إقــــرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان:

Study on thermal performance of urban courtyards in the housing projects of the Gaza Strip

دراسة حول تأثير الأفنية الحضرية على الأداء الحراري للمباني في مشاريع الإسكان بقطاع غزة

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نتيجة الحكم على أطروحة ماجستير

بناءً على موافقة شئون البحث العلمي والدراسات العليا بالجامعة الإسلامية بغزة على تشكيل لجنة الحكم على أطروحة الباحثة/ **هاله سالم أحمد عليوة** لنيل درجة الماجستير في **كلية *الهندسة*** قسم الهندسة المعمارية وموضوعها:

دراسة حول تأثير الأفنية الحضرية على الأداء الحراري للمباني في مشاريع الإسكان بقطاع غزة

Study on thermal performance of urban courtyards in the housing projects of the Gaza Strip

وبعد المناقشة العلنية التي تمت اليوم السبت 25 ربيع الآخر 1436هـ، الموافق 2015/02/14م الساعة الواحدة ظهراً بمبنى طيبة، اجتمعت لجنة الحكم على الأطروحة والمكونة من:

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وبعد المداولة أوصت اللجنة بمنح الباحثة درجة الماجستير في **كلية *الهندسة*** / قسم الهندسة المعمارية.

واللجنة إذ تمنحها هذه الدرجة فإنها توصيها بتقوى الله ولزوم طاعته وأن تسخر علمها في خدمة دينها ووطنها.

والله ولي التوفيق ،،،

مساعد نائب الرئيس للبحث العلمي و للدراسات العليا

أ.د. فؤاد علي العاجز

Dedication

I dedicate this work to my parents who have given me the drive and discipline to tackle any task with enthusiasm and determination. The work is dedicated also, to all my friends who supported along my study.

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In the first place… My deep thanks to Allah…...His generosity and bountifulness, the bulk of the credit help me to complete this work. I am grateful to my supervisor Dr. Ahmed Muhaisen for patiently listening and offering valuable advice throughout the research process. For his help and encouragement since I have started; for guidance and wisdom during this research; for keeping me focus while navigating through numerous obstacles. Another big thank goes to Department of Architectural Engineering in Islamic university...
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Abstract

There is a growing concern about the environmental issues in Gaza Strip. This concern comes as a result of overcrowded urban fabric of the city. Climate changes and global warming which affected the environment badly in the last few decades play a vital role in that issue. Climate is one of the most important factors that affect both urban planning and architectural design. Energy consumption of a building is strongly related to the climatic conditions surrounding it, which has a major effect on its thermal performance. Residential buildings are considered as the most architectural structures consuming energy in the world. Finding out solutions for this problem in housing projects, urban courtyards are considered one of the main solutions. This research sheds light on the thermal performance of urban courtyards in housing projects and their impact on thermal comfort. Also, it provides an overview of the most common urban courtyards of the housing projects in the Gaza Strip and their design, especially, with regard to their orientation and number of buildings, which form the courtyard.

Most of urban courtyards at housing projects in the Gaza Strip don't pay a special attention to the climatic factors; they need improvement and development to achieve the desired environmental performance. In this context, the research assumes that the shape and orientation of those courtyards as well as the orientation of its urban configuration significantly affects the thermal performance of the building, and thus the heating and cooling loads. Hence, the research seeks to evaluate the thermal performance of different courtyards shapes which already exist in different housing projects .The research is carried out using the analytical approach by using the computer programs ECOTECT and IES. It aims to expertise the best courtyard model which presents the high thermal performance in order to use it in housing projects in the Gaza Strip.

The research concludes that closed urban courtyards are better than the semi closed ones. Also, parameters of them play great roles in determining the amount of solar radiation received by the building’s surface. This affects the thermal performance inside buildings. It is found that the best proportions of the courtyard is 1:1.8 (W: L), and the ratio between the parameter and the height buildings is 8.94. The optimum building according to its thermal performance is the south-eastern to the courtyard, and the optimum floor is the third one (as the building consists of five floors).

Therefore, the research recommends applying urban courtyard design strategies, especially, with regard to orientation and elements of courtyard such as vegetation and shading in the first stage of the design process. Thermal simulation programs have to be used in order to evaluate the thermal performance of buildings. Urban courtyards proportions have to be determined with a full understanding to their relations with the surrounding buildings.

الملخص:

هناك قلق متزايد حول القضايا البيئية في قطاع غزة ، و يأتي هذا القلق كنتيجة طبيعية للاكتظاظ في النسيج الحضري للمدينة ،فظاهرة التغير المناخي و الاحتباس الحراري في العقود القليلة الماضية والتي تؤثر على البيئة بشكل سيئ ، تلعب دوراً هاما في هذه القضية . حيث يعتبر المناخ أحد أهم العناصر المؤثرة على كلاً من التخطيط الحضري و التصميم المعماري . هذا و يرتبط استهلاك الطاقة في المباني بالبيئة المحيطة ، و هو الأمر الذي من شأنه التأثير على الأداء الحراري بداخلها. كما تحتل و المباني السكنية النصيب الأكبر من استهلاك الطاقة في العالم .

تعتبر الأفنية الحضرية في مشاريع الإسكان أحد أهم الحلول لهذه المشكلة ، ويأتي هذا البحث ليسلط الضوء على الأداء الحراري لتلك الأفنية على المباني في مشاريع الإسكان وأثرها على الراحة الحرارية.

إن معظم الأفنية الحضرية في مشاريع الإسكان في قطاع غزة لا تولي اهتماما للعوامل المناخية. وهي تحتاج إلى التحسين والتطوير لتحقيق الأداء البيئي المطلوب.

ومن هذا السياق يلقي البحث نظرة عامة على الأفنية الحضرية الأكثر شيوعا من مشاريع الإسكان في قطاع غزة وتصميمها وخاصة فيما يتعلق بتوجيهها وعدد المباني التي تشكل الفناء. وفي هذا السياق، يفترض البحث أن شكل وتوجيه تلك الساحات وكذلك توجيه النسيج الحضري يؤثر و بشكل كبير على الأداء الحراري للمبنى، وبالتالي طاقتي التدفئة والتبريد. من هنا فإن البحث يسعى إلى تقييم الأداء الحراري للأشكال المختلفة للأفنية الحضرية في مشاريع الإسكان باستخدام المنهج التحليلي وبالاستفادة من برامج التحليل الحراريECOTECT و IES , وصولاً إلى نموذج محقق لأعلى أداء حراري بحيث يصلح لاستخدامه في مشاريع الإسكان بقطاع غزة.

وقد خلص البحث إلى أن الأفنية الحضرية المغلقة بشكل عام هي أفضل من شبه المغلقة من حيث أدائها الحراري و تأثيرها على المباني المطلة . كما أن أبعاد تلك الأفنية تلعب دورا كبيرا في تحديد كمية الإشعاع الشمسي التي تسقط على سطح المبنى مما يؤثر على الأداء الحراري داخل المباني، و وجد أن أفضل نسب للفناء هو 1: 1.8 (الطول :العرض)، ونسبة أبعاد الفناء إلى الارتفاع تصل إلى 8.9، كما وجد أن المبني الذي في الاتجاه الجنوبي الشرقي(بالنسبة للفناء)هو الأفضل من حيث الأداء الحراري والطابق الثالث هو الأفضل من بين الطوابق الخمسة المكونة للمبنى.

وعليه يوصي البحث بضرورة تطبيق الأفنية الحضرية كأحد استراتيجيات التصميم الحراري كأولى اعتبارات التصميم المعماري الناجح، خاصة في توجيه تلك الأفنية و توفير العناصر التي تزيد من أدائها الحراري مثل التشجير و عناصر التظليل ,فضلاً عن استخدام برامج المحاكاة لتقييم الأداء الحراري للمنشآت المعمارية. كما يوصي البحث بضرورة تحديد النسب والأبعاد للأفنية في ظل فهم كامل للعلاقة بينها وبين النسيج العمراني ، فضلاً عن استخدام برامج المحاكاة لتقييم الأداء الحراري للمنشآت المعمارية.كذلك يوصي البحث بضرورة تحديد النسب والأبعاد المتعلقة بالمباني في ظل فهم كامل للعلاقة بينها وبين النسيج العمراني.

LIST OF ABBREVIATIONS

NRC	Norwegian Refugee Council
USGBC	US Green Building Council
ARIJ	Applied Research Institute
PCBS	Palestinian Central Bureau of Statistics
UNRWA	United Nations Relief and Works Agency
MPWH	Ministry of Public Works and Housing
PHC	Palestinian Housing Council
UDD	Urban Demographic Density
CIBSE	Chartered Institution of Building Services Engineers
UCHP	Urban courtyards in housing projects
CTTC	Cluster Thermal Time Constant
UCL	urban canopy layer
Tmrt	Radiant temperature
CO2	Carbon Dioxide
UHI	Urban Heat Island
PVC	Polyvinyl chloride
EIA	International Energy Agency
EPA	Environment Protection Agency
IDM	Integrated Data Model
NREL	National Renewable Energy Laboratory
WMO	World Metrological Organization
WHO	World Health Organization
WEA	Weather Data File used by ECOTECT
SSI	Solar Shadow Index

The basic equation in the research

a. **Thermal Conductivity λ**

Apparent thermal conductivity is defined based on test results as (Straube, 2007):
$k_{eff} = Q L/(T A)$ **(1.4)** where
k_{eff} is the effective thermal conductivity
Q is the measured rate of heat flow
L is the thickness of the sample (equal to the length of flow path)
T is the temperature difference, and A is the area through which heat flow is measured.

b. **Thermal Resistance of a Material, R or R-value**

R-value is defined by testing an assembly of known area exposed to a known temperature difference (Straube, 2007):

$R = (T A)/ Q$ where
R is thermal resistance
T is the temperature difference
A is the area through which heat flow is measured, and
Q is the rate of heat flow.

