E glass. However, the trend is low due to the high price, as the price per square meter can reach 450-550 shekels. However, awareness of the importance of installing glass with high physical and thermal properties began to spread, leading many companies and stores to use this type of glass in new projects, especially commercial projects that include large areas of glass in the facades, so they import glass directly from other countries so that the cost is lower..

5. Polyurethane insulation is the one with the best thermal performance used in the city of Hebron. Thermal insulation with larger thicknesses has higher thermal performance, which was derived from the results of the simulation of the study cases. The initial cost of large thickness insulation is high, but the operating cost of energy consumption for the building in which it is present is lower after a few years. It contributes 15-25% annually to reduce cooling and heating costs, it was concluded.

High-efficiency materials have a high initial cost, but they are very durable and easy to maintain, which increases the building's performance. They are also environmentally friendly materials, manufactured to protect the environment and provide greater thermal comfort. They are sustainable materials that the world is turning to day after day, recognizing their importance for people and the environment..

In addition, there are many recommendations for future and practical research, and research can be extended in various ways, such as:

1. Simulating the impact of advanced building materials that have different properties, such as phase change materials, different options of new insulation materials, and

types of glazing that have interlocking techniques, such as glass panels with photovoltaic cells and other materials that make up the building's facades and can affect its thermal performance.

2. A comprehensive study of the economic feasibility of modifying the facades of existing commercial buildings by adding new cladding materials, insulation materials, and glass types to improve the building's thermal performance.
3. Simulating the impact of sustainable construction techniques, particularly for building facades, such as living wall facades, cemented facades, and others.
4. Researching the impact of new materials for cladding different types of walls, other than concrete and stone, which can be used in cities other than the study city. In addition to conducting the study in areas with different climatic characteristics, such as valleys or desert areas.
5. It is recommended to study the effect of thermal insulation in the outer layer of the wall (after the cladding material). In this study, the effect of thermal insulation inside the wall cavity was investigated, and not the effect outside the wall cavity from the outside.

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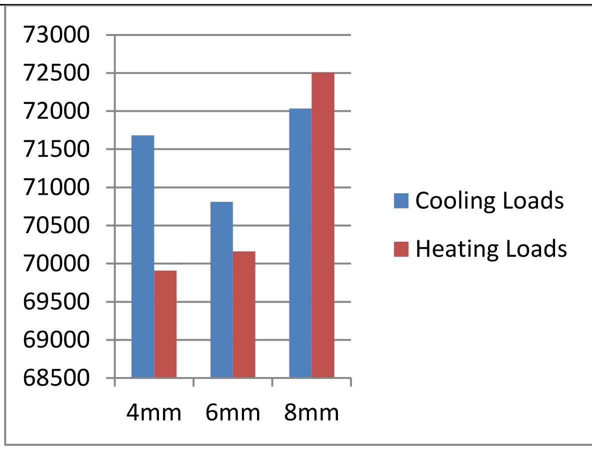
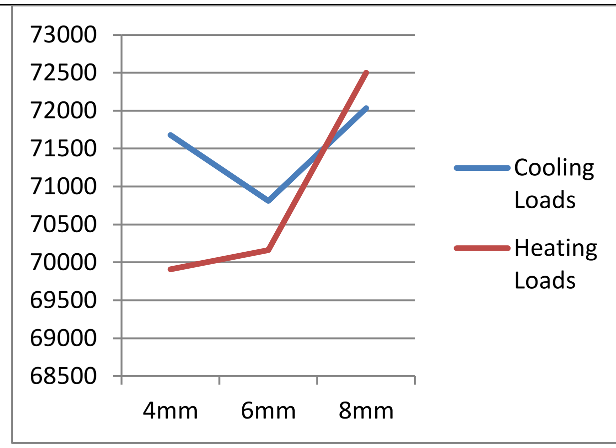
Appendices

Appendix A
Cases Description and Simulation

Case 1: Sbitany I store			
Structured information			
Building location	Al-Salam st.	Ground floor area	715 m^2,
Floors numbers	3	Main facade orientation	South – East
Material of Cladding system	Alucobond	Building use:	Retail sales
Visual information	Have not window	Textual information	
		The study case 1 is a retail sales three stories building. The building type is a simple commercial center with total areas is 715 m^2, with Alucabond external cladding	
Simulation results			
Stage 1			
Composite panels			
Aluminum material			
thickness	4mm	6mm	8mm
Cooling Loads	71681	70811	72033
Heating Loads	69910	70162	72502
Charts results			





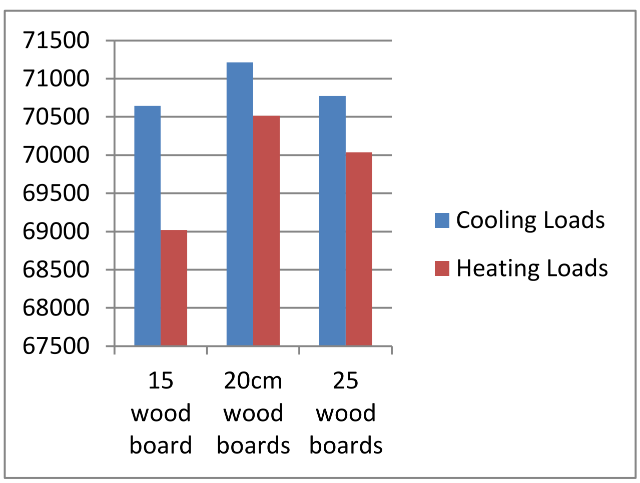
Wood materials

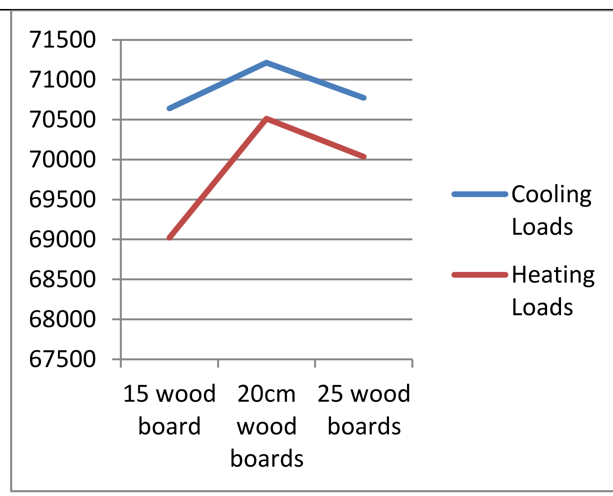
	Plywood			Wood boards		
	plywood 10mm	13 plywood	plywood 15 cm	15 wood board	20cm wood boards	25 wood boards
Cooling Loads	70797	71532	70588	70642	71212	70773
Heating Loads	71222	72497	72845	69021	70036	70036

Charts results

Plywood

wood boards

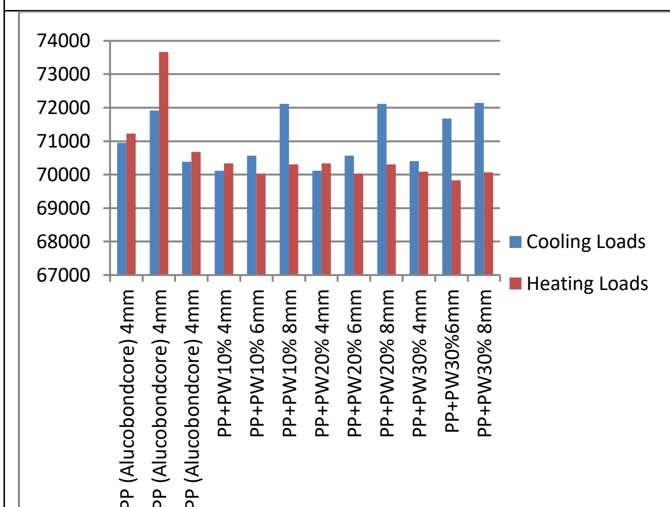


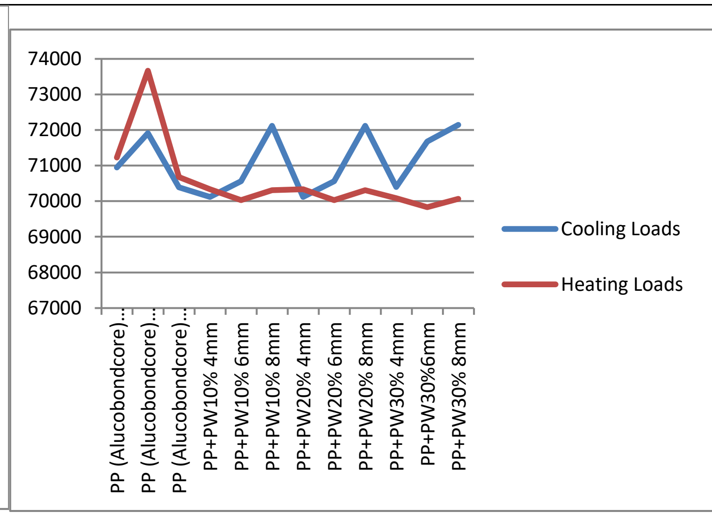


Wood composite panels

			Cooling loads	Heating Loads
PP	PP (Alucobondcore)	4mm	70949	71225
		6mm	71909	73665
		8mm	70386	70681

	PP+PW10%	4mm	70116	70337
		6mm	70561	70027
		8mm	72117	70308
	PP+PW20%	4mm	70116	70337
		6mm	70561	70027
		8mm	72117	70308
	PP+PW30%	4mm	70400	70083
		6mm	71679	69831
		8mm	72146	70068
HDPE	HDPE(Alucobond core)	4mm	71311	71541
		6mm	71311	71541
		8mm	71311	71541
	HDPE10%	4mm	71311	71541
		6mm	70456	70255
		8mm	70317	71863
	HDPE20%	4mm	70416	72625
		6mm	71406	70497
		8mm	70363	69707
	HDPE30%	4mm	69953	69742
		6mm	70704	71524
		8mm	70490	72268
Charts results				
Wood composite panels				
Pp				





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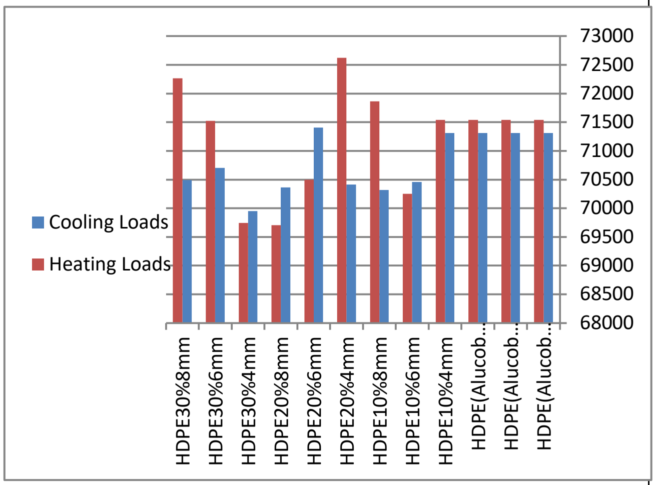
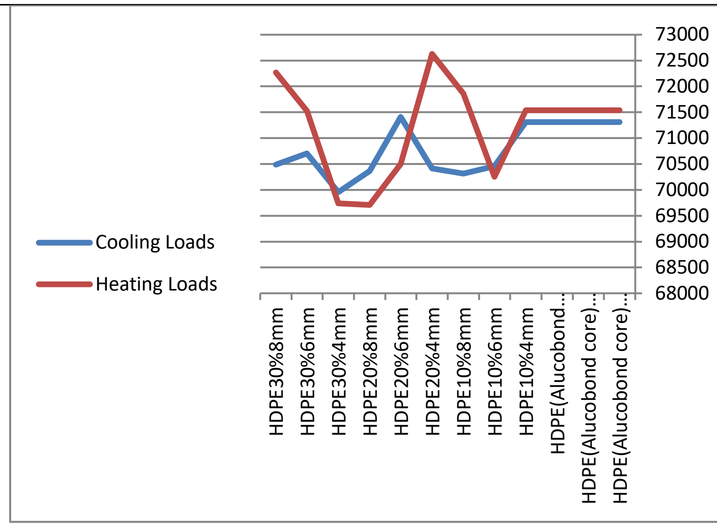
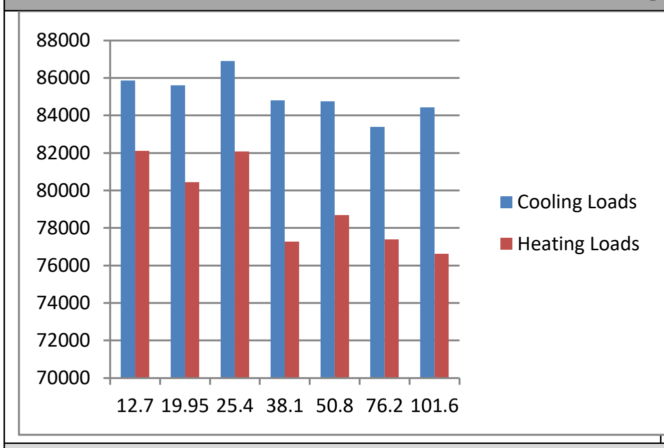
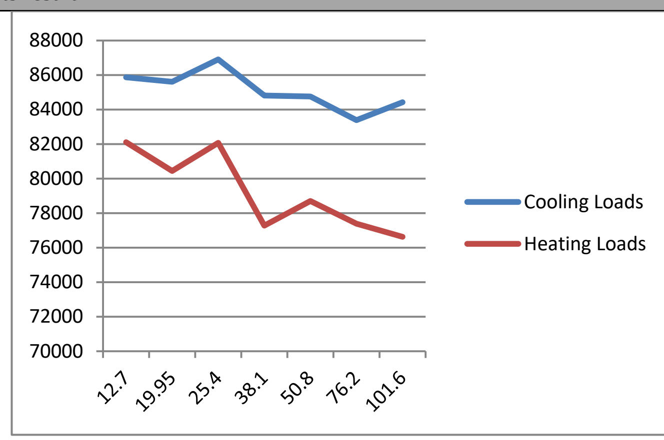




Wall insulation							
thickness	12.7	19.05	25.4	38.1	50.8	76.2	101.6
Cooling Loads	85863	85611	86907	84803	84755	83391	84425
Heating Loads	82106	80441	82071	77267	78694	77386	76621

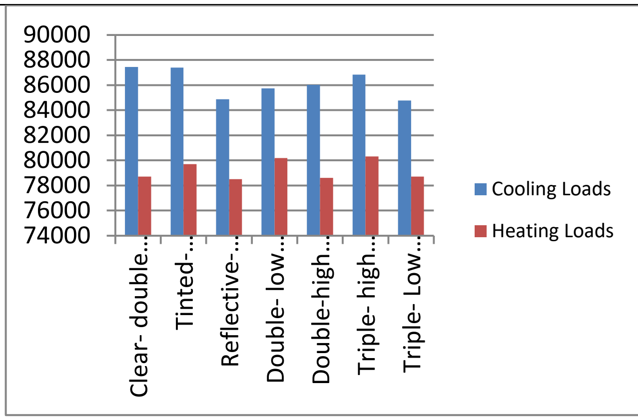
Charts result

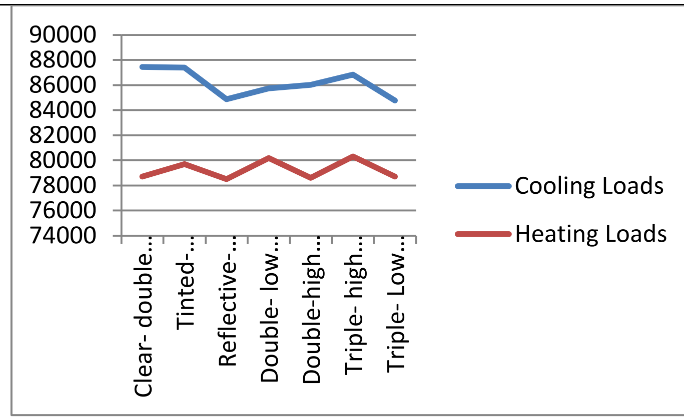




Glass types							
	Clear- double glass	Tinted- double glass	Reflective- double glass	Double- low solar gain- low E Glass	Double- high solar gain – low E Glass	Triple- high solar Gain- low E Glass	Triple- Low Solar Gain Low E Glass
Cooling Loads	87434	87386	84858	85747	86023	86824	84755
Heating Loads	78708	79691	78508	80181	78604	80305	78694

Charts result





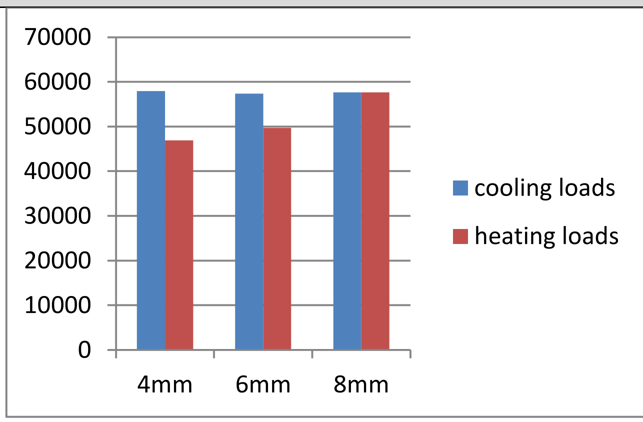
Stage 2

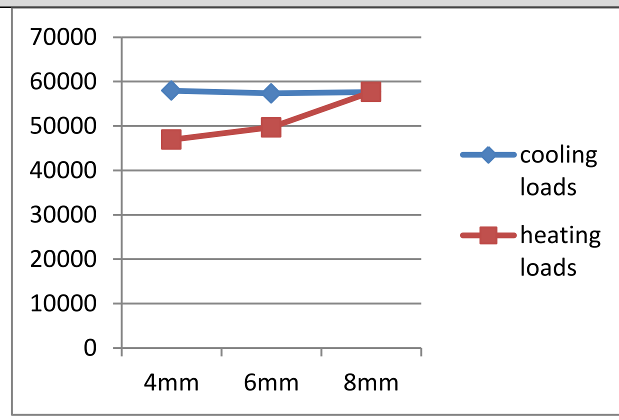
Cladding materials

Aluminum Composite panels

thickness	4mm	6mm	8mm
cooling loads	57940	57350	57668
heating loads	46918	49710	57668