c. **Thermal Transmittance, U**

U = 1 / R *where*
U = overall thermal transmittance (W/m2 ^{o}C)
R = thermal resistance ($m^{2o}C/W$)
Thermal resistance can be expressed by transforming (1) to
R = 1 / U

d. **Rate through the Building Walls**

The heat transfer rate through opaque building walls per unit floor area, $\hat{U}_{wall}$, is expressed mathematically as (Utzinger et al. 1997):

$\hat{U}_{wall} = U_{wall} A_{w}/A_{f}$

e. **Heat Transfer Rate through the Building Roof**

The heat transfer rate through the building roof per unit floor area, $\hat{U}_{roof}$, is expressed mathematically as (Utzinger et al. 1997):

$\hat{U}_{roof} = U_{roof} A_{r}/A_{f}$

f. **Heat Transfer Rate through the Building Glazing**

$\hat{U}_{glzg}$, is given by (Utzinger et al. 1997):

$\hat{U}_{glzg} = U_{glzg} A_{g}/A_{f}$

g. **Heat Transfer Rate through the Ground**

$\hat{U}_{grnd}$, is expressed mathematically as (Utzinger et al. 1997):

$\hat{U}_{grnd} = U_{grnd} \text{Perimeter}/A_{f}$

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CHAPTER 1: INTRODUCTION

1.1 Introduction:

For most people, home is a place for rest and relaxation and where relief from stress and demands of everyday's life is sought. It is therefore essential that the housing environment is designed to support this aim, (Environ, 2001). However, many residents, particularly in urban areas, are exposed to overcrowded buildings. These far exceed what characterizes a healthy and sustainable environment and may cause adverse in the indoor environment.

The World is facing a big challenge; ecosystems cannot sustain the current levels of economic behavior and material consumption. It suffers from global warming and climate change.
The International Energy Agency (2010) further draws a significant impact generated by the residential building industry as well as the electricity demand with regard to the total carbon dioxide emissions. Furthermore, the US Green Building Council (USGBC, 2008) reports that the building industry in developing countries has a very important contributor to the overall ecological footprint. According to USGBC statistics, residential buildings account for a massive 40% of the total carbon dioxide emissions, 40% of all energy usage, 68% of electricity utilization, 10% clean water consumption and 50% of non-industrial waste generation.

Architects can bear an important responsibility toward the built environment by adhering to social, cultural and climatic identities and are therefore able to achieve a significant footprint reduction without compromising quality of life. Furthermore, architects can learn from history where the built environment was a sustainable response and a natural reflection of the society, culture and climate, thus causing less destruction to natural resources.

According to the Palestinian Central Bureau of Statistics (2007), the Population in the Palestinian Territory Mid-Year by Governorate, 2014 is 1,760,037 people and this causes overcrowded buildings. According to the data of General Directorate of Customs Security (2013), the current number of the housing units in the Gaza Strip is estimated by 261,000 housing units. In collaboration between Norwegian Refugee Council (NRC) and the Ministry of Public Works and Housing (MPWH,2010), a study was done and the shortage in the housing units till the mid of 2011 was estimated by 75.334 housing units. According to the Palestinian Central Bureau of Statistics, the need of housing units annually is 800-1100 units. The need of housing units in 2020 might be 242.505 housing units, (Palestinian Central Bureau of Statistics, 2010).

As a result of lack of land, some housing projects have been created with adjacent buildings and limited setback, which cause many environmental problems related to lighting and ventilation.

All of the above raise the need to apply protective measures and more environmentally considerate life style. Thus, urban courtyards in housing projects (UCHP) were created as planning approach to improve the environmental performance.

The idea of courtyards as a planning configuration goes back to thousands of years to Neolithic Settlements,(Edward,2006).Initially, the logic behind this type of planning was mainly to provide protective area from outside forces, such as invasion by human and wild animals. Over the time, it has developed into a solid, logical configuration that maximizes the built-up area in the urban context and allows controlled sunlight, especially in regions where it is abundant, (Edwards, 2006).

The research is an attempt to primarily introduce the existent environmental problems in housing projects in the Gaza Strip. Focusing on the urban courtyards in those projects, as they ameliorating the environmental performance. Therefore, the study examines the thermal performance of these courtyards to determine the best geometry of them, thus getting the desired benefit. Ultimately, Courtyards play an important role in the environmental performance of the building overlooking them.

1.2 Research Problem

The overcrowded nature of the urban fabric topologies in Gaza, according to the Palestinian Central Bureau of Statistics (2011), Gaza Strip is still in need of 91.026 housing units to cover the gap in the current shortage of houses (MPWH, 2014). This shortage of housing unites led to the increasing of populated built area and thus increasing temperature in urban areas. In addition, it is widely known that increasing of human activities result in increasing CO2 emissions and energy consumption .

Buildings consume large amount of energy in order to achieve thermal comfort for users. It is noted that urban courtyard becomes prevalent in the housing projects of the Gaza Strip. But it doesn’t take sufficient account to the climate, environmental factors and the considerations of energy-saving in buildings, especially with regard to its type and orientation. Hence, this research investigates the thermal performance of the urban courtyards in housing projects (as planning method) on the overlooking buildings, and energy consumption.

1.3 Research Hypothesis

The study assumes that improving the design of urban courtyard in the housing projects of Gaza Strip will enhance the environmental performance of the courtyards, and the overlooking buildings, consequently it improves the thermal comfort of the residents

1.4 Importance of the study

The importance of the study can be categorized into two categories:

1. **To researchers and Scientific field:** the topic is becoming more important as it is related to the most important dynamic aspect which affects all the life fields. Although, there are piles of available studies on the topic, few of them are focusing on the urban courtyard housing projects, and they rarely consider architectural design standards. Environmental issue is a self-enrich area of study that needs more exploration to its impacts on architecture or governments.

The research will use various simulation tools to help in measuring thermal comfort in relatively accurate manner and approximately close to actual performance.

2. **To the Community:** this study expects people and governments to benefit from the results and recommendations of this research by enhancing their understanding of the environmental performance of courtyards and its influence upon the housing projects. It may also provide useful insights into the advantages of courtyards which can act as the basis for making future decisions.

1.5 Research Aims and Objectives

The main aim of the current study is to investigate the effect of urban courtyard in the housing projects of Gaza Strip on the thermal performance of the overlooking buildings, and finding out the best possible configurations of those courtyards to reduce consumed-energy for achieving thermal comfort. The sub objectives of study are to investigate the following:

- Highlight the energy situation in the Gaza Strip,
- Study the factors that affect thermal performance of building,
- Investigate the role of climatic factors on urban courtyard in the housing projects.
- Examine the effects of urban courtyard orientation on thermal comfort.
- Determine the urban courtyards function, types, benefits and characteristics.
- Study the elements of courtyards, such as landscaping, irrigation systems, etc., and their impact on the environmental performance of the courtyard.
- Promote the idea of the urban courtyards in housing projects within the design criteria to improve environmental performance of the surrounding buildings.

1.6 Research Methodology

In recent years, researchers around the world have made large efforts to measure the thermal performance of courtyard. The following research attempted to achieve valuable results through using parametric analytic approach. An extensive literature review on the thermal performance and the climate responsive buildings design is carried out as theoretical background. It depends on theoretical sources such as researches, conference papers and previous studies. Also the research will carry out simulation processes using computerized program such as ECOTECT and Integrated Environmental Solutions (IES) which provides reasonable results. The most common urban courtyards at housing projects in Gaza Strip will be studied and analyzed to find out the effect of courtyard on the thermal performance of the overlooking buildings. The heating and cooling loads will be calculated for each model. The results will be evaluated in order to optimize the thermal behavior of the models.

ECOTECT software is a comprehensive, concept-to-detail sustainable design analysis tool, providing a wide range of simulation and building energy analysis functionality that can improve performance of existing buildings and new building designs. Online energy, water, and carbon-emission analysis capabilities integrate with tools visualize and simulate a building's performance within the context of its environment. It calculates heating and cooling loads for models and analyze effects of occupancy, internal gains, infiltration, and equipment. Also, it visualize incident solar radiation on windows and surfaces, over any period. It displays the sun's position and path relative to the model at any date, time, and location (Autodesk Ecotect Analysis, 2010).

The Virtual Environment is an integrated analysis platform developed by Integrated Environmental Solutions (IES). It is a collection of building performance modeling and analysis modules leveraging a single integrated data model. The intent is to provide the high quality information required to design, build and operate better performing, more sustainable buildings without having to build a different model for each type of analysis (ex. energy, day lighting, etc.). It can be applied from the earliest stages of the design process, when greatest opportunity often exists for making improvements right through to detailed design and even into operation of the building (Integrated Environmental Solutions, 2009).

1.7 The Research Limits:

This study focuses on residential buildings in the Gaza Strip that consumes the largest part of electricity, which is estimated to be 70% of the total amount of energy consumption .The intended buildings to be examined is residential buildings in Gaza. It focuses on the housing projects which contain urban courtyards, many configurations of urban courtyards were found in different projects such as Shihk Zayaid , Tal El Hawa, El Kawthar and Hamad housing projects.

- The study depends on realistic cases, with the aim of choosing the best configuration of the urban courtyard to reliable in the future projects.
- The study is carried out in the climate of the Gaza Strip is characterized by its location in hot humid region specifically on longitude 34^0 26' east and latitude 31^0 10' north.
- The study depends upon simulation programs namely IES and ECOTECT.
- The following design parameters in the urban configurations will be analyzed:

1. Type of courtyard (closed or –semi closed).
2. Ratio Of Courtyard
3. Orientation of courtyard.

1.8 Sources of information

The Research depends on several sources of information varied between the theoretical sources for the scientific information, the field study and computer simulation, these sources can be listed as follows:

- Journals and conference papers.
- Books that deal with similar subjects.
- Reports and statistics from pubic and non-public associations.
- Scientific internet sites
- Universities, and research centers sites.
- Field visits to collect information and data.
- Computer simulation of the selected models using the analysis program IES and ECOTECT.

1.9 Study Outline

The current study was displayed in six chapters. The first chapter was general introduction of the study that include overview, problem statement, hypothesis, objectives, methodology, limitations, source of information and literature reviews of similar studies.

Chapter 2 presented history of courtyards, their functions, types and courtyards parameters. The Gaza Strip urban situation was described too. It illustrated the location and topology, population density and the climate in the Gaza strip. It listed the most housing projects in the Gaza Strip, which contain urban courtyards.

Chapter 3 illustrated the thermal performance, identification, mechanism, and factors affecting thermal performance of buildings. Thermal balance of buildings and thermal comfort in buildings was described too. Also, it summarized passive solar design techniques as a solution for these problems. It presented general guidelines for improving the thermal performance of the urban courtyard elements.

Chapter 4 investigated on the most common urban courtyards at housing projects in the Gaza Strip. Total incident solar radiation, solar gain, and fabric gain in summer and winter, which are the main indicators on building thermal performance to choose the best model of urban courtyard. Also the best model was simulated in different orientations to get the optimum thermal performance of the urban courtyard.

Chapter 5 discussed the thermal performance of the best model of urban courtyard by simulating it with different orientations and comparing the result with linear building to affirm the effect of courtyard on the thermal performance of the buildings

Chapter 6 discussed deeply the results of study and gave some important recommendations accordingly.

1.10 Previous studies

Several Studies have investigated the effect of urban courtyard on the energy consumption and the thermal comfort of occupants , for example:

1. Enes Yasa , Vildan Ok (2013) Evaluation of the effects of courtyard building shapes on solar heatgains and energy efficiency according to different climatic regions.

The purpose of this study is to examine the energy efficiencies of the courtyard buildings used either as a micro climatic regulator in hot-dry climatic regions. By using the CFD program. This study has analyzed the thermal comfort statuses and energy performances of seven courtyard shapes in inter-courtyard and building volumes that are discussed in hot-dry, hot-humid and cold climatic regions.
As a result of the entire analysis made for all building shapes, the obtained values were interpreted and the total energy performances were evaluated for each climatic region.
At the end of the study the researcher noticed the following:

- The sun admission ratios of the courtyard surface areas increase as the depth in the courtyard decreases.
- The optimum courtyard ratio is a form that allows minimum radiation during summer and maximum radiation during winter.
- The required annual energy demand increases in parallel with the increase in courtyard length.

As the courtyard's plan come close to square, the inter-courtyard shadowy area increases and the required energy amount during the 21st July cooling period decreases; whereas during the 21st January heating period, its effect on the increased energy demand somewhat decreases.
Generally, annual energy consumption increases as the courtyard building shape gets longer as a direction of prevailing wind. The solar radiation received by the courtyard building surfaces, heat gain and therefore its effect on the required.

2. Al Masri Nada (2010): Courtyard Housing in Midrise Building .An Environmental Assessment in Hot-Arid Climate

This study is an evaluation of the environmental impacts of courtyard integration in midrise housing in the hot-arid climate of Dubai, The United Arab Emirates. A computer

simulation (IES 6.0) is utilized to measure selected parameters: thermal analysis, solar shading, daylighting and airflow patterns, and primarily to determine the overall energy reduction.
The study is carried out in three steps: The first step, a comparison of conventional and courtyard models is carried out in six-storey buildings. The second step, a courtyard building is studied to determine design optimum parameters in which one variable changes at a time when all other remain constant according to a suggested prototype model (reference model), and the third step compares it again to the conventional model.
The first step concludes a reduction of 6.9% energy for the courtyard model. The second step concludes that the optimum design parameters for a courtyard model is achieved with ten-storey height, triple-glazed opening, 40 cm-thick wall and 10-cm thick Cellular Polyurethane insulation material. The third step achieves 11.16% total energy use reduction for six-storey courtyard model with the optimum parameters.

3. Ali Zainab (2007) Comfort With Courtyards In Dhaka Apartments

The study indicated that the traditional residences, rural or urban, with interior courtyards created a living condition that was and still is, environmentally, functionally, and socially sustainable. The researcher, had studied a number of residential buildings both with and without courtyards, stresses that introduction of this important environmental element, can provide much better indoor comfort in terms of light, air and coolness. The study is a synthesis of recorded temperatures and make questionnaire for the people who live there.
At the end of the study the researcher noticed the following:

- The temperature, light and ventilation study along with the interviews among users and observations on the form, materials, environmental strategies, reveal that a courtyard apartment building is much more comfortable and thus desirable for the city dwellers of Dhaka.
- A city dweller will demand a place with good indoor environment of light and air, and possibly good view, which is necessary for healthy living.
- The courtyard concept may be successfully incorporated in the designs and thus a more comfortable thermal and luminous indoor environment can be achieved.

4. Tsianaka Eirini (2006). The Role of Courtyards in Relation to Air Temperature of Urban Dwellings in Athens.

This study examines the benefits of courtyards, which can be exploited so as to offer natural ventilation and lead to reduction of cooling consumption. The investigation is based on urban morphology and air temperature analyses. For the air temperature analysis both in-situ temperature measurements as well as the Cluster Thermal Time Constant (CTTC) prediction model are used.
The result of the study indicated that different urban geometry has an important impact on temperature rise. Lower floor facing courtyards are cooler than lower floor facing streets.

Hence courtyards tend to be valuable spaces for the city of Athens, contrary to streets, which are warmer, more noisy and polluted.

Temperature evaluation also showed that courtyards can reduce the energy use for cooling in the buildings. The apartments of the street side could also benefit, by making use of the courtyard cool air and bringing it to the building through the courtyard apartment. This is possible on the condition that there is access from the street to the courtyard, because only then can wind flow, thus cross ventilation through the buildings is achieved.

5. Limor Shashua-bar, yigal Tzamir and Milo e. Hoffman (2004). Thermal effects of building geometry and spacing on the urban canopy layer microclimate in a hot-humid climate in summer.

A quantitative analysis is presented for evaluating the diurnal thermal impact of proposed building arrangements on the urban canopy layer (UCL) air temperature, in summer in a hot-humid region. Building configuration specified in this study by the building dimensions. Sixty different building configurations were studied.

The analysis is applied on simulated summer air temperature data in a hot-humid urban region near the Mediterranean Sea coast. Building configurations were generated according to a generic form representing the residential buildings found mostly along urban streets in Israel. The analysis focuses on the potential maximum diurnal thermal effect, at 1500h (14: 10 solar time) in July. The main findings are:

- In shallow open spaces with wide spacing, to 2.1 K below it in deep open spaces with narrow spacing.
- The built-up depth ratio has a relatively weak cooling effect, but has a positive interactive influence on the spacing effect.
- The statistical analysis indicates the feasibility of assessing the total expected maximum thermal effect of a proposed building of the generic form studied
- The thermal impact on the UCL air temperature of the building configuration studied does not depend on the street orientation.

The results indicate significant thermal effects in the UCL due to the building form assessing the expected maximum thermal effect of building designs of the generic form studied here, through a general linear relationship.

6. Carlo Ratti, Dana Raydan, Koen Steemers (2003). Building form and environmental performance: archetypes, analysis and an arid climate.

This paper aims to extend the analysis of building form . The main findings are briefly reviewed and subsequently in environmental and energy terms. Using innovative techniques for environmental urban analysis, based on image processing. This analysis is further extended by examining a real urban case study in the hot-arid climatic context.

An integrated insight of the environmental behavior of urban built form is put to use. These tools shed light on the intricacy of environmental consequences that different urban configurations could trigger. The case study demonstrated that the courtyard configuration showed better response through the calculated environmental variables (surface to volume ratio, shadow density, daylight distribution, sky view factor)

The main findings are:

- Larger surface area and high thermal mass.
- Daylight via the courtyard and shallow plan form.
- Narrow spaces for shade and improved thermal comfort despite increased heat island.

The previous mentioned studies discussed different factors to examine the effect of courtyard design on energy consumption. These factors include shading devices, ratio of the courtyard, shape, orientation and height of buildings overlooking the courtyard. The studies consider the energy demand as an indicator to determine the optimum design. The computer programs are commonly used as a simulation tools in most of the studies. In addition, the experimental study can be used as an effective tool in this type of studies. It has been noticed that the focus of the studies is different according to building type and climate conditions, therefore these two factors should be taken into account to limit the study area.

Conclusion

This chapter presented the problem of discomfort built environment which appears as a result of the architectural design that neglected the climatic factors. The importance of this problem increases with the energy crisis which is linked with the ever increase in using heating and cooling energy. The chapter focused on the urban courtyards type in the housing projects of Gaza Strip as it is considered one of design strategy which determines the envelop morphology that links between the indoor and outdoor environment. It assumed that those urban courtyards have a great influence on the thermal performance of the indoor environment and thus the energy consumption. So, simulation processes using the thermal analysis programs IES and ECOTECT will be carried out to evaluate this assumption.

On the other hand, the chapter presented some previous studies which dealt with similar aspects. It is concluded that there is a lack of studies which dealt with the Mediterranean climate of the Gaza Strip. Each study had its own methods and parametric tools that differ according to the study objectives. Also, the most of these studies handled the effect of urban courtyard on the thermal performance for the building to find the optimum ratio of those courtyards which achieve the desired performance.

2 Chapter 2: Urban courtyard of housing projects in the Gaza Strip.

2.1 Introduction

Courtyard is defined by the Oxford English dictionary as "an open area surrounded by walls or buildings within the precincts of a large house, castle, homestead, etc."
Courtyard is a building element that originated from the hot and dry regions (Edwards, et al., 2006). The use of unsuitable courtyard forms of some regions, such as the basic form of a courtyard in the center of the plot does not perform well in the dry climates of another region. Many ancient courtyards in Arab countries have a clear indication that the design variants of courtyard have been designed and improved by the integration of social, cultural and environmental factors. The variations of the design such as area, number of floors, orientation, exposure, types of walls and many more were introduced to achieve successful oriented courtyard that respond to the human needs (Reynolds, 2002).