Charts result



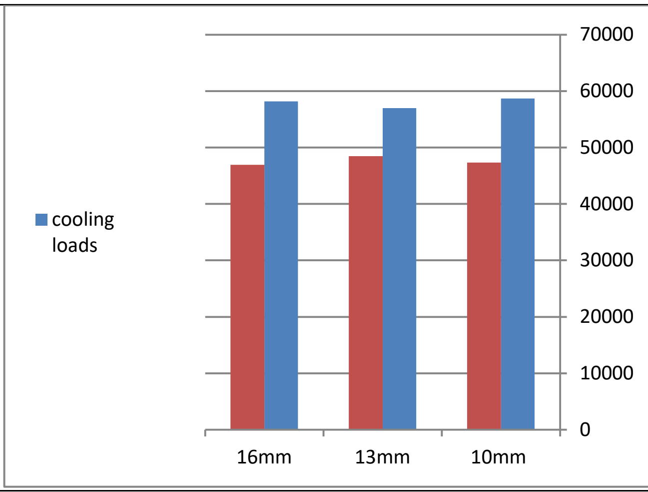


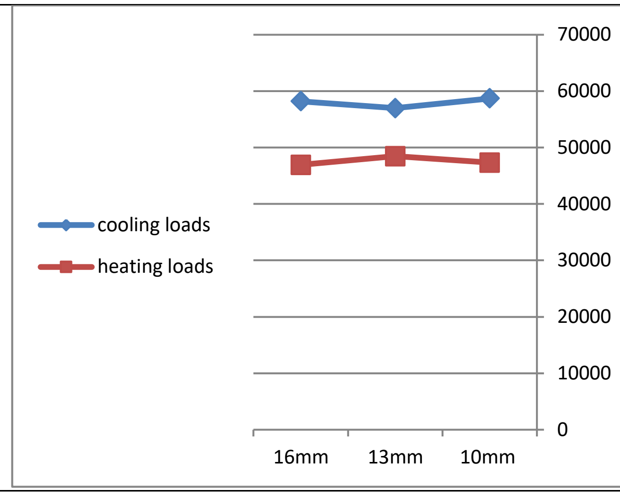
Wood materials

	plywood			Wood boards		
	10mm	13mm	16mm	15mm	19mm	25mm
cooling loads	58710	56964	58192	56589	57106	57977
heating loads	47333	48454	46916	47705	49713	48977

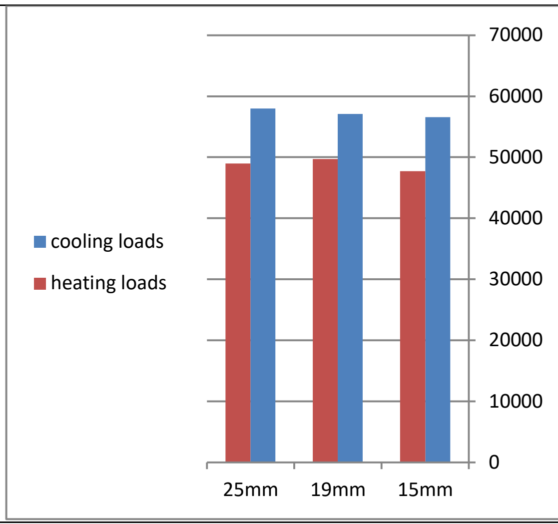
Charts result

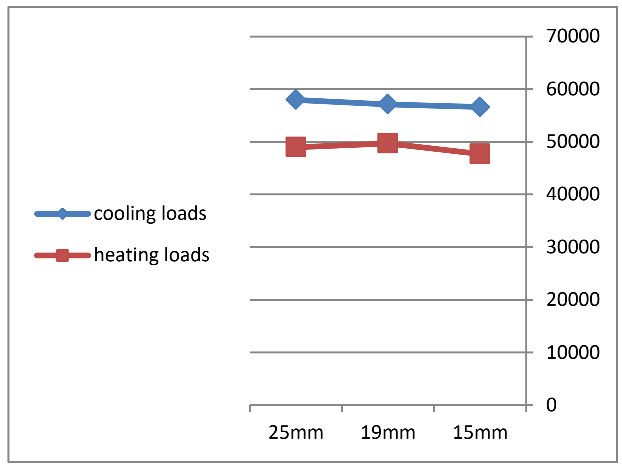
plywood





Wood boards





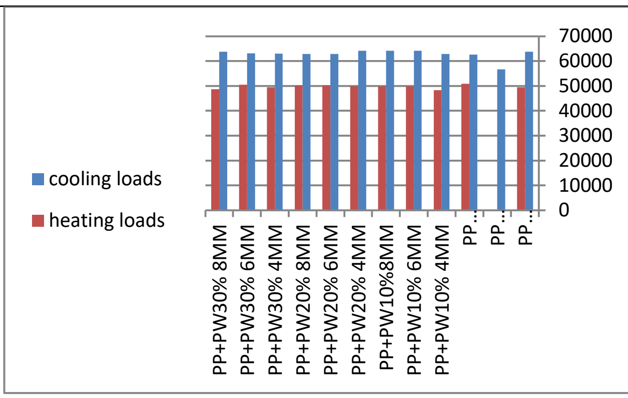
Wood composite panel

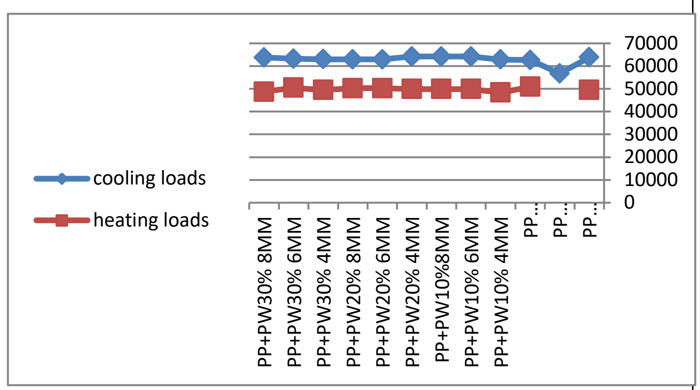
			Cooling loads	Heating loads
PP	PP (Alucobondcore)	4MM	63783	49443
		6mm		
		8mm	62619	50860
	PP+PW10%	4mm	62840	48351
		6mm	64141	49873
		8mm	64157	49906
	PP+PW20%	4mm	64157	49906
		6mm	62870	50243
		8mm	62870	50243
	PP+PW30%	4mm	62982	49505

		6mm	63181	50468
		8mm	63712	48680
HDPE	HDPE(Alucobond core)	4mm	64004	48324
		6mm	63291	50660
		8mm	62109	49109
	HDPE10%	4mm	63509	51031
		6mm	63479	48654
		8mm	63364	51125
	HDPE20%	4mm	63341	48109
		6mm	63713	49682
		8mm	63485	49421
	HDPE30%	4mm	63889	49576
		6mm	63731	48318
		8mm	62529	49934

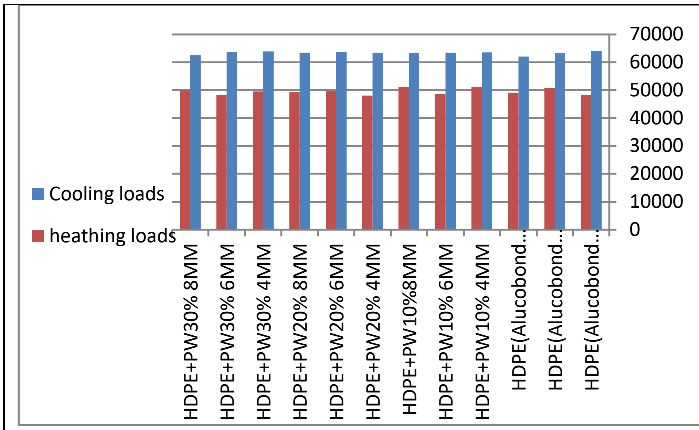
Charts result

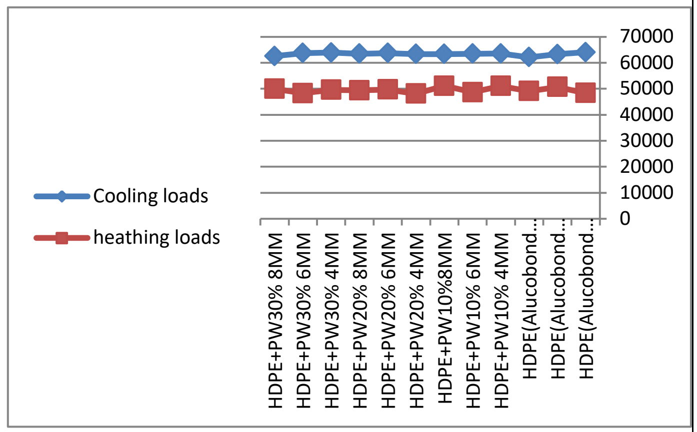
pp





HPDE

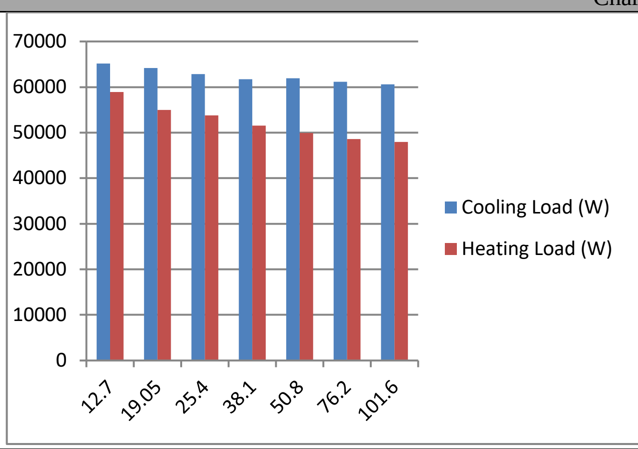


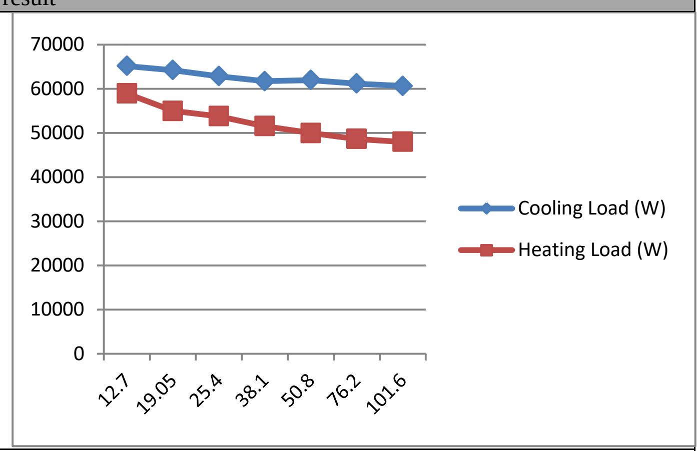


wall insulation

	12.7	19.05	25.4	38.1	50.8	76.2	101.6
Cooling Load (W)	65165	64213	62828	61720	61966	61187	60628
Heating Load (W)	58938	54957	53767	51539	49964	48631	47986

Charts result

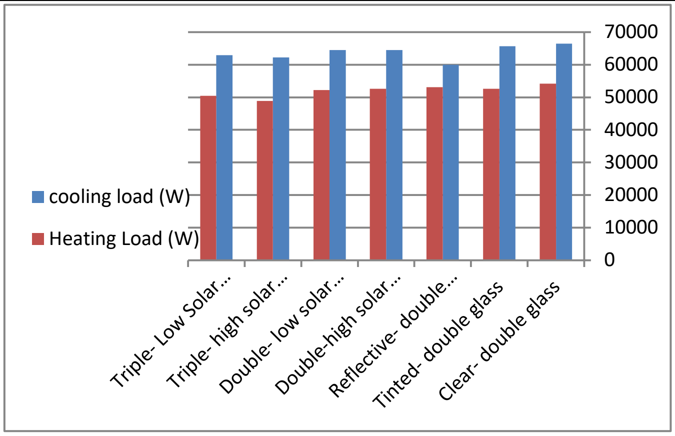


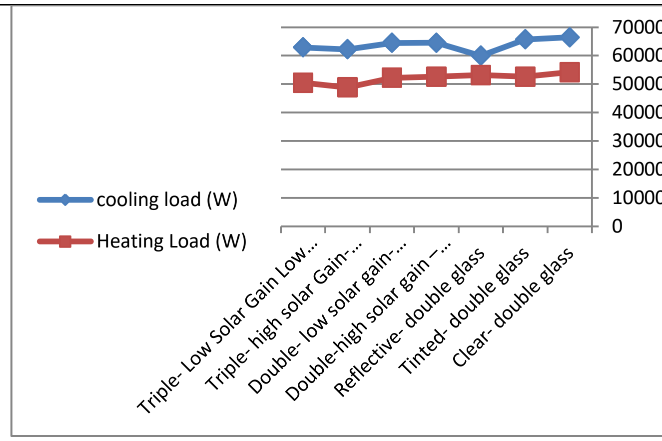


Glass types

	Clear-double glass	Tinted-double glass	Reflective-double glass	Double-high solar gain – low E Glass	Double- low solar gain- low E Glass	Triple- high solar Gain- low E Glass	Triple- Low Solar Gain Low E Glass
Cooling loads	66458	65684	5 9942	64512	64473	62223	62914
Heating loads	54188	52576	53138	52587	52175	48848	50455

Charts results

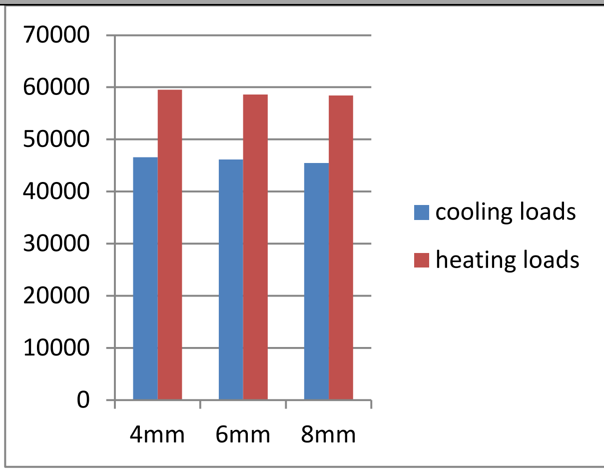


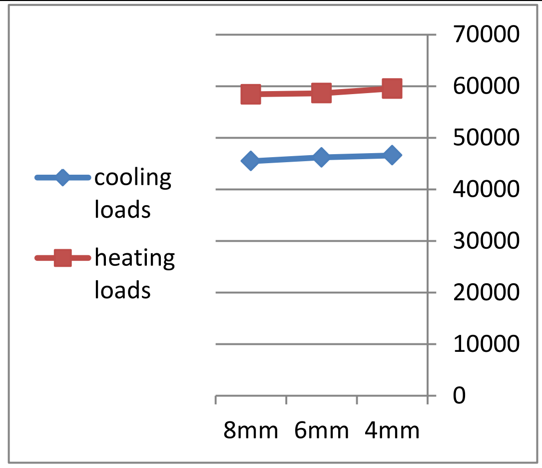


Case 2: AL-Bayed center			
Structured information			
Building location	AL- Haouz street	Ground floor area	350 (m^2)
Floors numbers	2	Main elevation orientation	South
Material of Cladding system	Alucobond	Building use:	Retail sales
Visual information		Textual information	
		The study case 2 is a two stories building. The building type is a simple commercial center with total areas is 350 m^2, with Alucabond external cladding	

Simulation results			
Stage 1			
Cladding materials			
Aluminum material			
	4mm	6mm	8mm
cooling loads	46603	46187	45459
heating loads	59534	58625	58411

Charts results



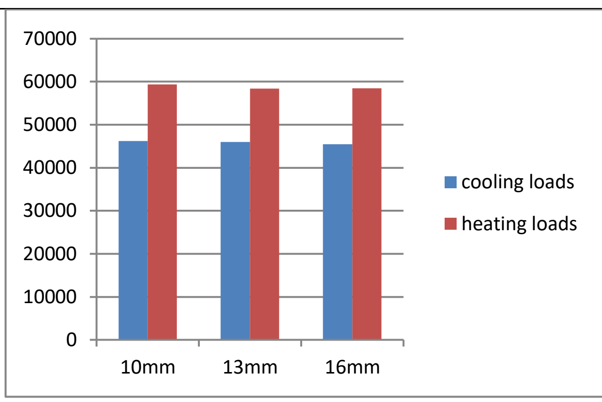


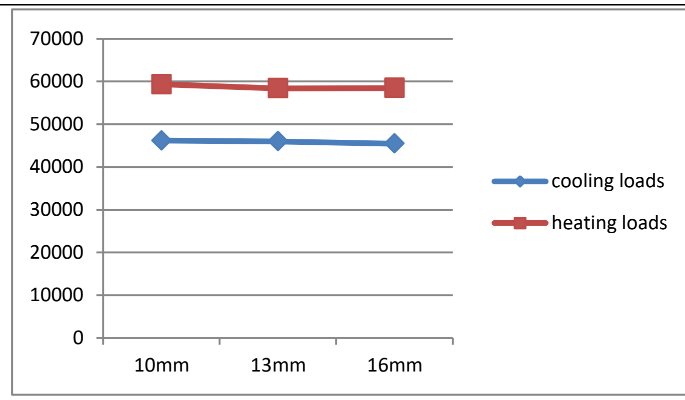
Wood materials

	plywood			Wood boards		
	10mm	13mm	16mm	15mm	19mm	25mm
cooling loads	46198	45995	45472	45586	46207	46114
heating loads	59351	58417	58491	58556	58509	57738

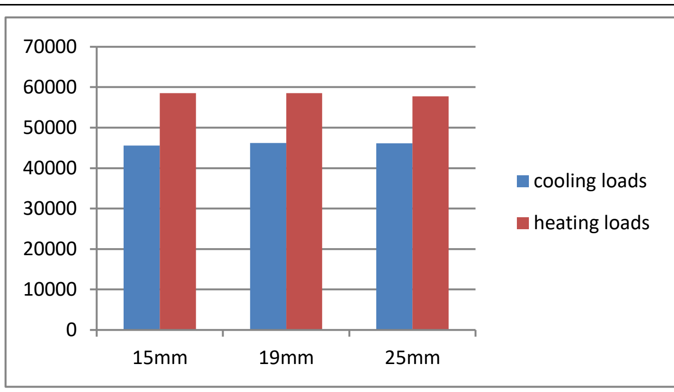
Charts results

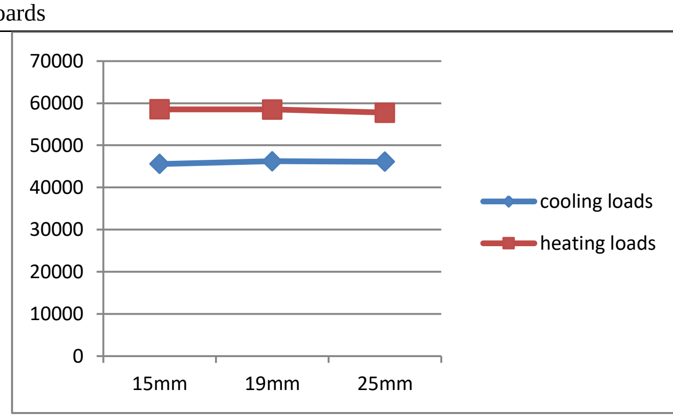
Plywood





Wood boards





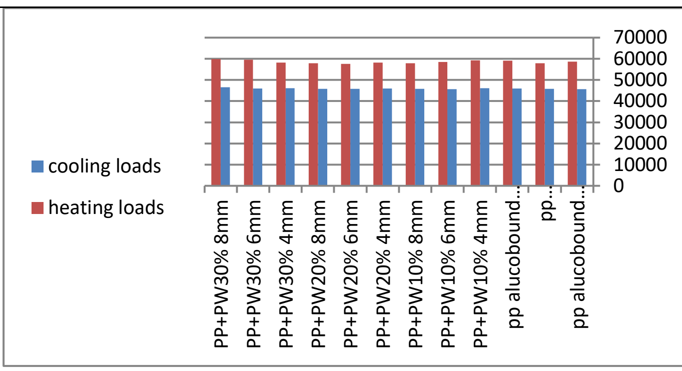
Wood composite panel

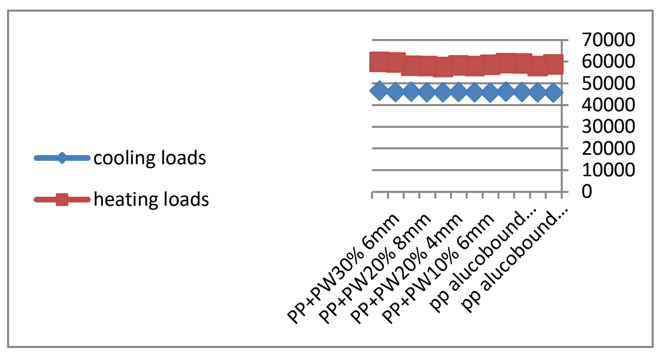
			Cooling loads	Heating loads
PP	pp alucobound	4mm	45589	58597