Residential buildings are considered the main construction subsector in Gaza stip. Detached buildings are the most commonly used style in residential complexes. The attached style is only found in the old town of Gaza. Most of the new housing projects comprise courtyards between the buildings.

This chapter is carried out to identify the history of courtyard along civilization, types, shapes and elements of courtyards. The chapter will indicate housing projects situation in the Gaza Strip. It is talking about location and topology, population density, and urban geometry in the Gaza Strip. Then, the chapter discusses the term of housing projects in the Gaza Strip and focuses on urban courtyards housing projects in the Gaza Strip; finally, it introduces some observations in those housing projects.

2.2 History of courtyard

Courtyard structure is as old as the man harping on earth. It is a component in the compositional dialect that is public all through the historical backdrop of numerous urban civilizations. Courtyard structure coordinated into man's abodes is experience in the aged civic establishments going over to 3000bc (Edwards et al., 2006). Courtyard is found from the Bronze time of Greece, all through the Classical period into the Hellenistic and Roman period, which then multiplied through the Americas, Europe, Africa, Middle East, and the Far East advancing from a development to an alternate; Bronze age Mesopotamian, Egyptian-Sumerian, Indus valley, Asia minor, and the Mediterranean (Meir,1995). The courtyard in the house is the core of investment and has truly been utilized for some reasons including cooking, working, playing, and aggregation, actually resting amid the hot summer nights. One sort of chronicled courtyard houses is found in Chinese society where houses were built with numerous yards to give security and agreement. Outsiders were gotten in the furthest courtyard, while the deepest ones were held for close relatives. These structures were foreign made to the Middle East. Figure (2.1) outlines the multiplication of the courtyard lodging. The Arab migrants have connected the courtyard idea in the desert by comprehensive a focal open space with their tents to give their steers security and haven.

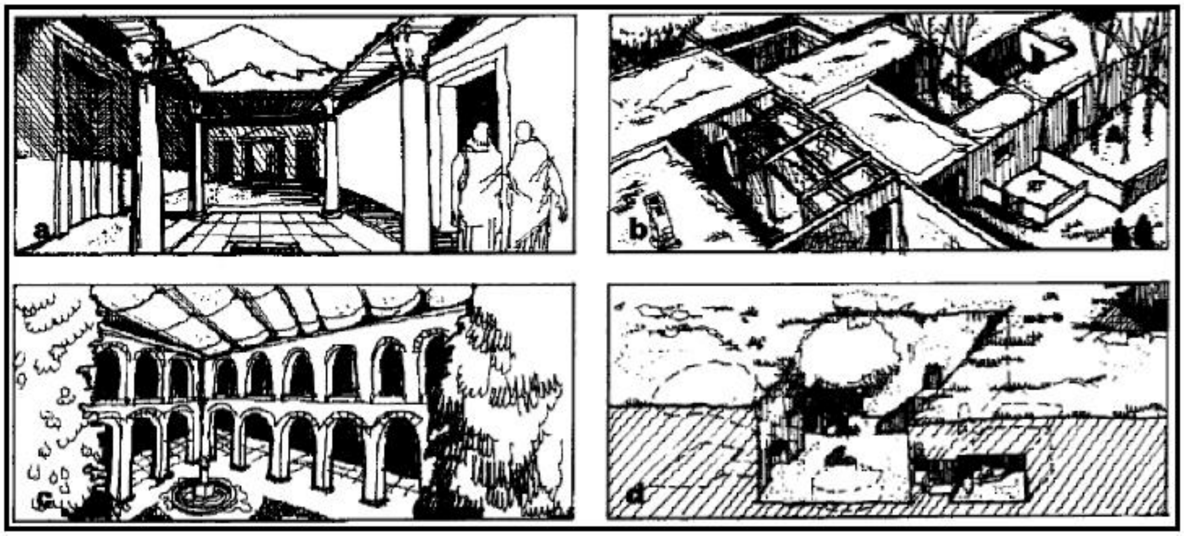


Figure (2. 1): Courtyard dwellings: (a) Greece, (b) Mongolia, (c) Spain, (d) North Africa

Source: (Meir, 1995).

Through history, courtyard structure is evidently in having a harmonious connection in the Middle Eastern culture where a surviving number of courtyard lodging going once more to pre-Islamic and Islamic periods are located,(Edwards, et al.,2006).

The courtyard lodging prototype structure may contrast from a zone to an alternate, however, it remains a common structure, see figure (2.2). The early courtyard lodging of Egypt going once more to the eighth and ninth century AD have impacted the Maghreb (the western; Tunisia, Morocco, Algeria, and Andalusia) courtyard lodging. They created traditional square-rectangular yard encompassed with symmetric rooms and t-formed multifunction halls.

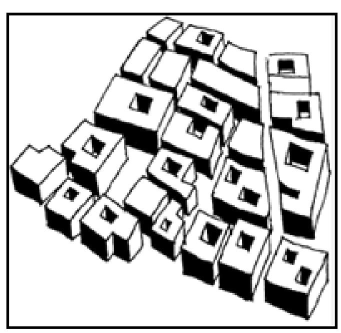
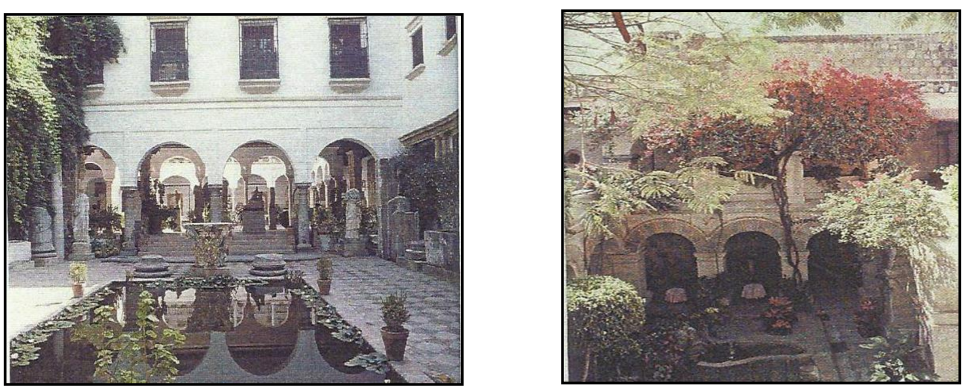


Figure (2. 2): Traditional urban fabric based upon courtyard housing(Qyrwan old city)
Source: (Edwards et al, 2006)

2.3 Courtyard functions

The courtyard does not generally perform the same capacity in residential building design. Its part contrasts starting with one area then onto the next in western range and Arab nations. It is a typical compositional gimmick that has been requested a great many years in numerous parts of the world especially in houses. Courtyards were regularly the essential gathering spots for particular purposes including planting, cooking, working, playing, resting, or even now and again as spots to keep creatures (Edwards et al., 2006). As an open space inside a bunch or urban fabric, courtyard satisfies different capacities, social, recreation and microclimate. The criticalness of such a space was by their being placed in focal locales inside the urban fabric or building. Encompassed by arcades and colonnades, cleared, finished with water bodies, different plants, shade and light see figure (2.3). They all assumed a critical part in our social and working life (Meir, 2000). Also, courtyard as a space can give climatic and in addition visual or acoustic assurance. The courtyard geometry and additionally its material cosmetics ought to be considered in the configuration arrange so as to give the largest amount of warm solace conceivable (Meir, 2000). Also, it was created to be atmosphere responsive. Besides, courtyard could be used as a fitting spot for advertising characteristic, nature's domain.



Figure(2. 3) Use of water and plants in courtyard
Source: (Reynolds, 2002)

In a Hong Kong study, Lau & Yang (2009) brought recuperating properties into college facilities Of Hong Kong University (HKU) yards. They inferred that presenting a courtyard, for example, visual association, protection and security, transparency from indoor to open air, advances client encounters. Discoveries from the detailed analysis at HKU demonstrated that the enclosures inside a courtyard space has pushed social help, while the contemplation enclosure was useful for the scholarly feeling and served to increase a decent feeling of control and security. The two courtyards ought to be recognized from one another regarding topic, utilization example, space and scene outline. As a library and perusing rooms encompass one of the courtyards, it was composed as a contemplation arrangement with the topic of serenity. The other courtyard was near the passage of the complex. It assumed a more open part to energize social communication and backing.

On a bigger scale, the courtyard idea was found in the old urban communities in an urban setting, where houses are grasping a huge, open and focal yard. Each house has rooms that grasp again a private yard. On the social level, the urban courtyard, as an open square, was a positive void where all open associations and get-togethers could happen. The courtyard or square is an open space that is regularly considered as hubs of a city. Spotted in the middle of the city fabric, it can serve as a space where the urban group performs their recreation exercises. As an open space, the square can work as a metro space for the groups to associate, assemble and take part in relaxed tracks, other than as a space to celebrate different exercises (Child, 2004).

Hanging loose a few fields of open investment get to be privatized, for example, instruction, open welfare, lodging and open space (Kressel, 1998). Privatization of open space might be as structures, for example, shopping centers, cafés, celebration commercial centers, wellness focuses, and so forth, (Day, 1999). Urban courtyard of lodging projects is one of the semipublic square where planned in numerous lodging undertaking.

By reference to variations of types, it is possible to identify the following functions of the courtyard:

- The creation of a garden or cool place.
- The promotion of ventilation.
- The definition of a place of privacy for the family.
- The combination of spaces and elements in a house.
- The provision of a circulation element.
- The civic space for the communities.
- The space to celebrate various activities.

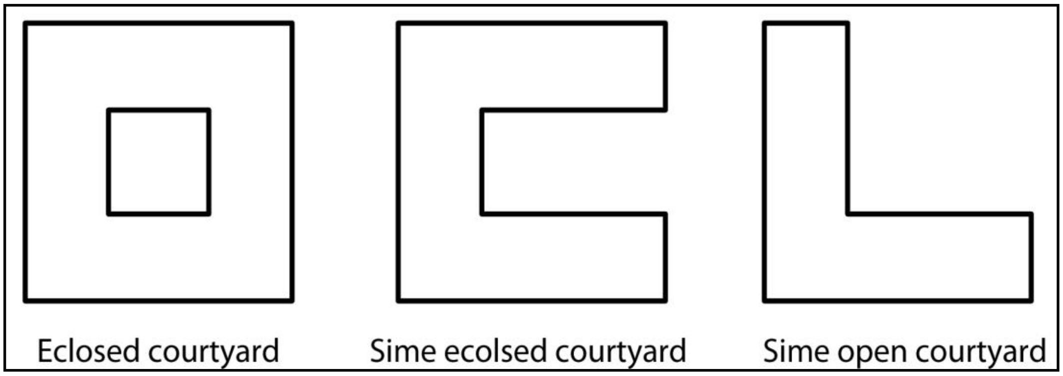
These functions are sometimes treated separately and sometimes work in combination.

2.4 Courtyard types

A courtyard does not have an adapted arrangement. In spite of the fact that the essential arrangement of a private yard is typically rectangular or square, it can additionally be roundabout or curvilinear. Through history, courtyards have been produced into different structures. Those structures division into completely enclosed, semi-enclosed and semi opened courtyards ,see figure (2.4). They speak to the degree of courtyard fenced in area embedded into the building mass, (Hyde, 2000).

- The fully enclosed courtyard is the customary yard outline that encases from each of the four sides and is incomprehensibly being used for private manufactured structures.

- The semi-enclosed courtyard is extremely uncommon, it has few openings; varying into the degree of openness, and is being used for different constructed structures in substantial scale not as a lodging unit.
- The semi-opened courtyard, structured from a building by at least fenced in area, the courtyard space is ordinarily open on one side, giving access to ventilation and opportunities for perspective.

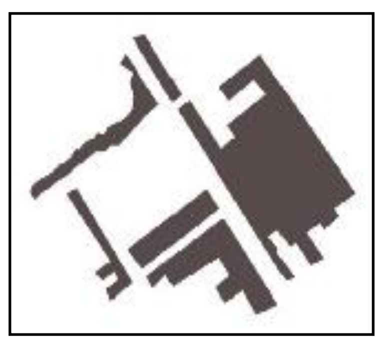


Figure(2. 4) Types of courtyards
Source : The researcher

In Public squares or urban courtyards are continuously arranged in four sorts, see figure (2.5), (Vadiati et al.,2011).

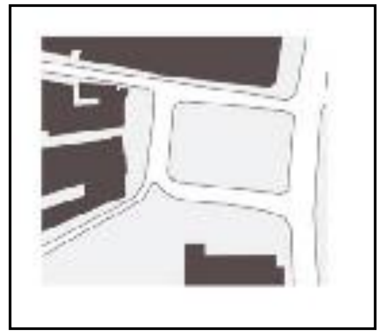
- Closed squares: are depicted by complete walled in area which is broken just by those roads heading into them.
- The dominate squares: they are stamped by coordinating towards one or a gathering of structures. These squares are ordinarily being controlled to emulating structures: church, castle, or town lobby, and additionally opening a perspective to a mountain, stream or vast ocean.
- The amorphous (shapeless) Squares: these sort demonstrations as a sort of get just for the past classes. Nonetheless, they don't concern any particular stylish and tallness width proportion.
- The street Plazas: This sort is constantly outfitted with green range and steps, seating spot with plentiful sun sparkle in overcast region and loads of shadow.

Type1: Closed squares
(Piazza Navona, Rome, Italy)



Type2: Dominate squares
(Bedford square, London, UK)

Type3: Amorphous squares
(Trafalgar, London, UK)



Type4: Amorphous squares
(In front of Parliament square, London, UK)

Figure(2. 5): Category of public square
Source: (Vadiati et al.,2011)

2.5 Courtyard Parameters: Length, Width and Height

The climatic properties of a courtyard and the encompassing structures depend on upon their extents. Figure (2.6) demonstrates a suggested courtyard width, which runs from x to 3x, where x is the courtyard stature (Koch, 2002).

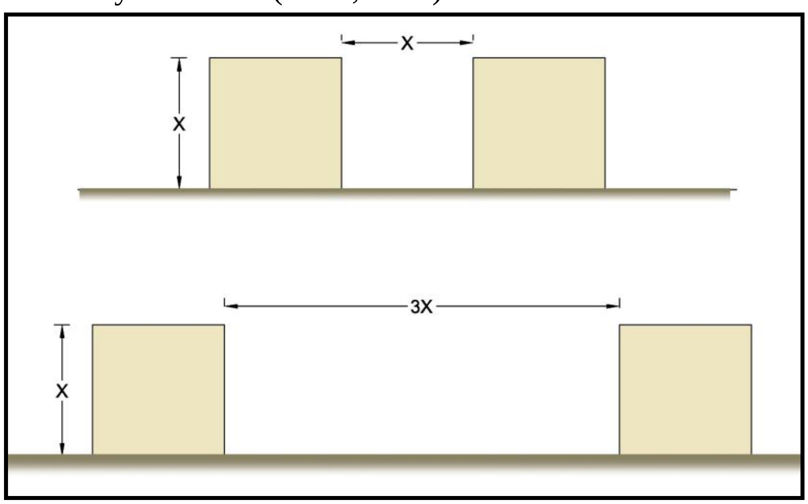


Figure (2. 6): Width of courtyard in relation to its height
Source: (Koch, 2002) with adaption.

Be that as it may, the vertically profound courtyard is proposed to upgrade the daytime inner shading, where as a more extensive courtyard would improve the ventilation over the house (Hyde, 2008).

The most widely recognized extents of width to length proportions are: 1:1.8 and 1:3.6, which depend basically on the sun way, (Edwards et al., 2006). An alternate element is the proportion of the manufactured range to the courtyard region, it ought to extend from 1.5 to 2.7, generally the courtyard will be excessively little or excessively expansive to be naturally compelling.

Reynolds further(2002), characterizes two parametric components that manage the courtyard introduction

1. Aspect Ratio (AR) is characterized as "the level of openness to sky". Along these lines, the more prominent the angle proportion, the more uncovered the yard is to the sky, (Reynolds, 2002).

This component is considered when outlining the house for the light, and is figured as takes after.

$$\textbf{Aspect Ratio} = \frac{\text{area of courtyard's floor } (m^2)}{(\text{Average height of walls})^2}$$

2. The Solar Shadow Index (SSI) is an alternate variable which manages winter sun introduction. The more noteworthy the sunlight based shadow record, the deeper the divider shaped by the courtyard and subsequently the less winter sun achieves the floor or the south divider, (Reynolds, 2002).

$$\textbf{Solar Shadow Index} = \frac{\text{south wall height (m)}}{\text{north –south floor width}}$$

Therefore, if the courtyard is wide and shallow (high perspective degree), it executes as sun gatherer. Then again, the restricted and profound yard (low perspective degree) executes as a sun defender, in which introduction has a feeble impact on the house.

As indicated by Hakmi (2006) he endeavored to develop the idea of the yard into the present day lodging fabric, so as to accomplish a superior reaction to the nearby atmosphere and social needs. He inspected the execution of single- and multi-family abiding utilizing expository systems to characterize the troubles and capability of such recommendations. Besides, he tried numerous conceivable option designs against social, atmosphere, protection and sunshine.

Then again, Hakmi expressed that the multi-story staying is transcendent in the advanced urban setting because of financial and social changes. Accordingly, he proposed conceivable plan of courtyard into an advanced connection. The principle attributes of these suggestions are:

- The courtyard constitutes 16-30% of the plot size.
- The courtyard assumes a crucial part in daylighting notwithstanding its social and style parts, the day and night zones are divided practically as needs be.
- Main course happens through the secured zone, instead of the customary yard house, where all development happens over the courtyard.
- The design of these choices guarantees complete protection for their residents, (Hakmi, 2006).

2.6 Overview of the Gaza Strip

2.6.1 Gaza strip urban situation

The Gaza strip is a small area in the world that has special environment features. This study summarizes these features and the environmental situation including location and topography, population density, climate, urban geometry and environmental issues.

2.6.2 Location and topology

The Gaza Strip is about 1.33% of historical Palestine area. It is a coastal area along the eastern side of the Mediterranean Sea. It lies on the Eastern coast of the Mediterranean Sea, at 31, 25° N and 34, 20° E. As shown in figure (2.7) the Strip borders are: Egypt on the southwest with 11km long, occupied lands on the east and north, 51km long. It is about 40 kilometers long, and between 6 and 12 kilometers wide, with a total area of 365 square kilometers. The terrain roughly, is flat or rolling, with dunes near the coast. The height from sea level does not increase more than 50 m generally and in some areas 10m, (Ministry of local government, 2004).

Figure(2. 7) : The Gaza Strip map
Source: (ARIJ, 2007)

2.6.3 Population density

According to the Palestinian Central Bureau of Statistics (PCBS) the population of Gaza Strip as the end of 2014 census is 1,760,037 million people, most of them descendants of refugees, see figure (2.8).One million of the population roughly was considered refugees, although the vast majority of them were actually born in the Gaza Strip, Population growth is 3.5 percent per year, (PCBS, 2009). Therefore, the Gaza Strip is one of the highest densities in the world. According to the ministry of local government, the issued constructions permits by municipalities increased a double from year 2000 to year 2011. The municipality of Gaza alone issued 1400 permits in year 2000, this number increased to 3500 permits in year 2011, (Ministry of local government, 2012). As a result, buildings are in a compact urban setting.