		6mm	45862	57889
		8mm	45908	59133
	PP+PW10%	4mm	46102	59243
		6mm	45615	58527
		8mm	45870	57870
	PP+PW20%	4mm	45977	58175
		6mm	45819	57501
		8mm	45870	57870
	PP+PW30%	4mm	46139	58111
		6mm	45959	59567
		8mm	46597	59902
HPDE	HDPE(Alucobond core)	HDPE(Alucobond core)4mm	45948	58438
		HDPE(Alucobond core)6mm	46308	59220
		HDPE(Alucobond core)8mm	45348	57403
	HDPE10%	HDPE10%4mm	46264	57945
		HDPE10%6mm	46001	58556
		HDPE10%8mm	46341	58283
	HDPE20%	HDPE20%4mm	45676	59343
		HDPE20%6mm	45841	59097
		HDPE20%8mm	45972	57808
		HDPE30%4mm	46034	57477
		HDPE30%6mm	45611	58959
		HDPE30%8mm	46245	58521

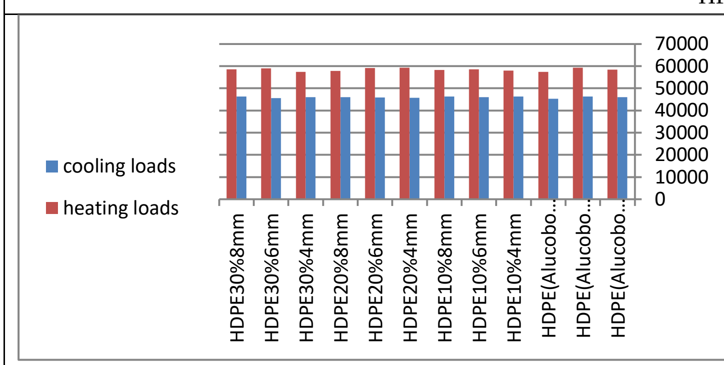
Charts results

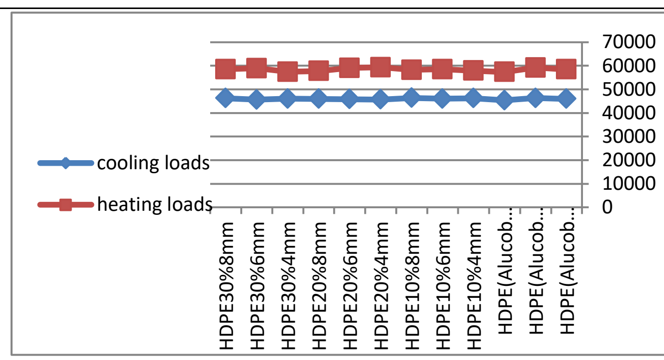
PP





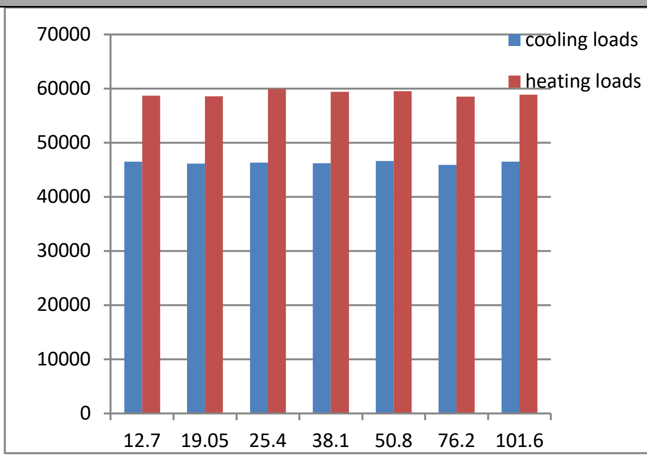
HPDE

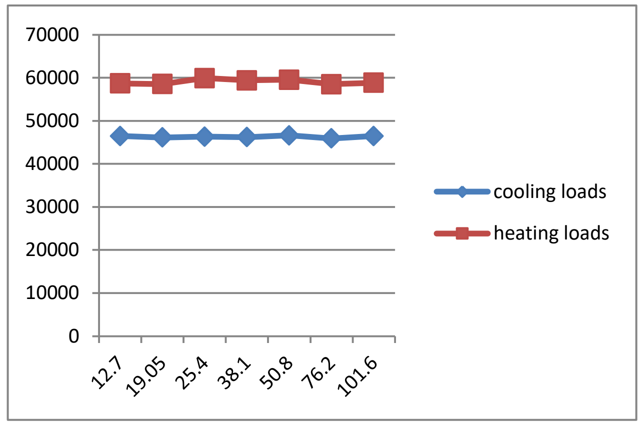




wall insulation							
	12.7	19.05	25.4	38.1	50.8	76.2	101.6
cooling loads	46489	46131	46335	46194	46603	45902	46485
heating loads	58690	58553	59940	59394	59534	58526	58863

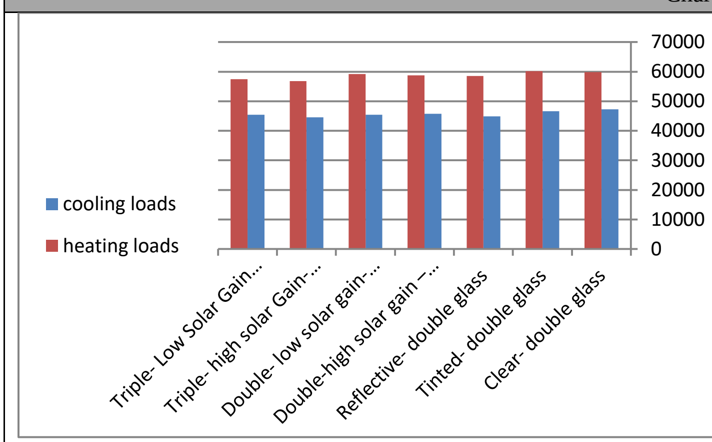
Charts results

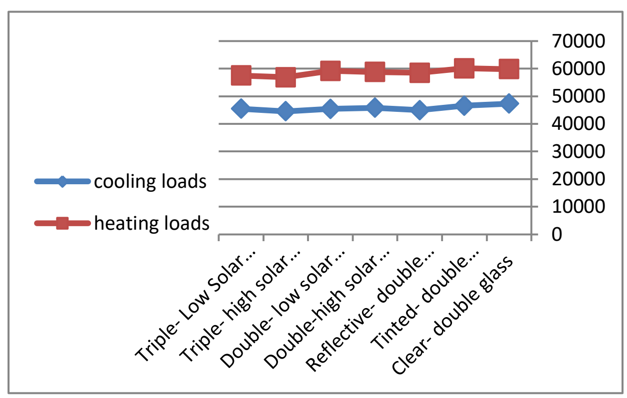




Glass types							
	Clear- double glass	Tinted- double glass	Reflective- double glass	Double- high solar gain – low E Glass	Double- low solar gain- low E Glass	Triple- high solar Gain- low E Glass	Triple- Low Solar Gain Low E Glass
cooling loads	47326	46578	44916	45793	45384	44544	45451
heating loads	59825	60127	58505	58793	59175	56868	57506

Charts results



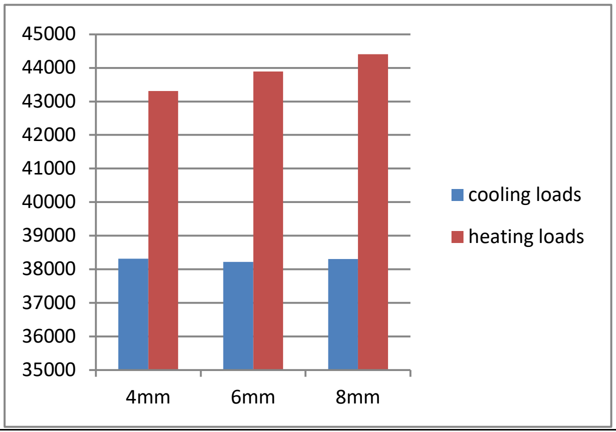


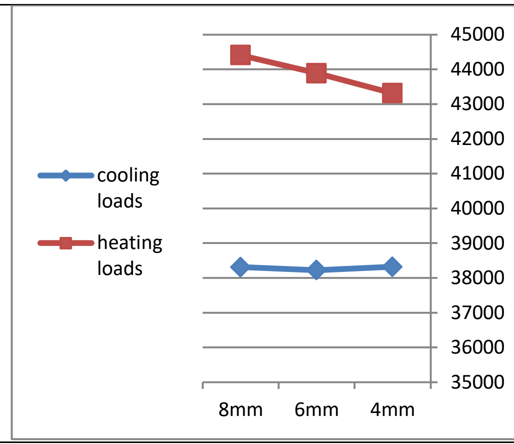
Stage 2

Cladding materials

Aluminum Composite panels			
alucabond	4mm	6mm	8mm
cooling loads	38319	38225	38310
heating loads	43313	43892	44408

Charts results

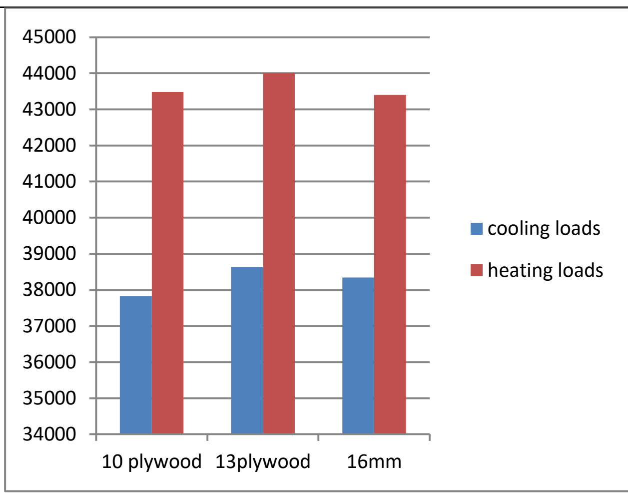


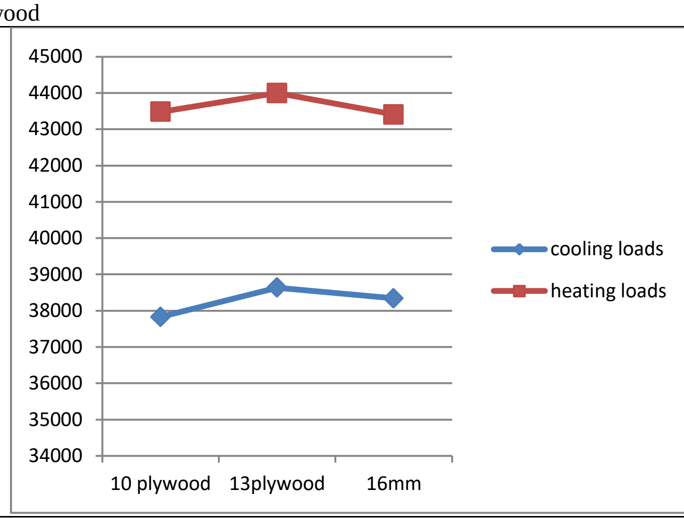


Wood materials						
	plywood			Wood boards		
	10 plywood	13plywood	16mm	15mm	19mm	25mm
cooling loads	37826	38636	38339	37600	38372	37953
heating loads	43483	43999	43404	43373	42896	44132

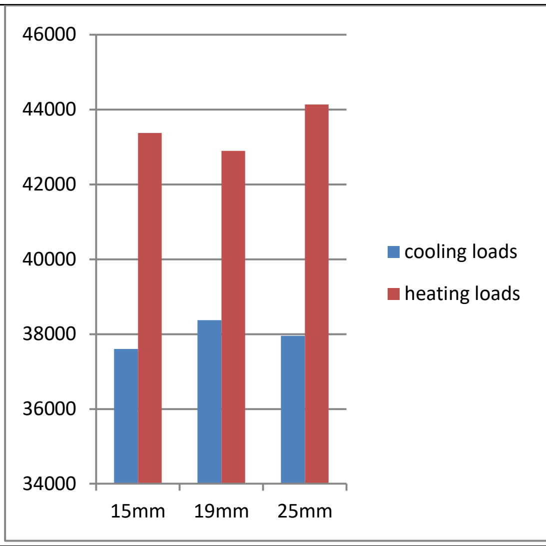
Charts results

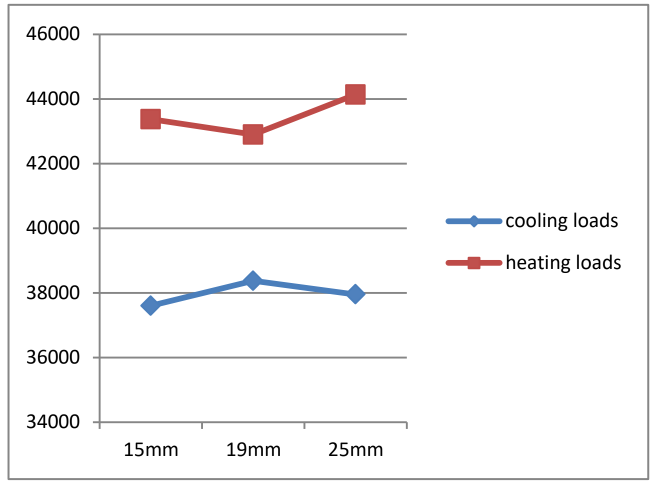
Plywood





Wood boards



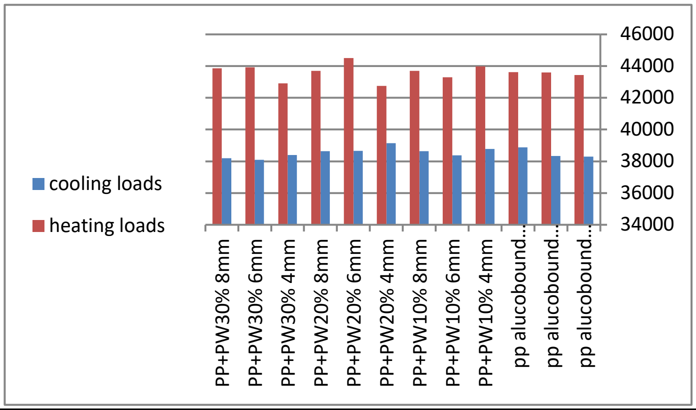


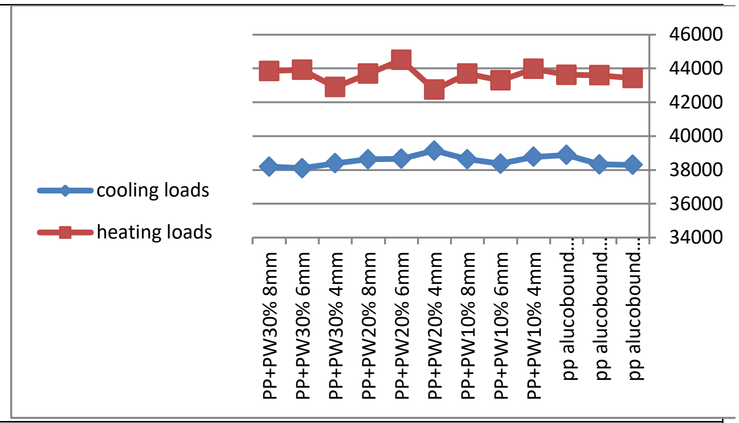
Wood composite panel

			Cooling loads	Heating loads
PP	pp alucobound	pp alucobound 4MM	38302	43431
		pp alucobound 6MM	38331	43594
		pp alucobound 8MM	38884	43622
	PP+PW10%	PP+PW10% 4mm	38775	43978
		PP+PW10% 6mm	38368	43292
		PP+PW10% 8mm	38629	43690
	PP+PW20%	PP+PW20% 4mm	39145	42748
		PP+PW20% 6mm	38658	44507
		PP+PW20% 8mm	38629	43690
	PP+PW30%	PP+PW30% 4mm	38394	42901
		PP+PW30% 6mm	38102	43920
		PP+PW30% 8mm	38196	43849
HPDE	HDPE(Alucobond core)	HDPE(Alucobond core)4mm	38762	44373
		HDPE(Alucobond core)6mm	37804	44318
		HDPE(Alucobond core)8mm	38027	44491
	HDPE10%	HDPE10%4mm	38351	44566
		HDPE10%6mm	38226	44228
		HDPE10%8mm	38948	43320
	HDPE20%	HDPE20%4mm	38240	44453
		HDPE20%6mm	38462	43284
		HDPE20%8mm	38047	43581
	HDPE30%	HDPE30%4mm	38786	43310
		HDPE30%6mm	37716	43545
		HDPE30%8mm	38790	43729