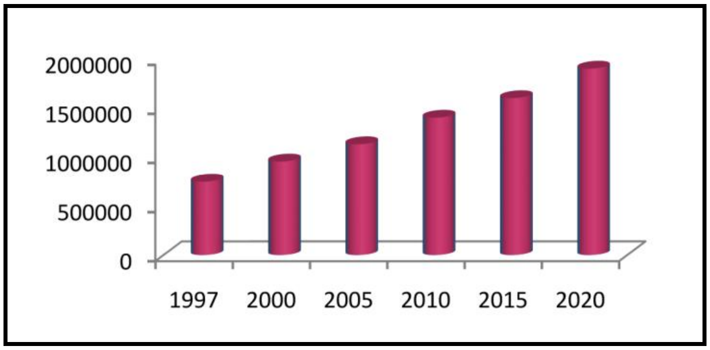


Figure (2. 8): Population in the Gaza Strip from 1997 to 2020
Source: (PCBS, 2007)

2.6.4 Climate

The Gaza Strip forms a transitional zone between the sub-humid coastal zone in the north, the semiarid losses plains of the northern Negev Desert in the east and the arid Sinai Desert of Egypt in the south. As shown in figure (2.9) and according to Köppen climate classification (the most widely used climate classification systems),Gaza Strip has a moderate Mediterranean climate , with rainy, mild, short winters, unpredictable springs and autumns, and dry, warm, hot, long summer.

Figure (2. 9): Palestine climatic zones
Source: (Applied Research Institute, 2003)

2.6.5 Urban geometry in the Gaza Strip

The urban fabric may have different characteristics from a small village than a city or a refugee camps, but all cities, villages, and refugee camps have common elements and components forming an urban fabric. Downtowns and neighborhoods are the two main types of development for urban areas; others may include educational institutions, industrial areas or individual buildings. Neighborhoods are primary residential areas, but also include commercial uses such as grocery stores, restaurants, and small offices. Neighborhoods have many types of buildings: detached houses, villas, and apartments,(Hadid, 2002).

The urban geometry complexes of Gaza are considered as dense in construction, high degree of impervious surfaces such as (asphalt, concrete, and interlock), high heat storage capacity of construction material, and the geometry block can easily trap the radiation that create air stagnation. Generally, street takes parallel and perpendicular orientations to the sea coast (north eastern- south western) and (north western- south eastern). Land plots take the same orientation of the streets. Thus, buildings take the same orientation of land plots due to the decrease in land area. So buildings orientation doesn't take into consideration the climatic factors especially the solar coefficient, see figure (2.10).

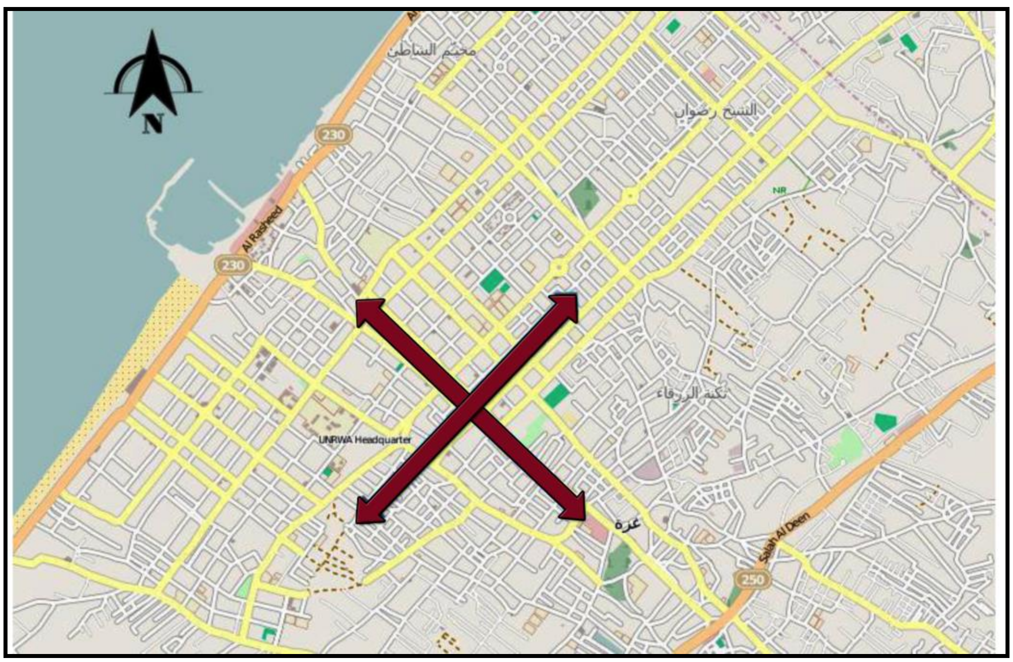


Figure (2. 10): Streets and parcel's orientation in Gaza city
Source: Open Street map, (2014) with adaption.

The main form of buildings range between the cube (square in plan) and cuboid (rectangular in plan) as the rectangular shape is the most popular geometric shape in parcels see figure (2.11). There are other small percentage forms such as circular, L shape and U shape, (Abed, 2012).

Figure (2. 11): View of Gaza city (Omer El Mokhtar Street)showing the common form of buildings
Source: Open Street map, (2014)

2.7 Housing projects in the Gaza strip

The housing sector in the Gaza strip is a major challenge in the Palestinian situation which requires concerted efforts of all governmental and private institutions. Since Al-Aqsa Intifada in September 2000, the growing demand for housing has increased the need for housing. As well as that population growth rates in the Gaza Strip is one of the highest rates of population increase in the world. The Gaza Strip needs 123106 housing units annually to meet the deficit in the housing sector. **(**PCBS, 2010).

Housing is one of the critical problems facing the Palestinian people in general and the Gaza Strip in particular. It has been developed in several stages, including the UNRWA camps to modern housing projects implemented by the Housing Council and the Palestinian Ministry of Housing. Residential buildings are considered the main construction subsector in Gaza. Detached buildings are the most commonly used style in residential complexes. The attached style is only found in the old town in Gaza city. Building's density, height, area and spacing are determined according to the local municipality's regulations.

Residential buildings range between 1-15 floors. Also, there areas range between 80- 500 m2 according to their type. To identify the history of housing in the Gaza Strip, (Salha, 2003), It can be categorized four phases as follows:

1. The first phase: during the British Mandate (1917-1948):

The British government carried out the first survey of the territory of Palestine. It did not have any urban activity except the implementation of a housing scheme in 1934.The residential land was divided into different areas with one acre. This plan anchored on the grid planning with wide and regular streets.

2. The second phase: during the Egyptian Administration (1948-1967):
In the early sixties, the Egyptian administration began planning housing from 1959 to1962. Housing projects were adopted on the grid planning. Each project area was two acres which led to the exhaustion of government land. Then, the space reduced to half acre and provided the necessary services to the population in these projects.

3. The third phase: during the Israeli occupation (1967-1994):
The main housing projects carried out by the occupation are Sheikh Radwan housing project in Gaza, Al Amal housing project in Khanyounis and Al Brazil project in Rafah.

4. The fourth phase: during the Palestinian National Authority (1994-to date):
The most important projects carried out by Ministry of Public Works and Housing (MPWH) are Alnada Towers, Sheikh Zayed city, Alkarama project in the northern Gaza Strip, Al-Zahra city in the center of the Strip, and Almashtal, Al Awda city, Tel al- Hawa project in Gaza, Alkalaa and Austrian neighborhood in Khanyounis. Also housing cooperatives have been introduced as one of the solutions developed.

2.8 Urban courtyards housing projects in the Gaza strip

The building activities in the housing project of the Gaza strip are primarily involved in mid to high rise apartments of various sizes and styles in almost every available space. The majority of these are, mostly six storied, and compact type of buildings with no courtyards inside. Subsequently there is a lack of natural ventilation and daylight in the interior spaces, which affect the level of indoor comfort. The age-old methods of designing in the context have proven that providing natural ventilation is an important strategy for having comfort. The traditional residences, rural or urban, with interior courtyards created a living condition that was and still is, environmentally, and functionally, sustainable.

2.8.1 Housing projects with urban courtyards

Several institutions implemented many housing projects in the Gaza strip such as the ministry of public works, Palestinian Housing Council and United relief and work agency. They implemented large housing projects some of them contain urban courtyards such as Sheikh Zayed ,and Tal Al- Hawa housing projects. Other projects are under construction, such as Al-Firdaws , Hamad, and others housing projects. The following sections will focused on these projects comparison between them.

a) El-Sheikh Zayed housing project

- **General information:**

The project is located in the town of Beit Lahiya, in the northern of the Gaza strip, with a total land area of 527,000 square meters. The project accommodates approximately 3,500 housing units, ranging between apartment buildings and towers. The apartment buildings consist of 70 building. Each building consists of five floors and each floor consists of two apartments with an area of 108 m^2. The tower buildings are 82 towers with 12 floors for each tower and 3 apartments for each floor. The apartment area's range between 116- 118 m^2, (MPWH, 2011).

- **Courtyard configuration:**

Form : the project take the style of detached buildings and groups of buildings clustered around a closed urban courtyard with square or rectangular shape , while other ones clustered around a semi closed courtyard with U shape or two U shape as shown in figure (2.12) and figure (2.13).

Size: the courtyard sizes are between 1500 and 2000 m^2 .

Elements: These courtyards have small trees, shrubs, seats and of course almost wide floor of concrete interlock. Most of the courtyards have a lack of water (fountain, pools) as shown in figure (2.14).

Access: access to courtyard occurs in line with the main axis (Central courtyard symmetry axis).

Entrance: entrance to the courtyard is done from the space between buildings.

Orientation: the courtyards take the (north eastern- south western) and (north western- south eastern) orientation and the buildings take the same orientation. The buildings take the rectangular shapes with the main proportions in some urban courtyards with ratio of 1:1.8 which define the geometric shape of the apartments.