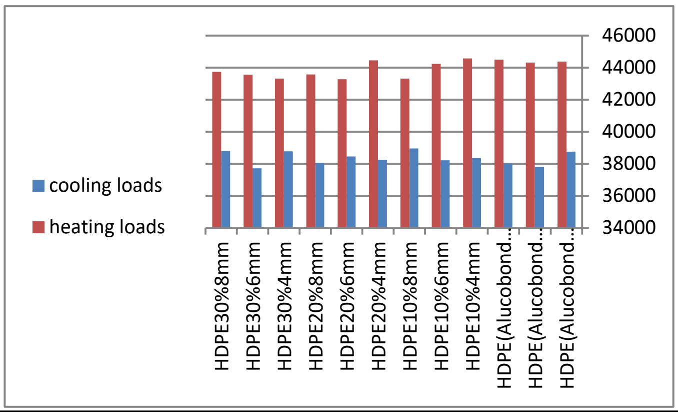
Charts results

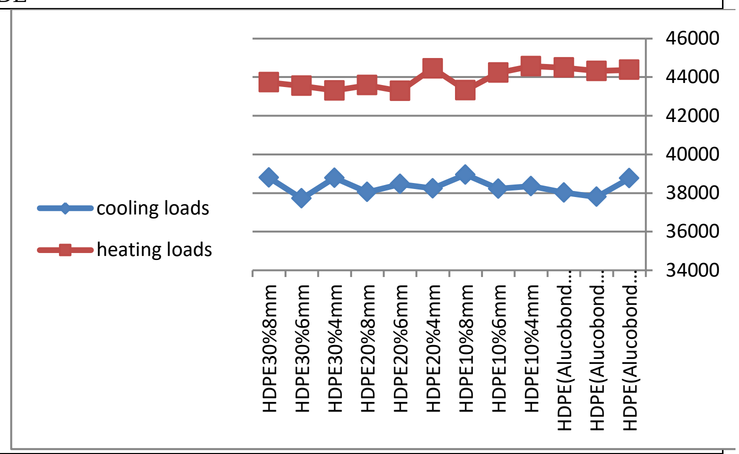
PP





HPDE

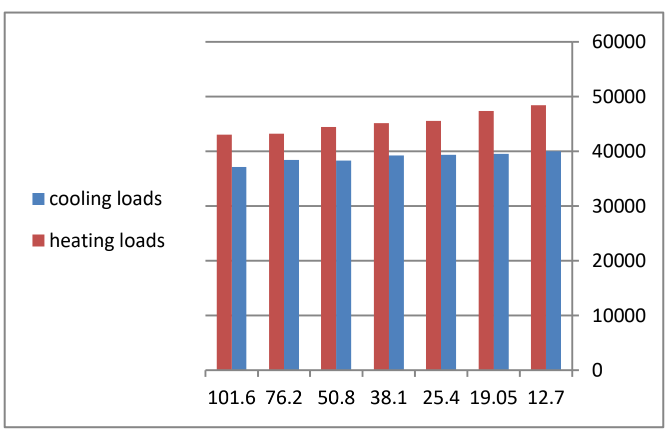


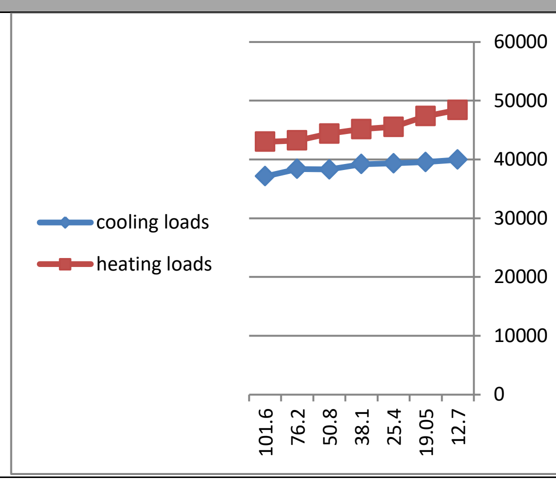


wall insulation

	12.7	19.05	25.4	38.1	50.8	76.2	101.6
cooling loads	39969	39537	39343	39201	38310	38380	37130
heating loads	48412	47372	45533	45150	44408	43212	42999

Charts results



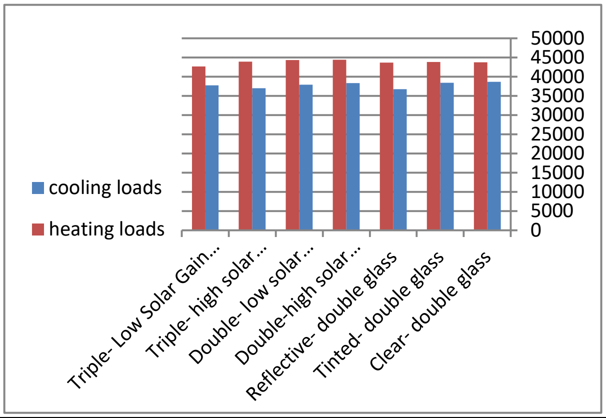


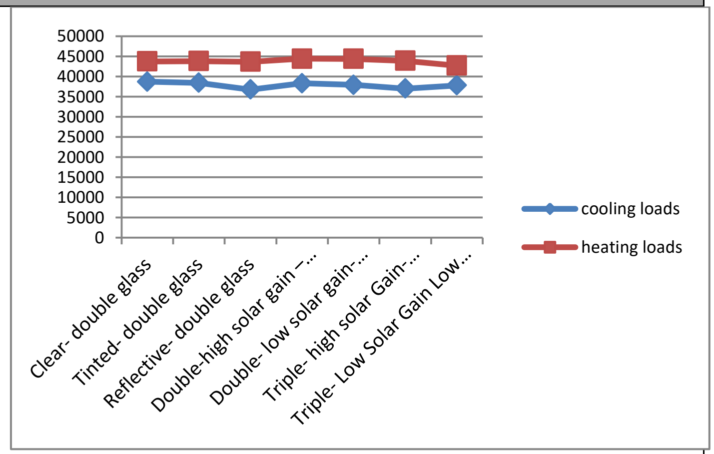
Glass types

	Clear-double glass	Tinted-double glass	Reflective-double glass	Double-high solar gain – low E Glass	Double- low solar gain- low E Glass	Triple- high solar Gain- low E Glass	Triple- Low Solar Gain Low E Glass

cooling loads	38682	38429	36763	38310	37905	36993	37780
heating loads	43731	43828	43663	44408	44356	43894	42684

Charts results





Case 3: Home Plaza			
Structured information			
Building location	Mafraq al-algama' st.	Ground floor area	300 m^2
Floors numbers	5	Main elevation orientation	North – West
Material of Cladding system	Alucabond- stone	Building use:	Retail sales
Visual information		Textual information	

The study case 3 is a five stories building. The building type is a simple commercial center with total areas is 300 m^2, with Alucabond and stone external cladding

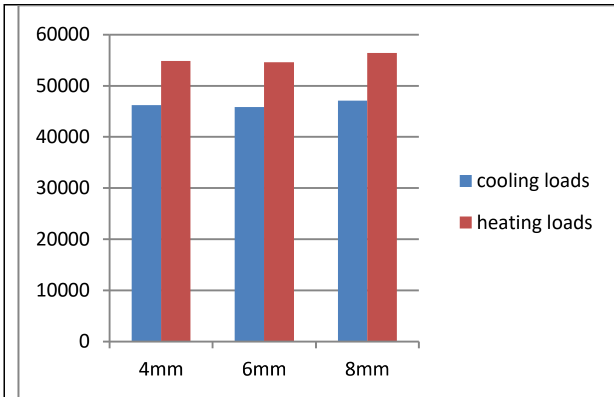
Simulation results

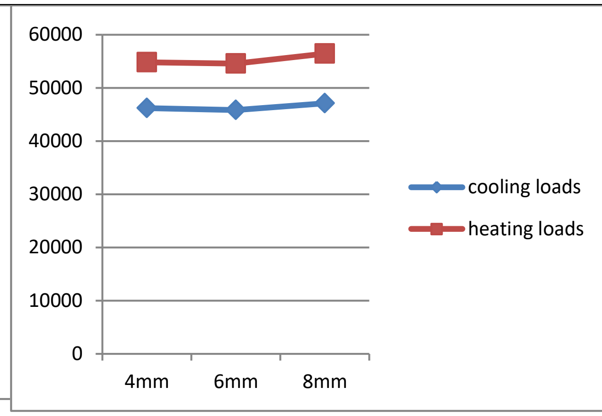
Cladding materials

Aluminum Composite panels

	4mm	6mm	8mm
cooling loads	46206	45849	47122
heating loads	54821	54573	56439

Charts results



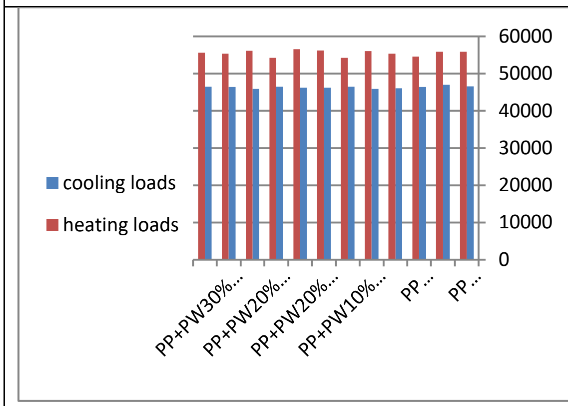


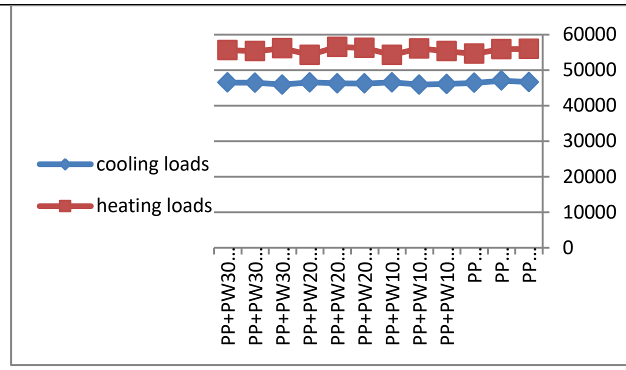
Wood composite panel

			cooling loads	Heating loads
	PP (Alucobondcore)	PP (Alucobondcore)4mm	46622	55939
		PP (Alucobondcore)6mm	47045	55926
		PP (Alucobondcore)8mm	46408	54587
	PP+PW10%	PP+PW10% 4mm	46099	55342
		PP+PW10% 6mm	45919	56104
		PP+PW10% 8mm	46521	54268
	PP+PW20%	PP+PW20% 4mm	46209	56210
		PP+PW20% 6mm	46269	56549
		PP+PW20% 8mm	46521	54268
	PP+PW30%	PP+PW30% 4mm	45909	56128
		PP+PW30% 6mm	46443	55341
		PP+PW30% 8mm	46484	55646
	HDPE(Alucobond core	HDPE(Alucobond core)4mm	45960	54672
		HDPE(Alucobond core)6mm	46906	55284
		HDPE(Alucobond core)8mm	47000	55317
	HDPE10%	HDPE10%4mm	46507	55272
		HDPE10%6mm	46275	56231
		HDPE10%8mm	47006	55528
	HDPE20%	HDPE20%4mm	46316	54168
		HDPE20%6mm	47047	55072
		HDPE20%8mm	46878	54322
	HDPE30%	HDPE30%4mm	45620	54457
		HDPE30%6mm	47501	54855
		HDPE30%8mm	46127	54582

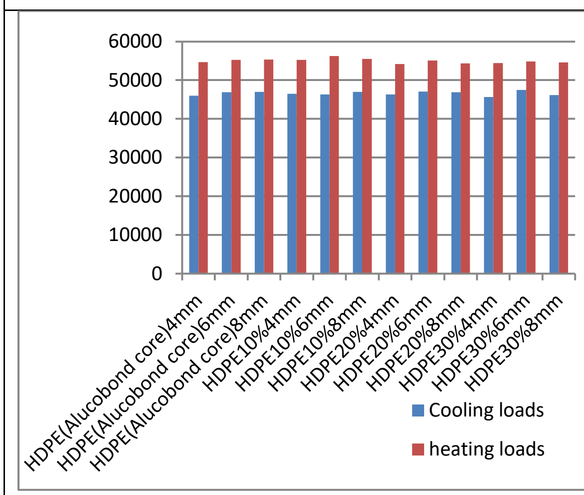
Charts result

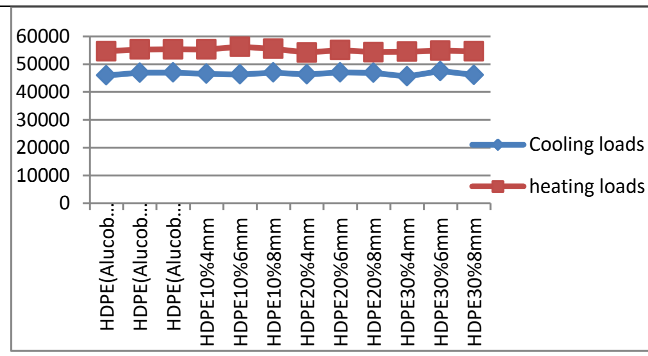
PP





HPDE



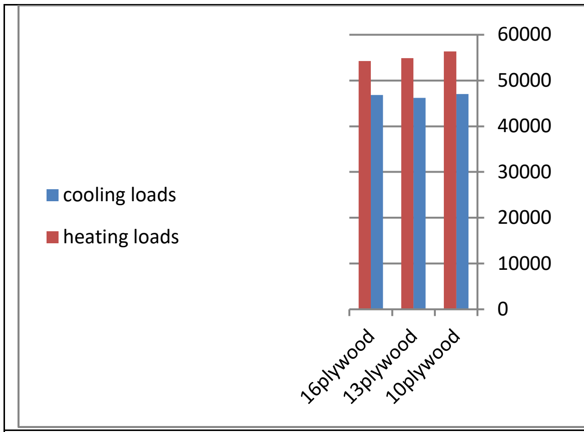


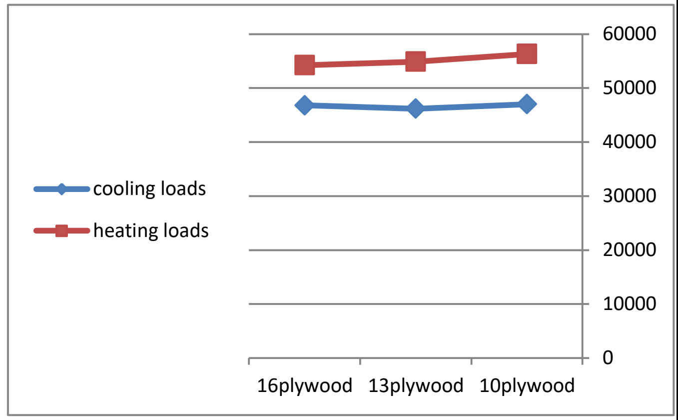
Wood materials

	10plywood	13plywood	16plywood	15mm	19mm	25mm
cooling loads	47019	46196	46812	45845	46806	46373
heating loads	56318	54894	54261	55922	54207	54074

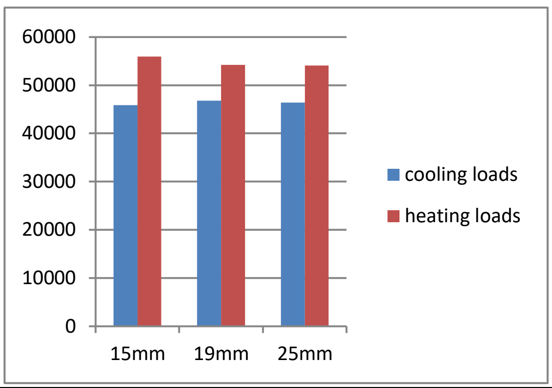
Charts results

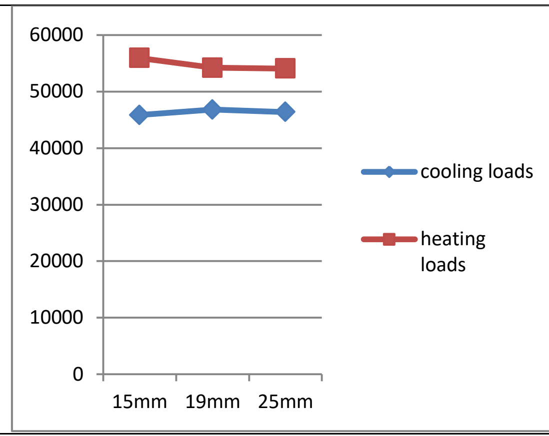
plywood





Wood boards

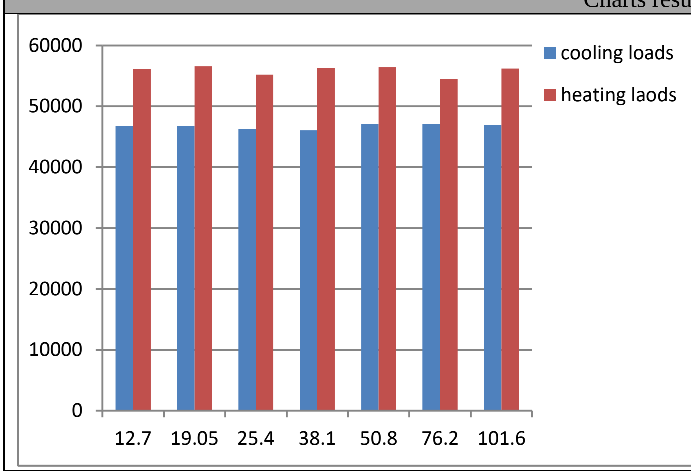


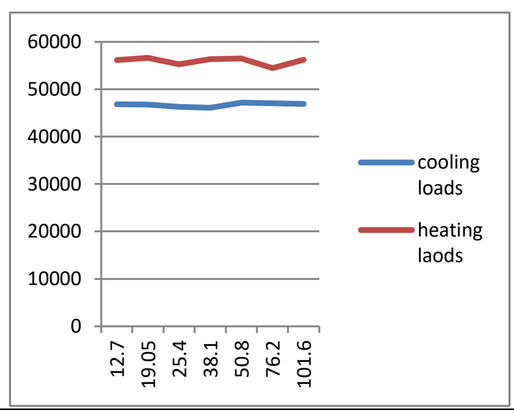


wall insulation

	12.7	19.05	25.4	38.1	50.8	76.2	101.6
cooling loads	46818	46722	46296	46076	47122	47036	46898
heating loads	56120	56584	55220	56310	56439	54452	56204

Charts result



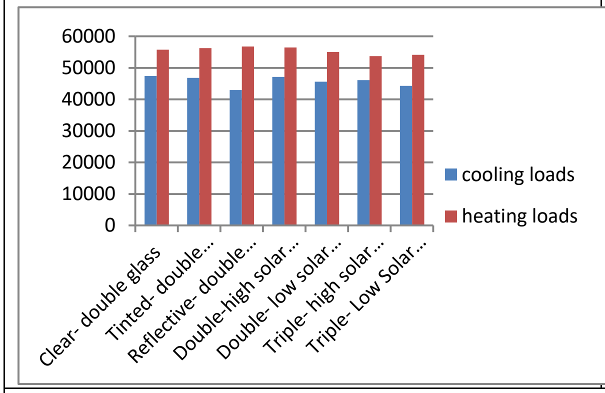


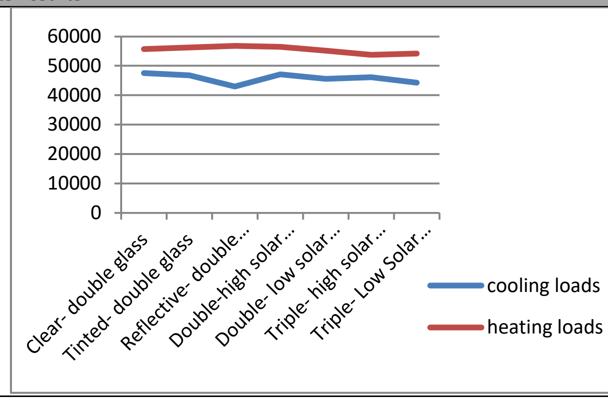
Glass type

	Clear-double glass	Tinted-double glass	Reflective-double glass	Double-high solar gain – low E Glass	Double- low solar gain-low E Glass	Triple-high solar Gain-low E	Triple-Low Solar Gain Low E Glass

						Glass	
cooling loads	47497	46803	43002	47122	45632	46128	44314
heating loads	55739	56247	56746	56439	55113	53709	54177

Charts results





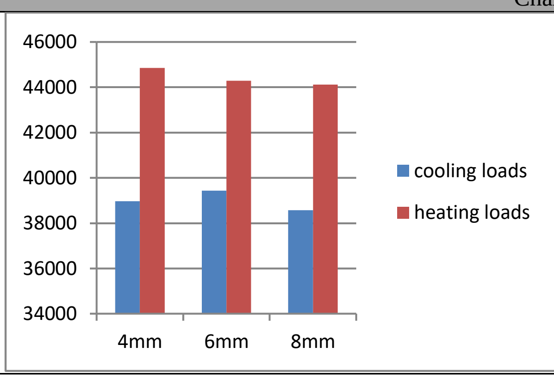
Stage 2

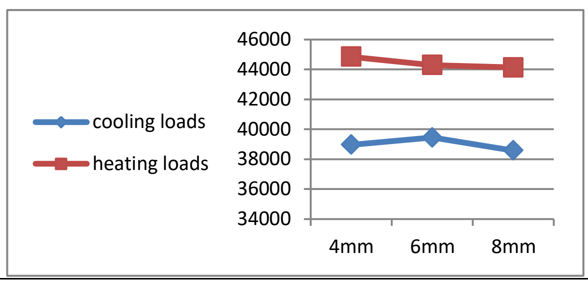
Cladding materials

Aluminum Composite panels

	4mm	6mm	8mm
cooling loads	38962	39436	38572
heating loads	44845	44289	44121

Charts results





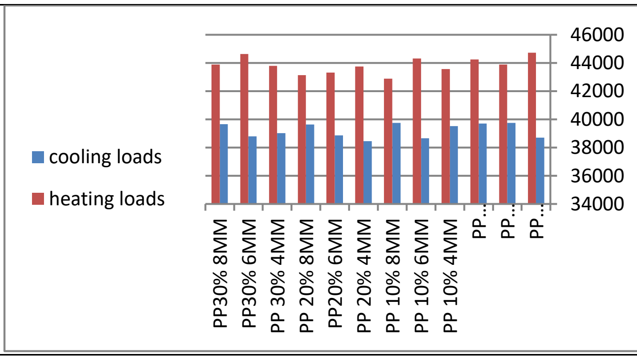
Wood composite panel

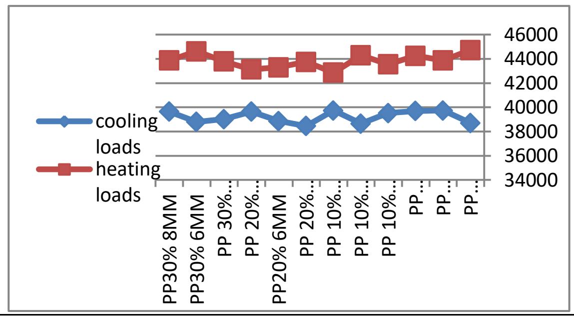
			cooling loads	Heating loads
	PP (Alucobondcore)	PP (Alucobondcore)4mm	38704	44732
		PP (Alucobondcore)6mm	39740	43870
		PP (Alucobondcore)8mm	39693	44254
	PP 10%	PP 10% 4MM	39532	43560
		PP 10% 6MM	38657	44303
		PP 10% 8MM	39745	42876
	PP20%	PP 20% 4MM	38451	43754
		PP20% 6MM	38872	43303
		PP 20% 8MM	39645	43131
	PP 30%	PP 30% 4MM	39024	43795
		PP30% 6MM	38803	44628
		PP30% 8MM	39647	43870
	HDPE(Alucobond core)	HDPE(Alucobond core) 4mm	39208	44352

		HDPE(Alucobond core)6mm	38730	43871
		HDPE(Alucobond core)8mm	39933	43898
	HDPE+PW10 %	HDPE+PW10% 4MM	39793	44359
		HDPE+PW10% 6MM	39847	44105
		HDPE+PW10% 8MM	38717	43332
	HDPE+PW20 %	HDPE+PW20% 4MM	39487	43087
		HDPE+PW20% 6MM	39803	43836
		HDPE+PW20% 8MM	39571	44267
	HDPE+PW30 %	HDPE+PW30% 4MM	39025	43168
		HDPE+PW30%6MM	39283	43709
		HDPE+PW30%8MM	38658	44188

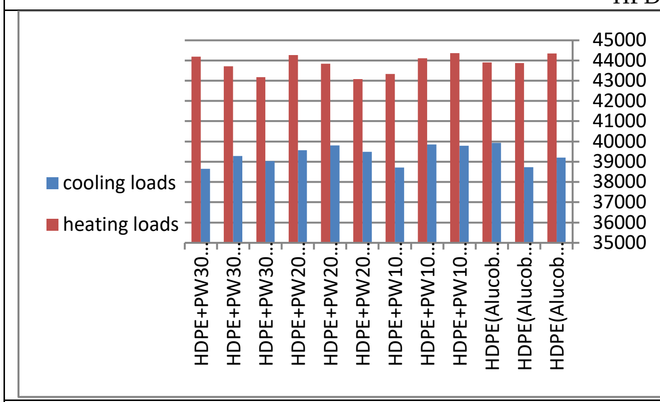
Charts results

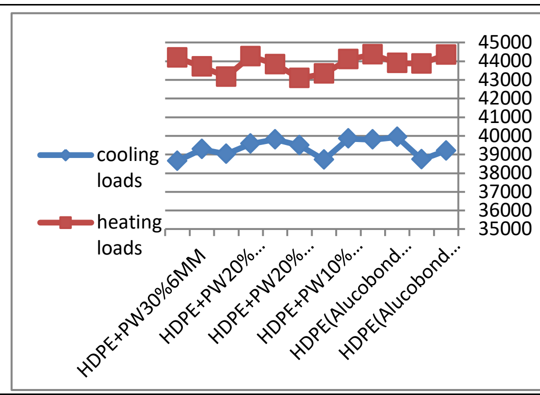
PP





HPDE



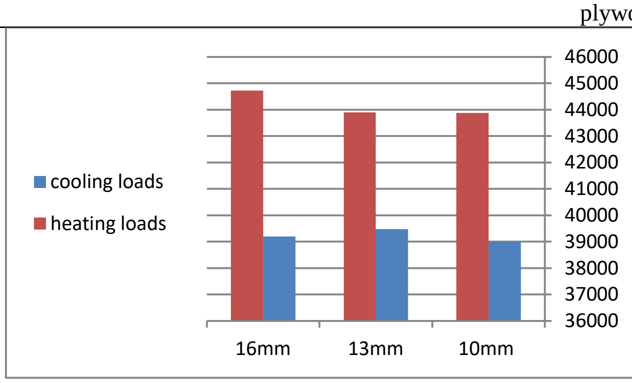


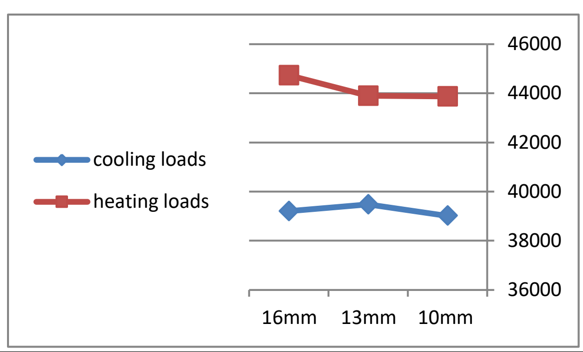
Wood materials

	plywood			Wood boards		
	10mm	13mm	16mm	15mm	19mm	25mm
cooling loads	39014	39474	39201	38784	38606	38874
heating loads	43869	43894	44728	44026	44814	44211

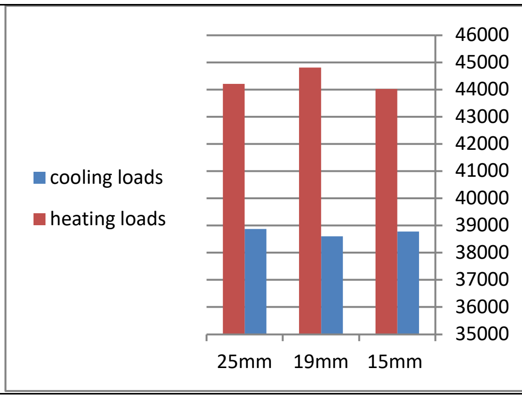
Charts results

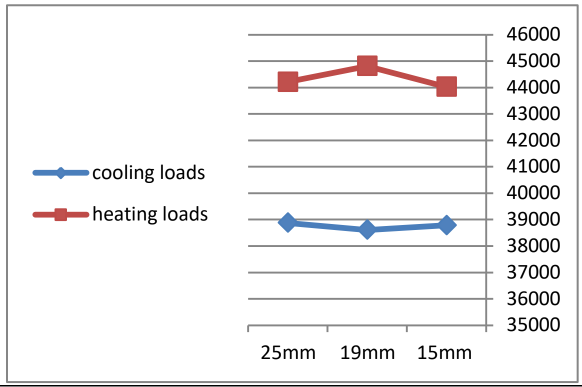
plywood





Wood boards

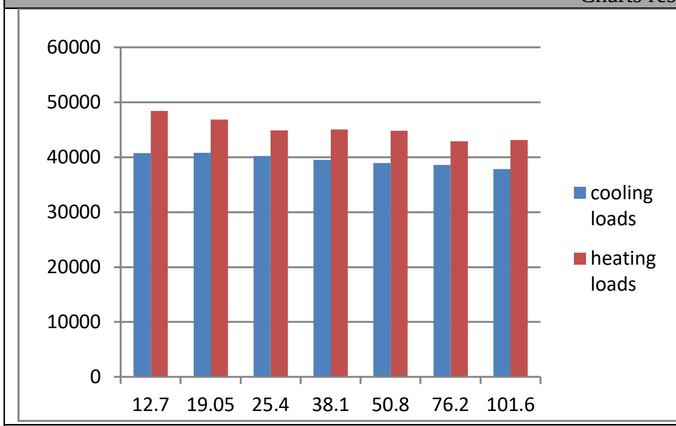


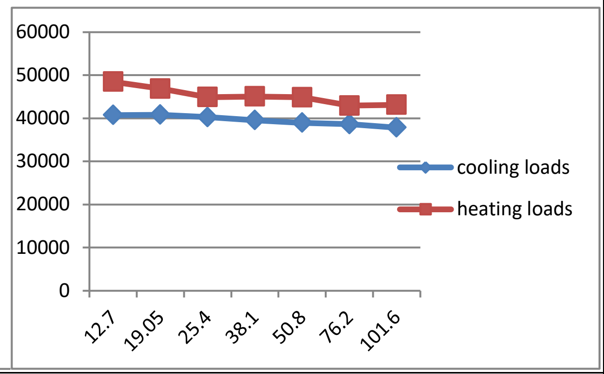


wall insulation

	12.7	19.05	25.4	38.1	50.8	76.2	101.6
cooling loads	40740	40816	40237	39529	38962	38604	37834
heating loads	48449	46867	44906	45046	44845	42920	43119

Charts results

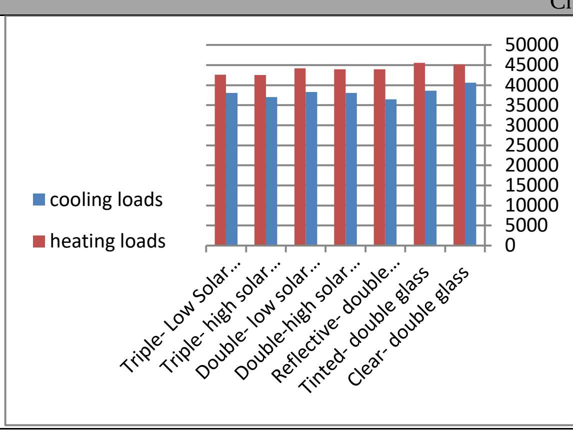


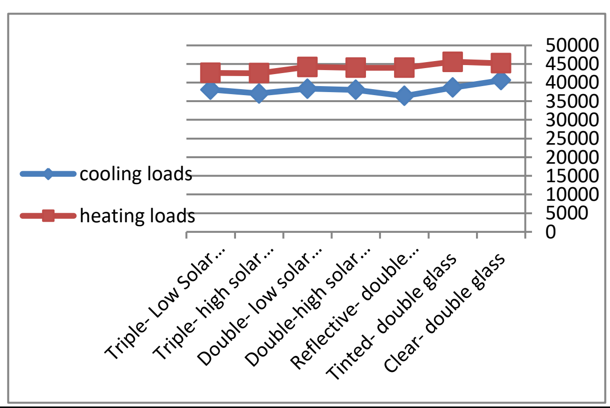


Glass type

	Clear- double glass	Tinted- double glass	Reflective- double glass	Double- high solar gain – low E Glass	Double- low solar gain- low E Glass	Triple- high solar Gain- low E Glass	Triple- Low Solar Gain Low E Glass
cooling loads	40636	38643	36432	38042	38327	37050	38100
heating loads	45186	45570	43955	43960	44176	42500	42582

Charts results



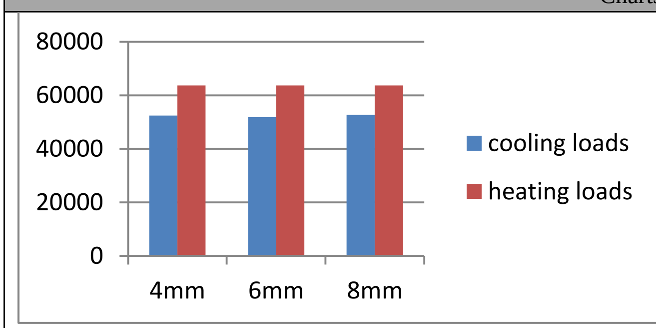


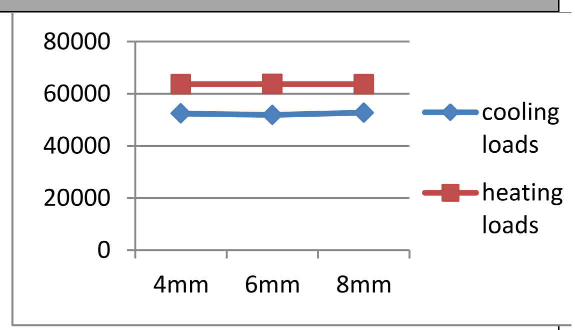
Case 4: LC WAKIKI			
Structured information			
Building location	Al-haras st.	Ground floor area	390 m^2,
Floors numbers	2	Main elevation orientation	West
Material of Cladding system	Alucobond	Building use:	Retail sales
Visual information		Textual information	

The study case 4 is a two stories building. The building type is a simple commercial center with total areas is 390 m^2, with Alucabond external cladding

Simulation results			
Stage 1			
Cladding materials			
Aluminum Composite panels			
	4mm	6mm	8mm
cooling loads	52404	51832	52671
heating loads	63627	63723	63626

Charts results



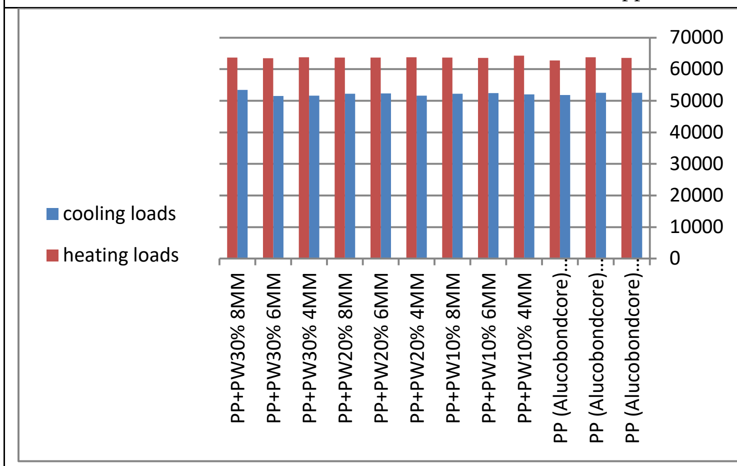


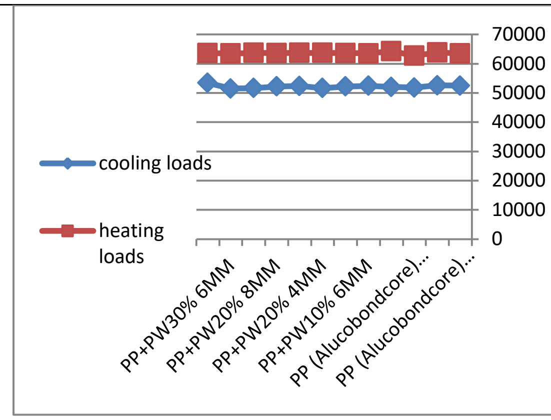
Wood composite panels

	`		COOLING LOADS	Heating loads
PP	PP (Alucobondcore)	PP (Alucobondcore) 4MM	52495	63537
		PP (Alucobondcore) 6MM	52576	63821
		PP (Alucobondcore) 8MM	51832	62801
	PP+PW10%	PP+PW10% 4MM	52070	64256
		PP+PW10% 6MM	52417	63559
		PP+PW10% 8MM	52229	63646
	PP+PW20%	PP+PW20% 4MM	51640	63739
		PP+PW20% 6MM	52353	63728
		PP+PW20% 8MM	52229	63646
	PP+PW30%	PP+PW30% 4MM	51640	63739
		PP+PW30% 6MM	51507	63511
		PP+PW30% 8MM	53437	63678