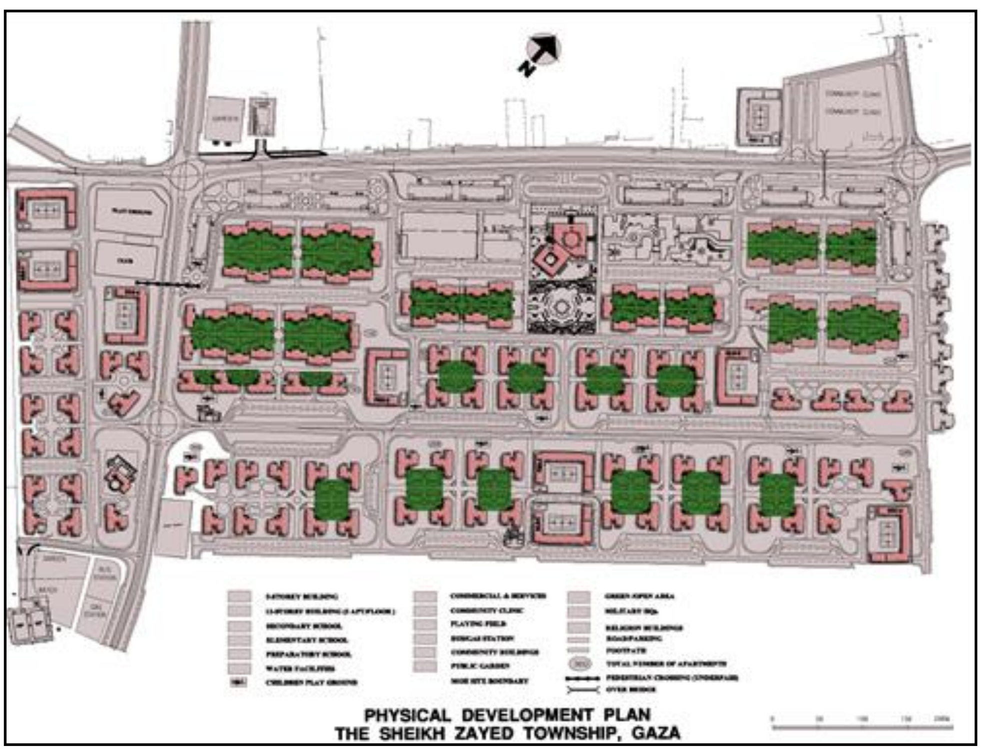


Figure (2. 12): Site plan of Sheikh Zayed housing project
Source: MPWH, (2014), with adapted

Figure(2.13) Sheikh Zayed housing project
Source: Google earth, (2014)

Figure (2. 14): Views of urban courtyard at Sheikh Zayed housing project
Source: MPWH, (2014)

b) Tal El Hawa Housing Project

- **General information**

The project is located in the west of Gaza city, with a total land area of 430,000 square meters see figure (2.15). The project contains approximately 72 apartment buildings. Each building consists of 5-7 floors in addition to the ground floor. The first model consists of 4 apartments in each floor with an area of 140 m^2. The second model consists of 3 apartments in each floor with an area of 189 m^2 (MPWH, 2014).

- **Courtyard configuration**

Form: the project take the style of detached buildings and groups of buildings clustered in a form of L shape and two L groups around a closed urban courtyard with a rectangular shape as shown in figure (2.16) and (2.17).

Size: the courtyard sizes are between 1400 and 2200 m^2 .

Elements: some of these courtyards have few shrubs, seats and of course almost wide floor of concrete interlock. Other ones look like a desert without any natural elements. All of the courtyards have a lack of water (fountain, pools) as shown in figure (2.17).

Access: access to courtyard occurs in line with the main axis (Central courtyard symmetry axis).

Entrance: entrance to the courtyard is done from the space between buildings.

Orientation: the courtyards take the (north eastern- south western) and (north western- south eastern) orientation and the buildings take the same orientation. The buildings take the rectangular shapes.

Figure(2. 15):Tel al-Hawa housing project
Source: Google earth, (2014)

Figure(2. 16):urban courtyard plan of Tel al-Hawa housing project
Source: The researcher (2014)

Figure(2. 17): view of one of urban courtyard at Tel al-Hawa housing project
Source: The researcher (2014)

c) Al-Firdaws Housing Project:

- **General information:**

The project is located within the boundaries of the town of Beit Lahiya in the voucher number (36) of Plot No. 1742. The project covers an area of about 754,800 m^2. The project is containing 1162 apartments and a population of 6972 inhabitants, (MPL, 2010).

- **Courtyard configuration**

Form: the detached buildings are the main style in the project. Groups of buildings clustered in a form of U shape and two U groups clustered around an urban courtyard. Show figure (2.18)

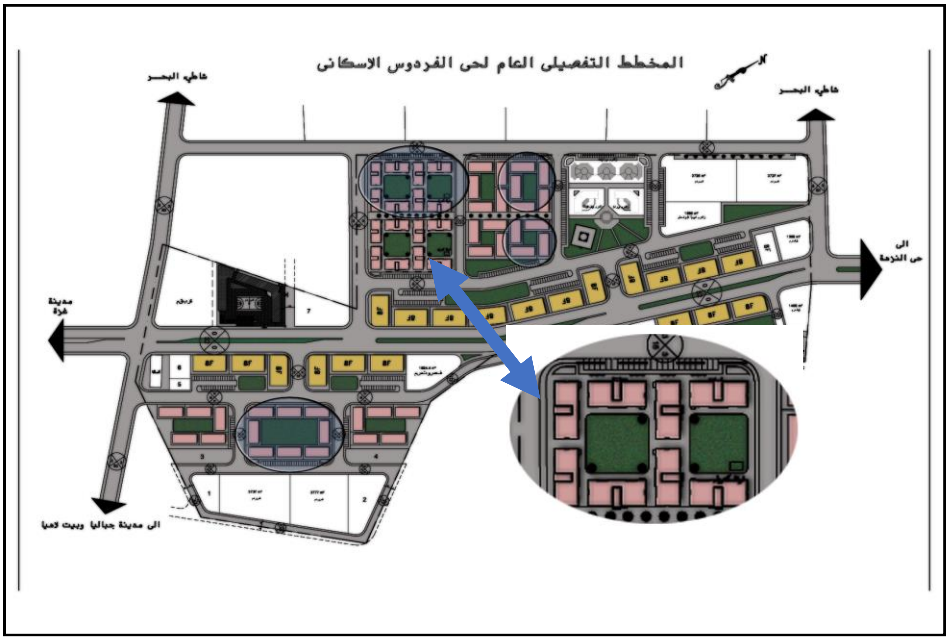


Figure (2. 18):urban courtyard at Al-Firdaws Housing Project
Source: MPL, (2010) with adaptation.

Size: the courtyard sizes are between 160and 1000 m^2 .

Access: access to courtyard occurs in line with the main axis (Central courtyard symmetry axis).

Entrance: entrance to the courtyard is done from the space between buildings.

Orientation: the project’s streets take the (north eastern- south western) and (north western- south eastern) orientation and the buildings take the same orientation

d) Hamad housing project:

- **General information:**

The project is located in the western part of Khan Younis, with a total land area of 404.446 square meters. The project contains 3628 residential units of varying sizes. Each building consists of 4 floors in addition to the ground floor, see figure (2.19).

- **Courtyard configuration**

Form: the detached buildings are the main style in the project. Groups of buildings clustered in a form of U shape, two U groups and rectangular clustered around an urban courtyard another type is semi closed, see figure (2.19)

Size: the courtyard sizes are between 2000 and 3000 m^2 .

Access: access to courtyard occurs in line with the main axis (Central courtyard radial axis).

Entrance: entrance to the courtyard is done from the space between buildings.

Orientation: the project street take the (north eastern- south western) and (north western-south eastern).

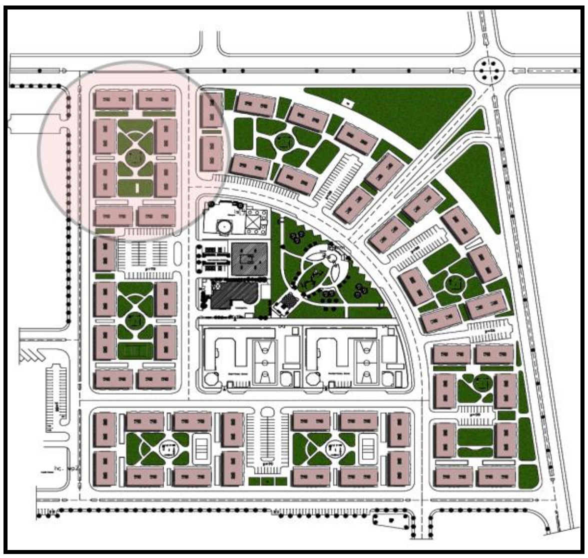


Figure (2. 19): Urban plan of courtyard at Hamad housing project
Source: MPWH, (2014) with adapted

Figure (2. 20): prespictive of Urban courtyard at Hamad housing project
Source: MPWH, (2014)

2.9 Comments and Observations

The following table (2.1) compare between the features of urban courtyard archetype in each project

Table (2.1) comparison between the features of urban courtyard at housing projects

The project	No. of floors	Dimension of courtyard W*L	Height of buildings overlooking courtyard	width/ length ratio	Perimeter/ height ratio	Type of courtyard	Shape of courtyard
	Source: (MPWH, (2014)						
El-Sheikh Zayed housing project	5	36*52 m	16 m	.69	177/16=11.06 **0.11**	Simi Closed	U shape
	5	78*29	16	0.37	214/16=13.37 **0.13**	Simi Closed	U shape
	12	41*36	38.4	0.87	154/38.4=4.01 **0.04**	closed	rectangular
Tal El Hawa Housing Project	8	28*58	25.6	0.48	172/25.6=45.78 **0.45**	closed	rectangular
	8	27*83	25.6	0.32	222/25.6=8.67 **0.086**	closed	rectangular
Al-Firdaws Housing Project	6	32*34	19.2	0.94	130/19.2=6.7 **0.067**	closed	rectangular
	6	34*19	19.2	0.55	106/19.2=5.52 **0.055**	Simi Closed	U shape
	6	19*19	19.2	1	76/19.2=3.87 **0.038**	closed	square
Hamad housing project	5	34*88	16	0.38	245/16=15.31 **0.15**	closed	rectangular
	5	34*78	16	0.43	225/16=14.06 **0.14**	Simi Closed	U shape

The above table shows that there are no standard dimensions or criteria in designing the urban courtyards of housing projects. This means that it was not taken into account the environmental issues of those urban, courtyards; disregard the suitable geometry, the aspect ratio, and the height of buildings overlooking it. But concerning of aspects of planning and population density of the project, where the buildings take the same orientation of the street's project. On another hand there is a trial to combine between the principles of the modern courtyard with the past one pattern and to create another type that achieves the environmental issues.