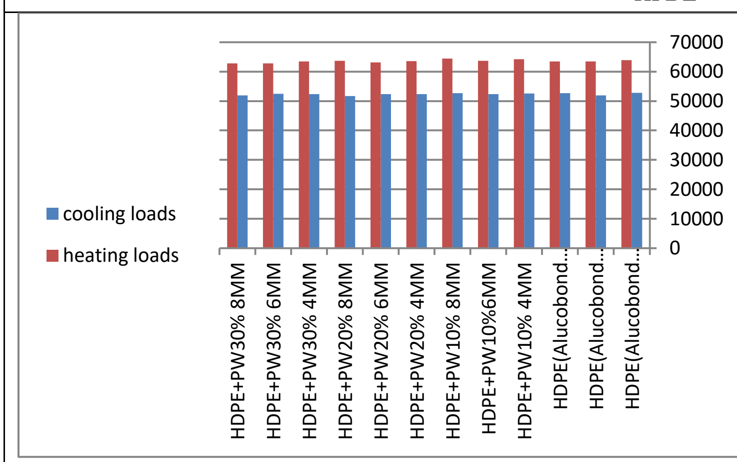
HPDE	HDPE(Alucobond core)	HDPE(Alucobond core) 4MM	52777	63884
		HDPE(Alucobond core) 6MM	51924	63385
		HDPE(Alucobond core) 8MM	52696	63448
	HDPE+PW10%	HDPE+PW10% 4MM	52603	64207
		HDPE+PW10%6MM	52341	63667
		HDPE+PW10% 8MM	52680	64387
	HDPE+PW20%	HDPE+PW20% 4MM	52360	63591
		HDPE+PW20% 6MM	52384	63144
		HDPE+PW20% 8MM	51732	63688
	HDPE+PW30%	HDPE+PW30% 4MM	52364	63387
		HDPE+PW30% 6MM	52408	62787
		HDPE+PW30% 8MM	51943	62837

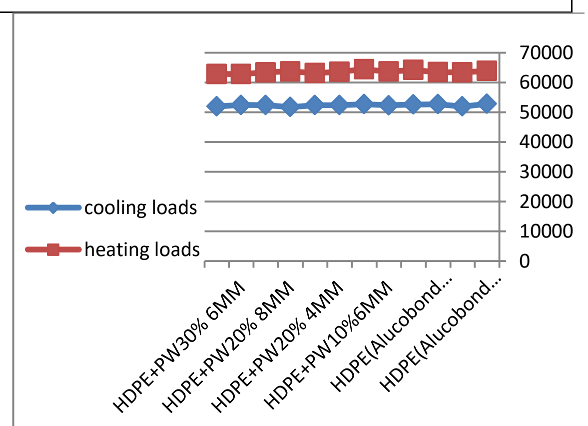
pp





HPDE



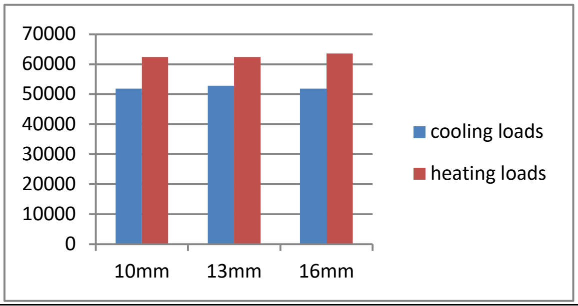


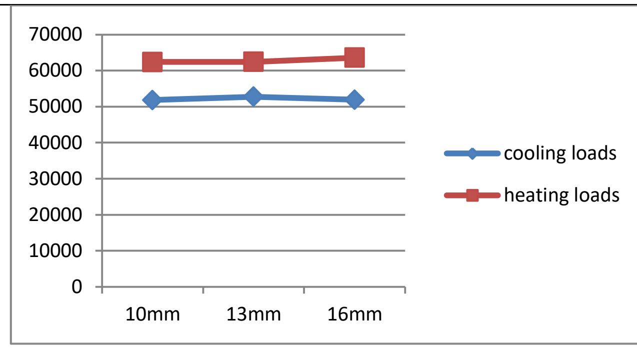
WOOD MATERIAL

	plywood			WOOD BOARDS		
	10mm	13mm	16mm	15mm	19mm	25mm
cooling loads	51808	52779	51904	51914	52277	53701
heating loads	62415	62430	63598	62521	63517	64167

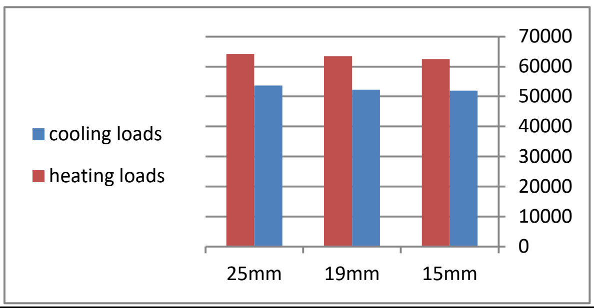
Charts results

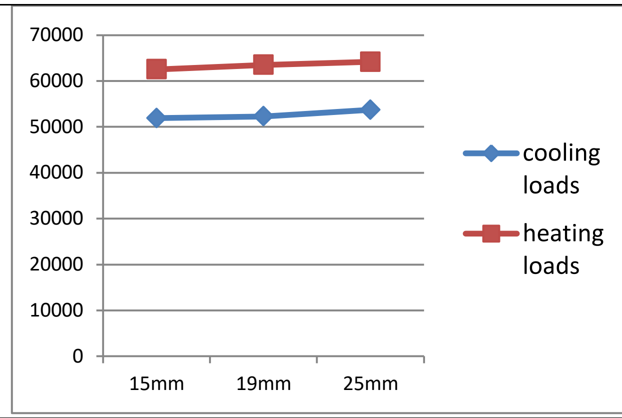
plywood





Wood boards

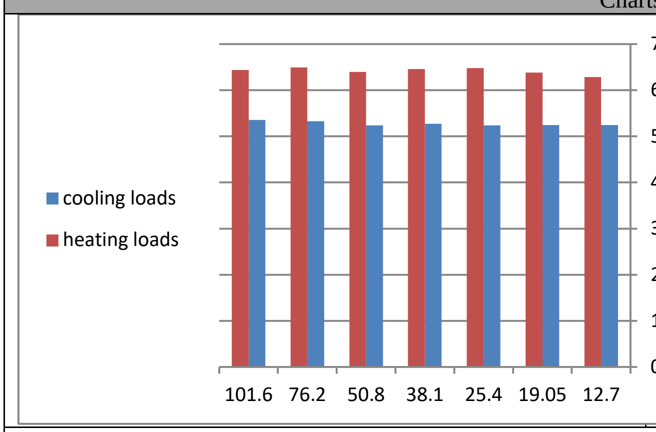


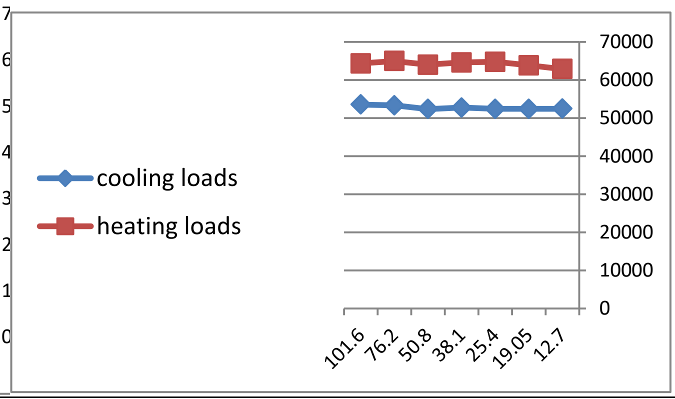


Wall insulation thickness

	12.7	19.05	25.4	38.1	50.8	76.2	101.6
cooling loads	52425	52410	52389	52730	52351	53299	53517
heating loads	62853	63836	64746	64561	63967	64932	64337

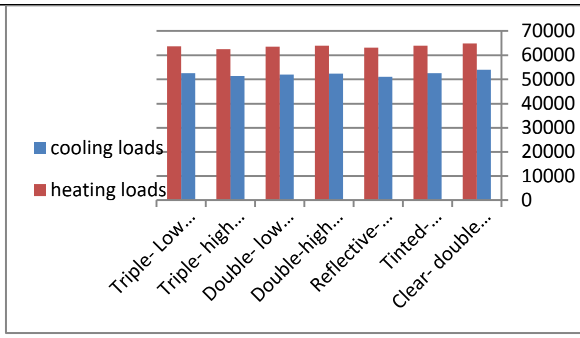
Charts results

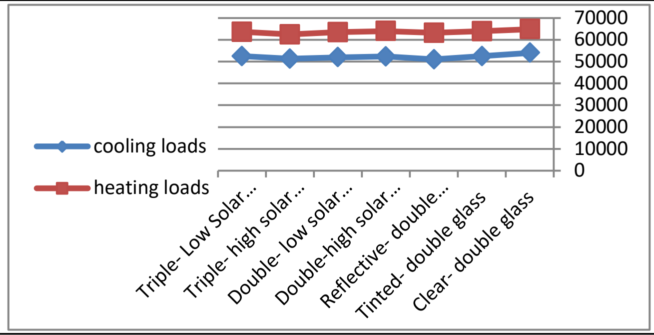




Glass types

	Clear- double glass	Tinted- double glass	Reflective- double glass	Double- high solar gain – low E Glass	Double- low solar gain- low E Glass	Triple- high solar Gain- low E Glass	Triple- Low Solar Gain Low E Glass
cooling loads	54036	52500	51033	52351	51982	51316	52480
heating loads	64900	63897	63195	63967	63506	62439	63653





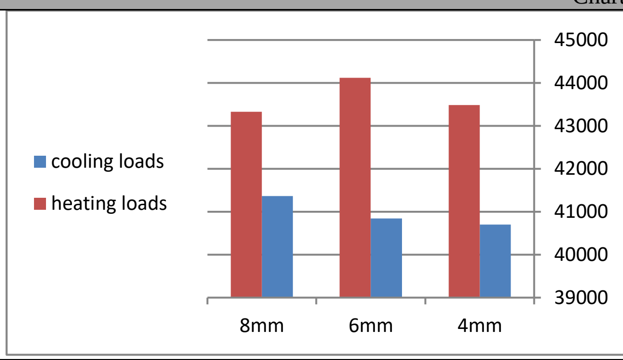
Stage 2

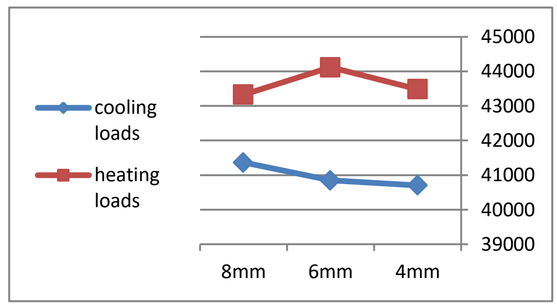
Cladding materials

Aluminum Composite panels

	4mm	6mm	8mm
cooling loads	40705	40847	41366
heating loads	43483	44115	43326

Charts result





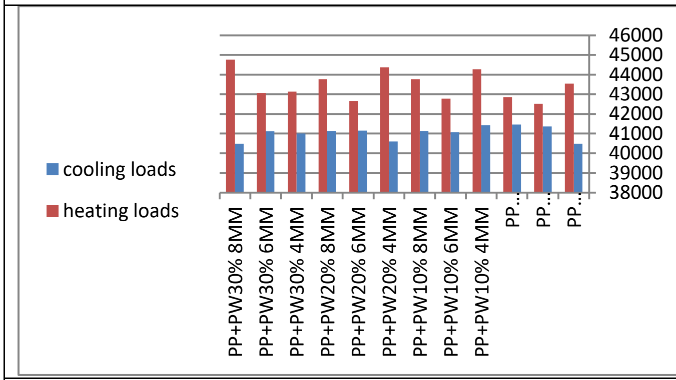
Wood composite panels

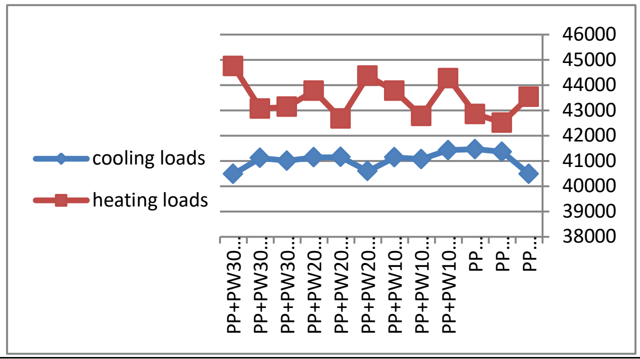
			Cooling loads	Heating loads
	PP (Alucobondcore)	PP (Alucobondcore) 4MM	40480	43539
		PP (Alucobondcore) 6MM	41359	42512
		PP (Alucobondcore) 8MM	41459	42852
	PP+PW10%	PP+PW10% 4MM	41423	44268
		PP+PW10% 6MM	41068	42770
		PP+PW10% 8MM	41141	43774
	PP+PW20%	PP+PW20% 4MM	40594	44366
		PP+PW20% 6MM	41152	42669
		PP+PW20% 8MM	41141	43774
	PP+PW30%	PP+PW30% 4MM	41006	43138
		PP+PW30% 6MM	41110	43067
		PP+PW30% 8MM	40480	44751
	HDPE(Alucobond core)	HDPE(Alucobond core) 4MM	40572	44462
		HDPE(Alucobond core) 6MM	41412	44881
		HDPE(Alucobond core) 8MM	40456	44285
	HDPE+PW10%	HDPE+PW10% 4MM	41134	43080
		HDPE+PW10%6MM	40753	44284
		HDPE+PW10% 8MM	41111	43295
	HDPE+PW20%	HDPE+PW20% 4MM	41390	43012
		HDPE+PW20% 6MM	40289	44075
		HDPE+PW20% 8MM	41109	44278
	HDPE+PW30%	HDPE+PW30% 4MM	40444	44192
		HDPE+PW30% 6MM	40642	43818

		HDPE+PW30% 8MM	41151	43290

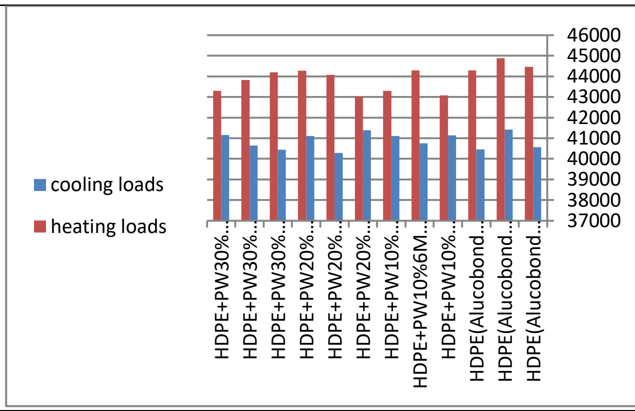
Charts reslts

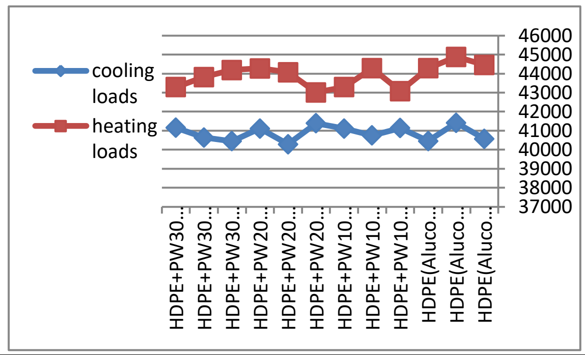
PP





HPDE



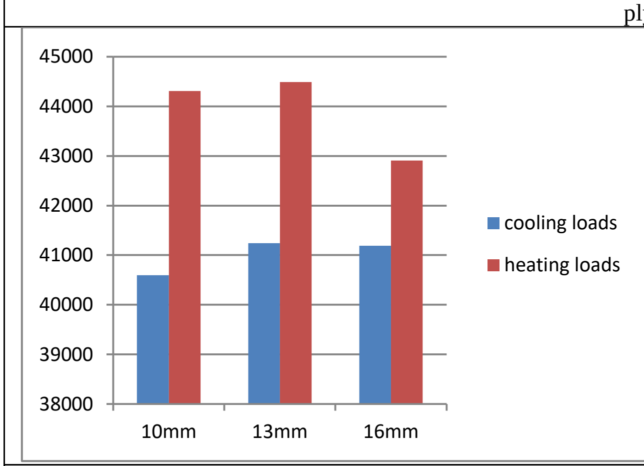


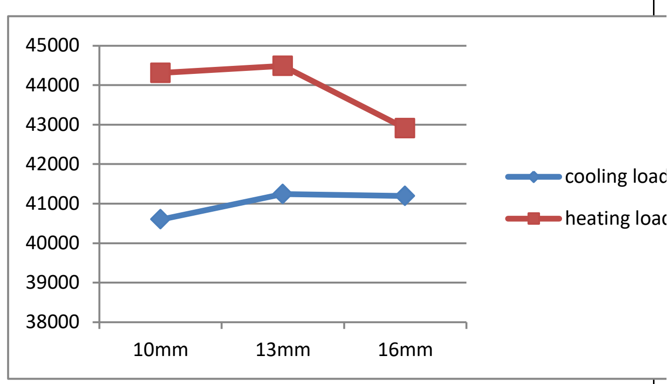
Wood materials

	plywood			Wood boards		
	10mm	13mm	16mm	15mm	19mm	25mm
cooling loads	40597	41241	41191	41114	41445	41162
heating loads	44309	44487	42907	43531	43331	43311

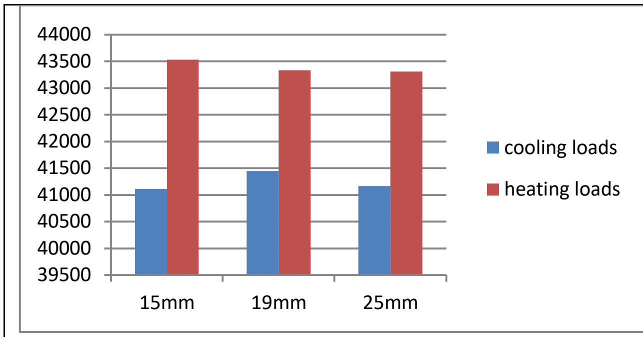
Charts results

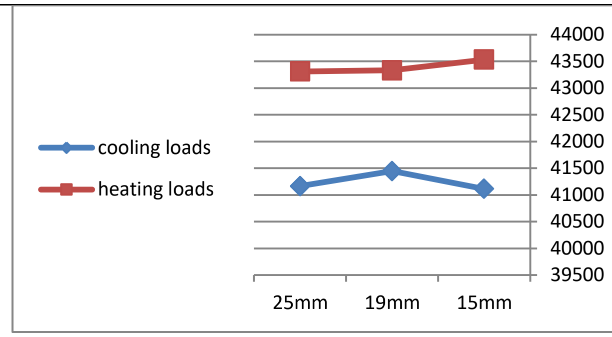
plywood





Wood boards

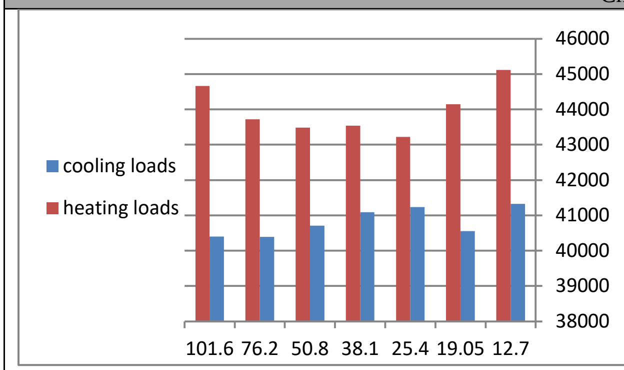


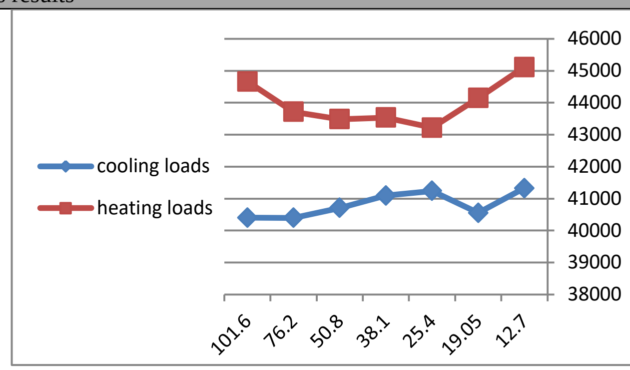


Wall insulation thickness

	12.7	19.05	25.4	38.1	50.8	76.2	101.6
cooling loads	41324	40552	41237	41093	40705	40394	40399
heating loads	45114	44147	43218	43536	43483	43717	44661

Charts results

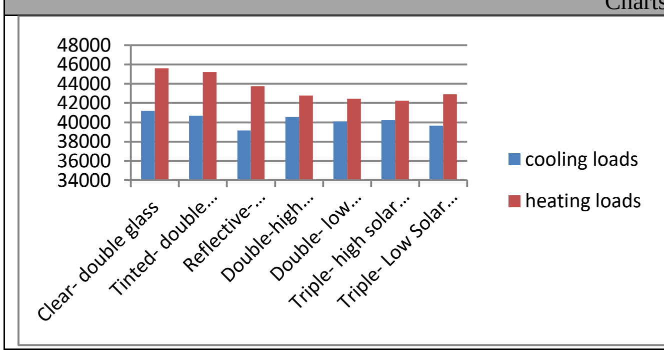


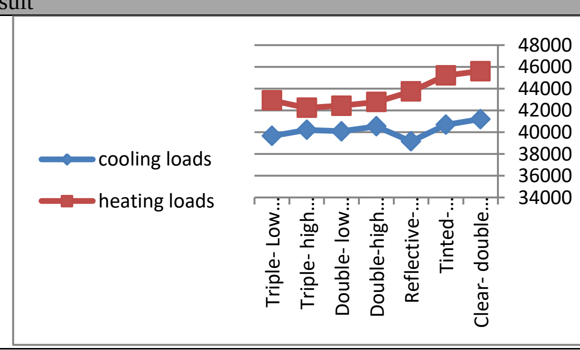


Glass type

	Clear-double glass	Tinted-double glass	Reflective-double glass	Double-high solar gain – low E Glass	Double- low solar gain- low E Glass	Triple-high solar Gain-low E Glass	Triple- Low Solar Gain Low E Glass
cooling loads	41199	40689	39162	40545	40086	40218	39653
heating loads	45602	45213	43737	42775	42435	42239	42923

Charts result





Case 5: Alsalam center			
Structured information			
Building location	Alsalam st.	Ground floor area	700 m^2
Floors numbers	2	Main elevation orientation	East
Material of Cladding system	Alucobond	Building use:	Retail sales

Visual information	Textual information
	The study case 5 is a three stories building. The building type is a simple commercial center with total areas is 700 m^2, with Alucabond external cladding

Simulation results

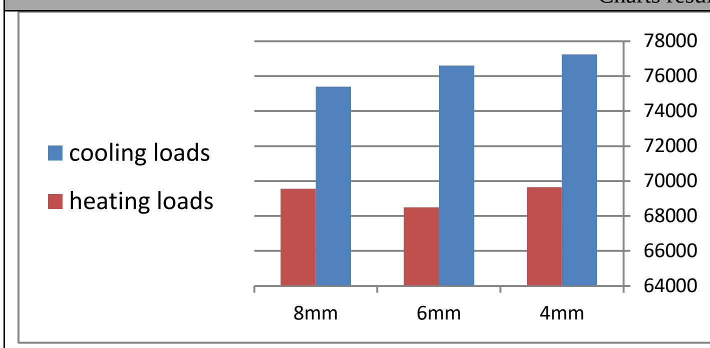
Stage 1

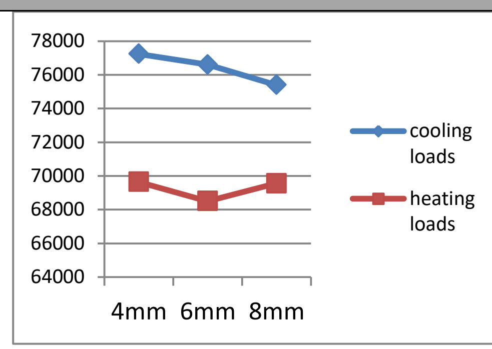
Cladding materials

Aluminum Composite panels

	4mm	6mm	8mm
cooling loads	77235	76607	75396
heating loads	69644	68505	69562

Charts results





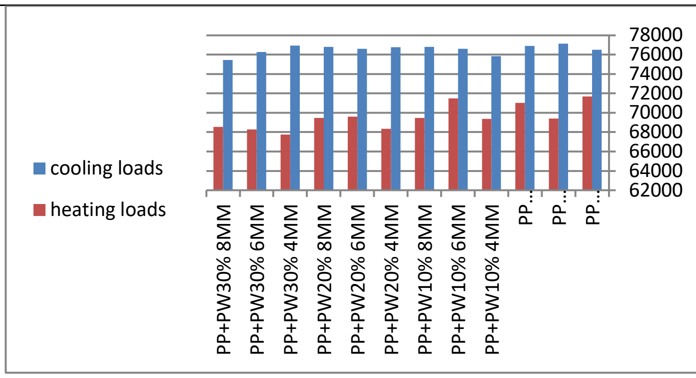
Wood composite panels

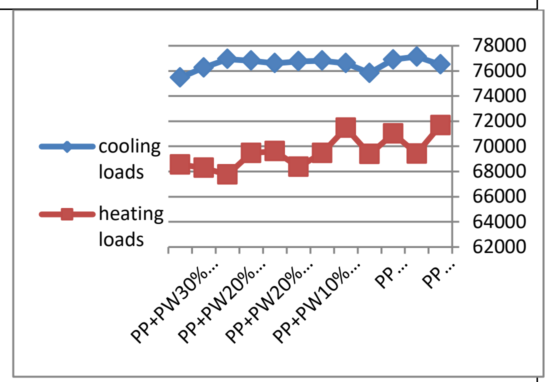
			Cooling loads	Heating loads
	PP (Alucobondcore)	PP (Alucobondcore) 4MM	76504	71668
		PP (Alucobondcore) 6MM	77134	69418
		PP (Alucobondcore) 8MM	76897	71009
	PP+PW10%	PP+PW10% 4MM	75835	69377
		PP+PW10% 6MM	76607	71468
		PP+PW10% 8MM	76809	69472
	PP+PW20%	PP+PW20% 4MM	76763	68363
		PP+PW20% 6MM	76600	69608
		PP+PW20% 8MM	76809	69472
	PP+PW30%	PP+PW30% 4MM	76931	67748
		PP+PW30% 6MM	76263	68284
		PP+PW30% 8MM	75457	68556
	HDPE(Alucobond core	HDPE(Alucobond core) 4MM	77083	70581
		HDPE(Alucobond core) 6MM	75592	69790
		HDPE(Alucobond core) 8MM	78014	67949
	HDPE+PW10%	HDPE+PW10% 4MM	77301	68602

		HDPE+PW10%6MM	76937	68214
		HDPE+PW10% 8MM	76597	69670
	HDPE+PW20%	HDPE+PW20% 4MM	76115	68034
		HDPE+PW20%6MM	76190	68716
		HDPE+PW20% 8MM	76719	69684
	HDPE+PW30%	HDPE+PW30% 4MM	75547	67487
		HDPE+PW30% 6MM	76419	68974
		HDPE+PW30% 8MM	76231	68261

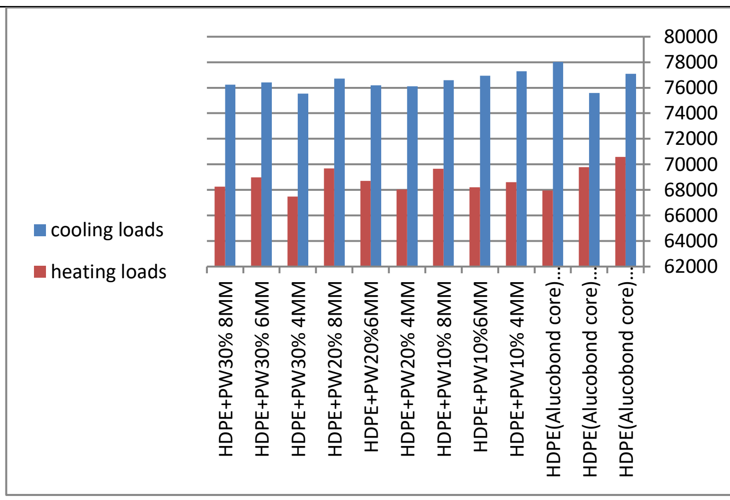
Charts results

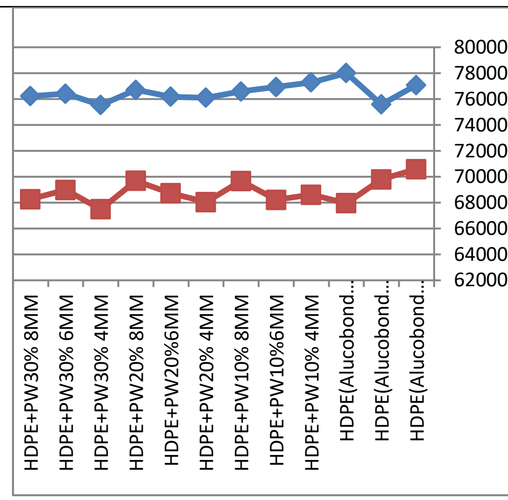
PPP





HPDE



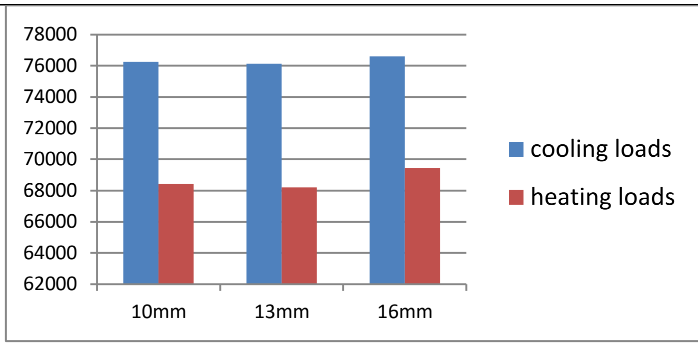


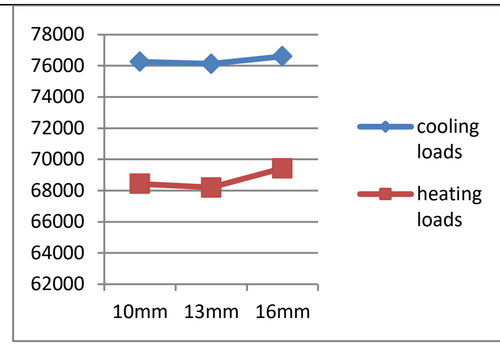
Wood materials

	plywood			Wood boards		
	10mm	13mm	16mm	15mm	19mm	25mm
cooling loads	76259	76126	76603	76894	75991	76842
heating loads	68436	68200	69427	68964	68166	69322

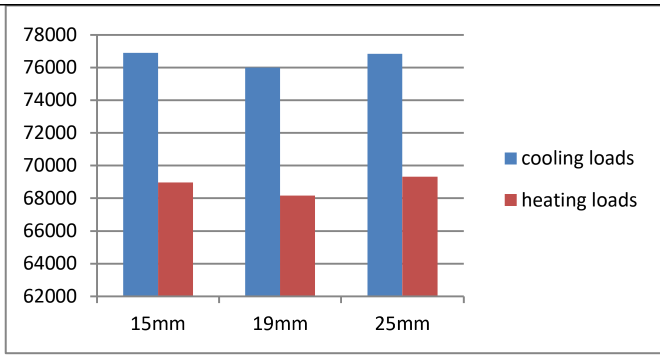
Charts results

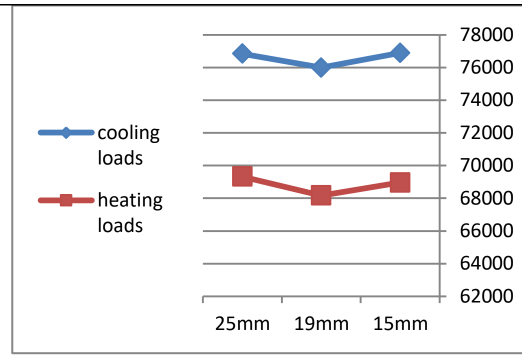
plywood





Wood boards

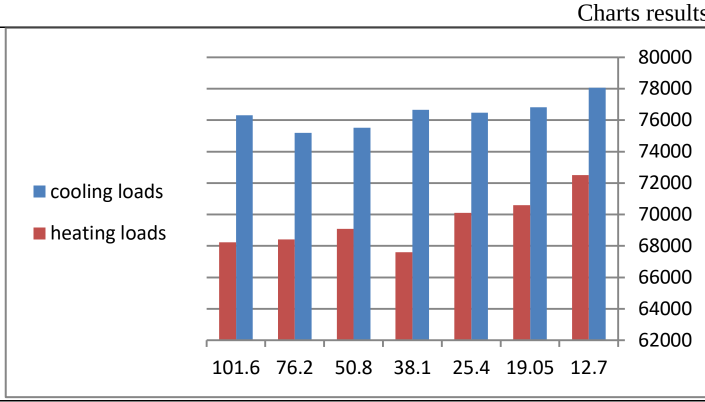


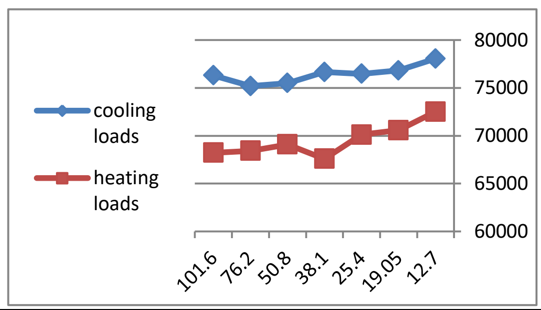


Wall insulation thickness

	12.7	19.05	25.4	38.1	50.8	76.2	101.6
cooling loads	78054	76821	76476	76654	75507	75194	76314
heating loads	72512	70587	70110	67593	69090	68423	68235

Charts results

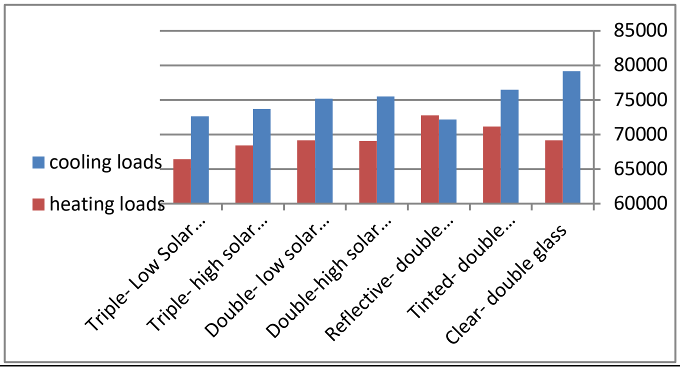


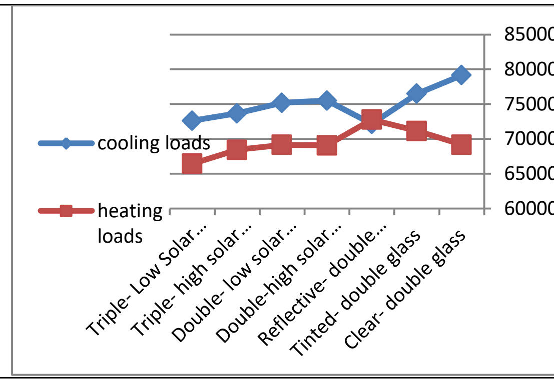


Glass types

	Clear- double glass	Tinted- double glass	Reflective- double glass	Double-high solar gain – low E Glass	Double- low solar gain- low E Glass	Triple- high solar Gain- low E Glass	Triple - Low Solar Gain Low E Glass
cooling loads	79157	76490	72163	75507	75188	73679	72626
heating loads	69180	71149	72782	69090	69146	68430	66443

Charts results





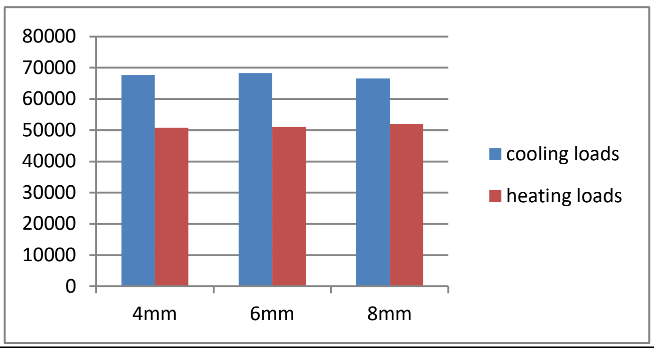
Stage 2

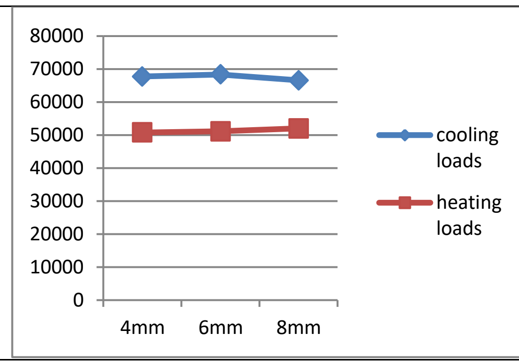
Cladding materials

Aluminum Composite panels

	4mm	6mm	8mm
cooling loads	67697	68341	66529
heating loads	50778	51099	51992

Charts results





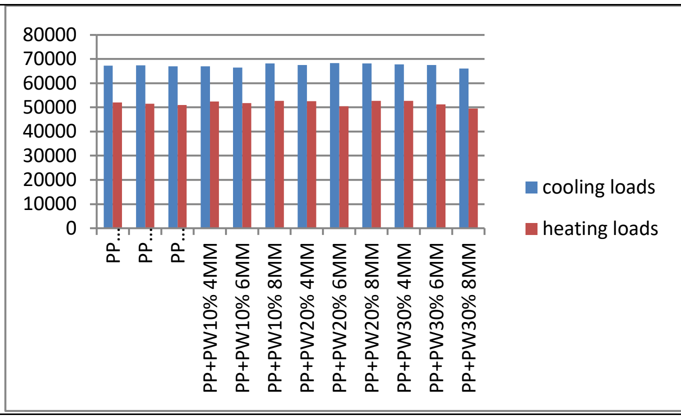
Wood composite panels

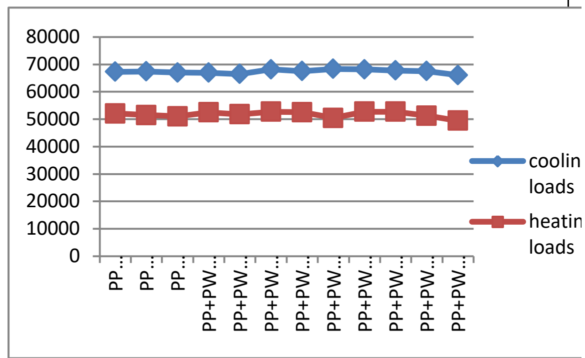
			Heating loads	Cooling loads
	PP (Alucobondcore)	PP (Alucobondcore) 4MM	67282	52075
		PP (Alucobondcore) 6MM	67414	51495
		PP (Alucobondcore) 8MM	66989	51039
	PP+PW10%	PP+PW10% 4MM	66981	52479
		PP+PW10% 6MM	66495	51772
		PP+PW10% 8MM	68180	52721
	PP+PW20%	PP+PW20% 4MM	67544	52554
		PP+PW20% 6MM	68333	50481
		PP+PW20% 8MM	68180	52721
	PP+PW30%	PP+PW30% 4MM	67773	52717
		PP+PW30% 6MM	67568	51250
		PP+PW30% 8MM	66076	49464
	HDPE(Alucobond core)	HDPE(Alucobond core) 4MM	67994	51992
		HDPE(Alucobond core) 6MM	67681	53080
		HDPE(Alucobond core) 8MM	67414	53029
	HDPE+PW10%	HDPE+PW10% 4MM	67651	50581
		HDPE+PW10%6MM	67622	50647
		HDPE+PW10% 8MM	67692	53208
	HDPE+PW20%	HDPE+PW20% 4MM	67507	51178
		HDPE+PW20% 6MM	67578	52719
		HDPE+PW20% 8MM	66385	51404
	HDPE+PW30%	HDPE+PW30% 4MM	66837	50618
		HDPE+PW30% 6MM	66623	49396

		HDPE+PW30% 8MM	66925	51313

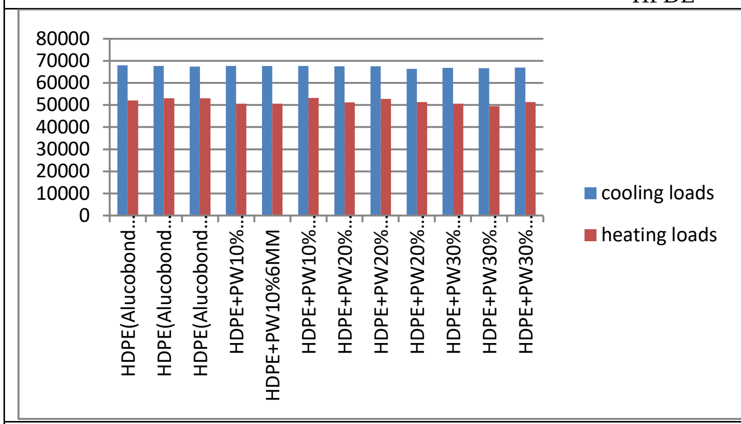
Charts results

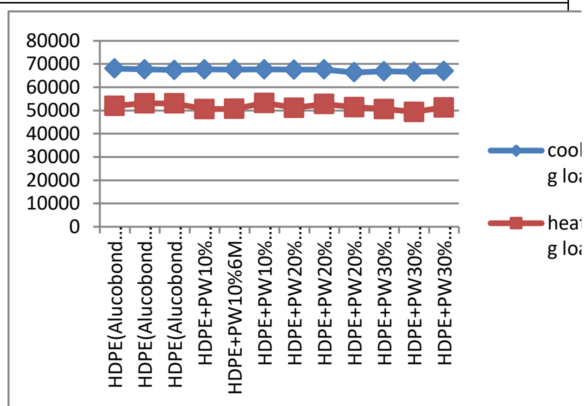
PP





HPDE



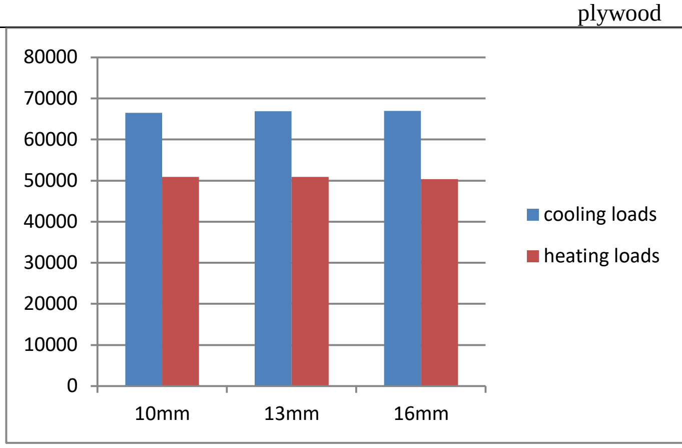


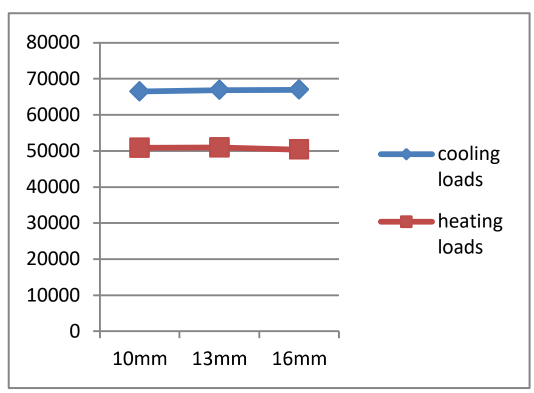
Wood Materials

	plywood			Wood boards		
	10mm	13mm	16mm	15mm	19mm	25mm
cooling loads	66475	66869	66950	67910	66289	67333
heating loads	50868	50919	50339	50570	51594	52093

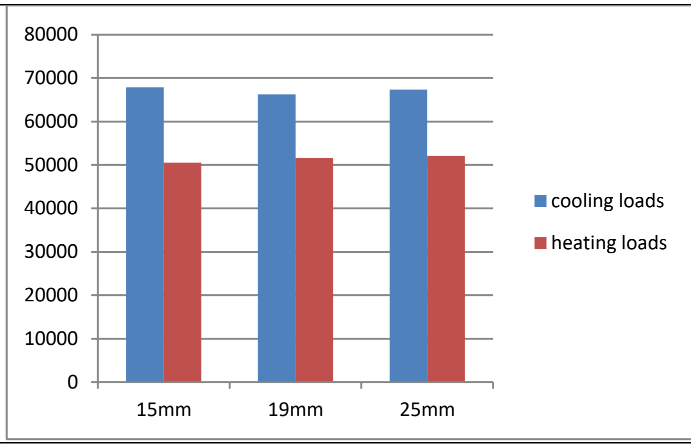
Charts results

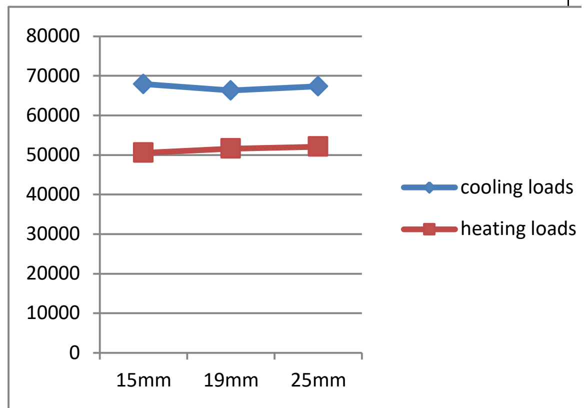
plywood





Wood boards

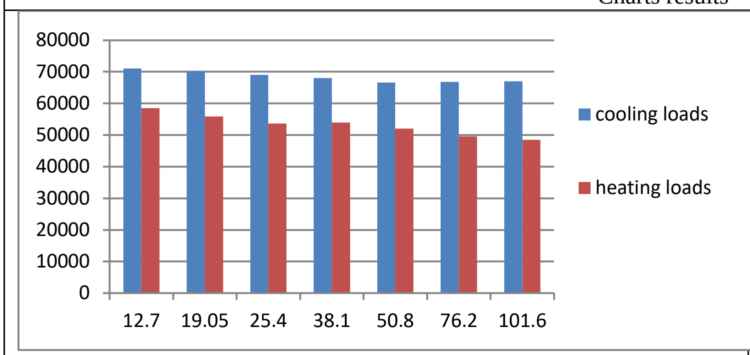


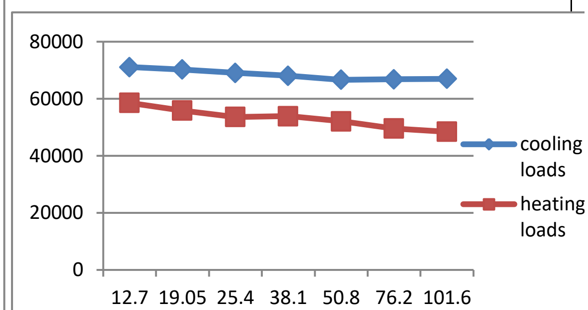


Wall insulation

	12.7	19.05	25.4	38.1	50.8	76.2	101.6
cooling loads	71080	70267	69067	68052	66631	66802	66991
heating loads	58541	55890	53621	53918	52074	49576	48451

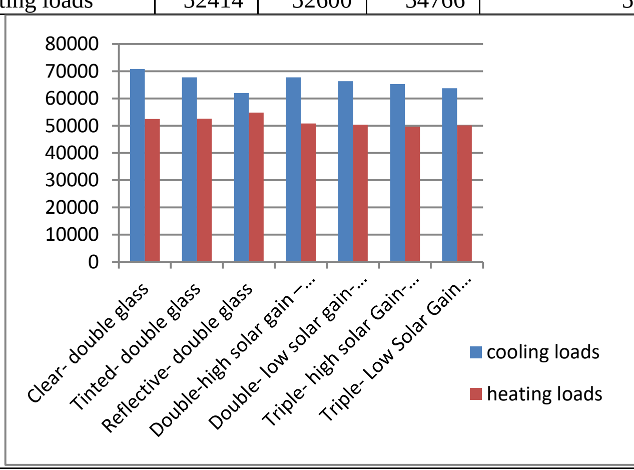
Charts results

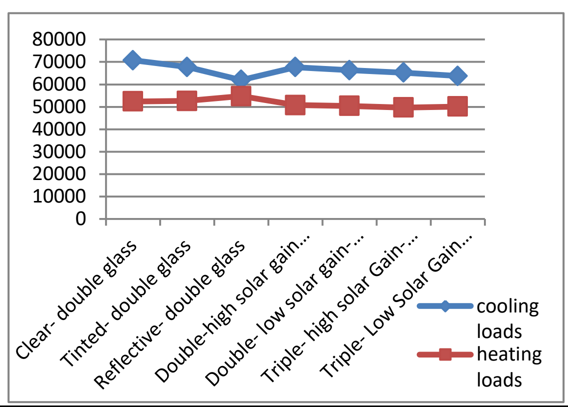




Glass types

	Clear-double glass	Tinted-double glass	Reflective-double glass	Double-high solar gain – low E Glass	Double- low solar gain- low E Glass	Triple- high solar Gain- low E Glass	Triple- Low Solar Gain Low E Glass
cooling loads	70733	67748	61958	67697	66325	65273	63729
heating loads	52414	52600	54766	50778	50386	49681	50137



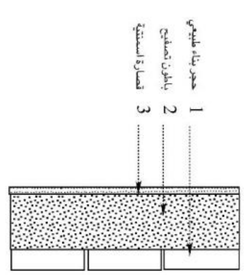


Appendix B

Thermal Properties for Construction Materials

Source: Guidelines for Energy Efficient Building Design (Chapter 6) – Ministry of Local Government (Ministry of Local Government, 2004)

السماكة d (m)	الموصلية الحرارية k (W/m.K)	السعة الحرارية C (J/kg.K)	الكثافة ρ (kg/m³)	الطبقة	القطـــاع الإنشائي
0.07	1.70	1000	2250	1	
0.20	1.75	1000	2300	2	
0.03	1.20	1000	2000	3	
2.63	منطقة محمية		الانتقالية الحرارية (U) W/m.K		
2.77	منطقة معتدلة التعرض				
3.03	منطقة شديدة التعرض				
7.97	التخلف الزمني (ϕ) ساعة				
0.26	معامل النقص (μ)				

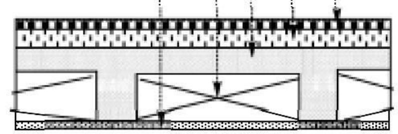


جدول رقم: (1-5/6)
مقطع جدار حجري غير معزول

الطبقة	الكثافة ρ (kg/m³)	السعة الحرارية C (J/kg.K)	الموصلية الحرارية k (W/m.K)	السماكة d (m)
1	2300	1000	1.10	0.02
2	2300	1000	1.75	0.08
3	2500	1000	1.75	0.07
4	1620	1000	1.10	0.18
5	2000	1000	1.20	0.02

الانتقالية الحرارية (U) W/m.K	منطقة محمية	2.20
	منطقة معتدلة التعرض	2.36
	منطقة شديدة التعرض	2.47
التخلف الزمني (ϕ) ساعة		10.50
معامل النقص (μ)		0.15

القطـــاع الإنشائي



جدول رقم: (13-5/6)
مقطع سقف باطوني مسلح ذو أعصاب غير معزول

TOTAL THICKNESS PANEL (mm)	TOTAL WEIGHT PANEL (kg/m^2)	
	Thickness of lacquered sheet 0,5 (mm)	Thickness of lacquered sheet 0,3 (mm)
3	6,10	5,70
4	7,80	7,40
5	9,50	-
6	11,20	-

ALUMINIUM ALLOY	VALUE	NORM
Front side	5005	UNE EN 573-3
Reverse side	3005 / 3105*	UNE EN 573-3

PANEL DIMENSIONAL SPECIFICATIONS	UNIT	VALUE
Width (min. / max.)	mm	800 / 2.000**
Length (min. / max.)	mm	2.000 / 6.000**
Thickness tolerance	mm	- 0,15 / + 0,20
Width tolerance	mm	± 2
Length tolerance	mm	- 0 / + 15
Diagonals tolerance	mm	± 3
Width tolerance of the protective film	mm	0; -5

TECNICAL SPECIFICATIONS	UNIT	VALUE	NORM
Peeling	N/mm	≥ 9,80	ASTM D903-98 (2004)
Accoustic insulation Rw (C;Ctr)	dB	29 (-1; -3)	ISO 717-1
Thermal transmission (U)	W/m^2K	5,62	UNE-EN ISO 12567-1
Temperature utilization	ºC	-50 / +80	

FR CORE SPECIFICATION	UNIT	VALUE	NORM
Densidad	g/cm^3	1,70 ± 0,10	
Fire reaction		B - S1, d0	UNE-EN-13501-1:2007

ALUMINIUM TECNICAL SPECIFICATIONS	UNIT	VALUE	NORM
Alloy		5005	UNE EN 573-3
Elasticity module (E)	N/mm^2	70.000	EN 485-2
Proof stress ($R_{p\ 02}$)	N/mm^2	≥ 80	
Tensile strength (R_m)	N/mm^2	$125 \leq R_m \leq 240$	
Elongation (A_{50})	%	≥ 4	
Density (ρ)	kg/m^3	2.700	
Thermal expansion (α)	mm/m (100º)	2,36	

Figure 0.1Panel Physical specifications(“Technical documents archivos,” 2021)

Product details

Product information

- Seal cut edges with a suitable treatment when used externally

Features and benefits

Tongue and groove cladding can be fixed in either a vertical or horizontal position. When installing vertically start the project in one corner of the room with the groove side of the board facing the adjoining wall. Cladding can be adhered to a smooth surface or stud work or fixed to timber battens. Cladding can be face fixed or secret fixed by nailing through the base of the tongue at an angle into the stud, wall or batten. When fitting the last board this may need to be trimmed to fit by removing a section from the tongue side of the cladding. If a tight fit the under section of the groove of the cladding can be cut away so the board fits neatly on the tongue of the previous board. This must be glued or face fixed. When fitting cladding in a horizontal position begin with the lowest cladding board at the bottom of the project with the groove nearest the ground. this can also be fixed onto the surface by nailing at an angle through the base of the tongue. Work upwards and complete the project with the last board being cut to fit if necessary.

- Precision finished
- Preservative treated
- Slow grown & kiln dried to make it more stable & easier to work with
- Made from responsibly sourced, Forest Friendly timber
- Precision finished

Health and safety

Please note that this item has additional safety or regulatory datasheets available. The product may have possible health and safety hazards covered in these documents. Refer to the container for full information and always follow the instructions.

Specifications

Pack quantity	1
Location	External
Product width	119mm
Product weight	3919g
Product thickness	14.5mm
Product length	3000mm
Material	Spruce
Colour group	Natural
Surface finish	Planed
Product code	5397007203080

Figure 0.2 An example of wood panels from the manufacturer("Planed Spruce Tongue & groove Cladding (L)3m (W)119mm (T)14.5mm | DIY at B&Q," 2021)

Product details

Product information

- For garden projects or non structural internal work, such as carcassing, boxing in, battening and framing, this kiln dried treated sawn timber is treated to help prolong it's life and protect against rot or insect attack

Features and benefits

- Suitable for garden projects such as raised beds, composters, pergolas and general fencing or non structural internal work, such as carcassing, boxing in, battening and framing, this kiln dried treated sawn timber from Metsäwood is treated to help prolong it's life and protect against rot or insect attack
- Slow grown & kiln dried to make it more stable & easier to work with
- Pressure treated to protect against fungal & insect attack for longer life
- Seal cut edges with a suitable treatment when used externally

Health and safety

Please note that this item has additional safety or regulatory datasheets available. The product may have possible health and safety hazards covered in these documents. Refer to the container for full information and always follow the instructions.

Specifications

Colour group	Natural
Location	External
Material	Whitewood spruce
Pack quantity	6
Product length	2400mm
Product thickness	25mm
Product weight	9000g
Product width	50mm
Range	Treated
Treatment	Pressure treated
Timber type	Softwood
Product code	5022652847241

Figure 0.3 An example of wood panels from the manufacturer("Planed Spruce Tongue & groove Cladding (L)3m (W)119mm (T)14.5mm | DIY at B&Q," 2021)