There is no real planning or criteria in designing the urban courtyards of housing projects. As shown in table (2.1) that the ratio between parameters to the height of buildings vary between 0 .03 to 0.15 .Otherwise the ratio between width and length of the courtyard for semi closed ones were less than 0.5, and the same ratio for closed ones were more than 0.5 until reach to 1.This means that it didn't take any criteria to design those urban courtyards. Consequently it didn't pay attention to the environmental issues of them. This can be referred to the following difficulties:

- The limited financial resources of the Palestinian national authority (PNA) to rehabilitate the infrastructure required to the development and expansion of infrastructure.
- The high growth rate, companied with escalating in the family size and youth contribution to the population pyramid, are a prevalent condition in all areas in Gaza Strip. As for housing projects which formed urban courtyard, there is a lack of diversity in the types of urban courtyard during each project which may result in energy consumption. On another hand there are trials to form an urban courtyard that achieve the environmental issues as in the El shikh Zaid urban courtyard.

Conclusion

The chapter addressed the history of courtyard along ages and the function of it. It was clear that courtyards have a social and environmental role. The chapter mentioned the most courtyard types such as the fully enclosed courtyard, the semi-enclosed courtyard, and the semi-opened courtyard. Then the chapter displayed the parameters of courtyard. The most widely recognized range of width to length proportions are: 1:1.8 to 1:3.6, which depend basically on the sun rays. The environment and urban situation of Gaza Strip also discussed in terms of population density and urban geometry. The chapter outlined the most important actors for the housing sector in the Gaza Strip such as the Ministry of Works and Housing and the Council of Palestinian housing in addition to cooperative housing societies.

The most important projects implemented urban courtyards, such as (El-Sheikh Zayed housing project, Tal El Hawa Housing Project, Al-Firdaws Housing Project, and Hamad housing project) were identified and analyzed. At the end of chapter, the researcher showed the situation of the urban courtyard in the housing projects of Gaza Strip and concluded that there is no real planning or criteria in designing those urban courtyards which didn't take into account the environmental issues. Thus the next chapter will discuss thermal performance of urban courtyards.

3 CHAPTER 3: Thermal Performance of Urban Courtyards

3.1 Introduction

A building design can be considered a successful one if its thermal performance is taken in account. Energy efficient design aims to provide the most comfortable environment for occupants and thus minimizing the energy demand for cooling and heating requirements. Thermal performance of courtyard has been investigated by many researchers such as Mohsen (1978), Etzion (1995), Cadima (2000), with special evaluation concerning the influence of the geometrical and physical parameters of the courtyard on the solar radiation. They deal with the heat flow between buildings and outdoor environment, which can be expressed as heat gain and heat loss.

Yang et al, (2012) developed a temporal 3D air and surface temperature model and simulated a courtyard located in Beijing to understand the energy exchanges in an ideal courtyard. He revealed that increasing a courtyard height, thermal mass and material conductivity intensify the nocturnal micro-scale heat island effect in summer. Increasing thermal mass, surface reflection and conductivity efficiently reduce the peak temperature during daytime, which leads to a micro-scale urban cool island phenomenon in winter time. The conclusions of all these studies recommended protection of the form's surfaces and its surroundings from intense solar radiation and the hot dusty wind.

This chapter will display an overview of thermal performance, and it will explain the mechanism of heat transfer between the building and the external environment, which include conduction, convection and radiation. It will present the thermal balance of buildings and thermal comfort. It will display the factors affect the thermal performance, which are environmental factors and human ones. In addition, this chapter will be talk about urban courtyard its history and types. It will discuss the dimensions and geometry of urban courtyards. Finally, it will display the thermal behavior of urban courtyard and the geometrical parameter of it.

3.2 Thermal performance overview

Thermal performance can be considered as one of the most essential pillars for energy utilization in buildings. As a result of that foreseeing the thermal performance through heat transfer mechanisms is necessary for enhancing the indoor conditions. (Zain et al. 2007).

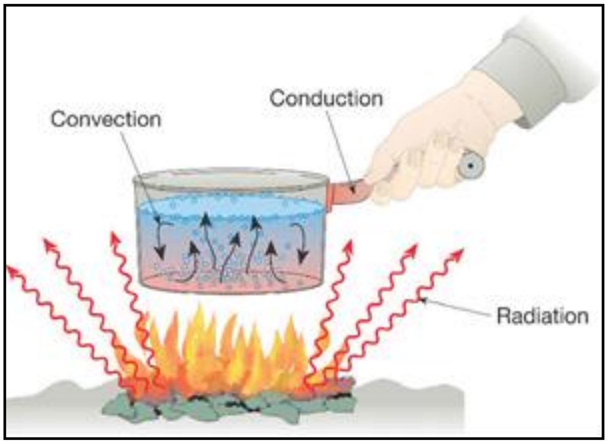
This section will display a general review and definitions of thermal performance, the mechanisms of thermal transfer, thermal balance of buildings, thermal comfort in buildings, and factors influencing human comfort inside buildings.

3.2.1 Definition of thermal performance

The thermal performance of a building means the process of modeling the energy transfer between a certain building and things that surround it, for a conditioned building, it estimates the heating and cooling load. From this, the size and the selection of HVAC equipment can be made in the right way. As for a non-conditioned building, it calculates temperature variation inside the building over a specified time and helps one to estimate the duration of uncomfortable periods (Zain et al. 2007).

3.2.2 Mechanism of thermal performance

As heat is known to be transferred between objects because of difference in temperature, it moves from the hot object to the cool one. (Roos, 2008). Three heat mechanisms which are conduction, convection, and radiation are hired in the passive solar buildings in such a way to control the process of distributing heat throughout the building .Figure (3.1) explains the three ways. (NREL, 2001).



Figure(3. 1)The three heat transfer
Source: NREL, 2001

a. Conduction

Heat can be transferred from one molecule to another in contact such as in solids liquids and gases. Conduction can be also defined as the process of heat transferring from one part to another in the same object. **(**Nayak et al., 2006).

b. Convection

It is the transfer of heat between a solid and a liquid or gas nearby in motion. (Roos ,2008). Heat transfer by convection takes place at the surface of the walls, floors and roofs. As there will be a difference in the temperature between the fluid and the surface contact, there will be a density variation in the fluid resulting in buoyancy,(Mahlia et al., 2007).

The convection is resulting from two ways; the difference in the temperature between zones (natural convection) and the other resulting from the movement of air by mechanical means (forced convection) in both cases convection is the main reason for the distribution of heat within the zones. **(**Nayak et al., 2006). In addition, the type of materials used in the building play an important role in convection.

c. Radiation

Radiation is considered the electromagnetic waves which move in the space. (Nayak et al, 2006). This is the way that the heat of the sun reaches the earth. Radiation can be transferred into the solid objects while it passes through the transparent surfaces as glass or air; here the color of the surface and its transparency play an important role in deciding the percentage of solar radiation absorbed, reflected, or transmitted, depending on certain properties of that object,(Roos, 2008).

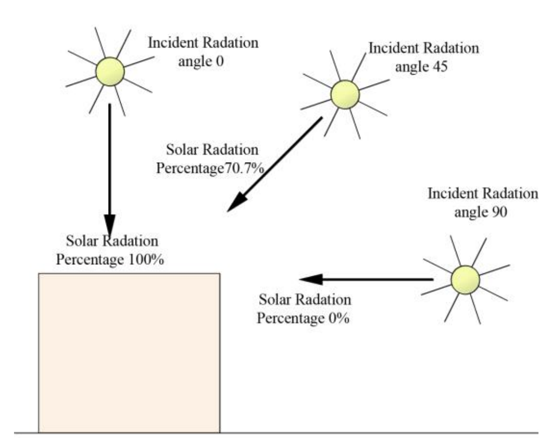
The solar radiation, which also called global solar radiation, is divided into three different components: the direct-beam component, the sky-diffuse component and the reflected diffuse component (reflected from the ground and the surroundings).

Direct radiation refers to the solar radiation arrives the earth's surface by passing straight through the atmosphere without any scattering in its way through the atmosphere. Diffuse solar radiation also refers to the solar radiation which is scattered by moisture vapour and small airborne particles. In addition, reflected solar radiation describes the incident solar radiation which is reflected back into space from clouds and atmospheric dust, and some reflection occurs at the surface of the earth such as water, snow and sand) (Vogel, 2004).

The amount of solar radiation reaching the earth's surface varies depending on three factors. First, angle of incidence, second factor of variations in cloud cover and pollution, and third, the duration of sunshine. The solar radiation during summer is expected to be more than during winter because the length of daylight hours) (Szokolay, 2004).When sun shines from east and begins to move to south, its radiation and intensity become greater gradually. However the effect of sun rays on south façade is low compared with east façade because of parallel sun rays to south in midday, the solar radiation intensity is the greatest in this period. Before reaching solar altitude angle to its perpendicularity on building roof, its radiation still effective on south of eastern façade. It can be seen in table (3.1) that the larger incident solar radiation angle on surface is the lower solar radiation percentage on this surface is.

Table (3. 1) The relationship between incident solar radiation angel and solar radiation percentage, (ministry of local government, 2004) with adaption

Incident solar radiation angel on surface	Solar radiation percentage	Incident solar radiation angel on surface	Solar radiation percentage
0°	100	55°	57.4
100	5°	70.7	50°
99.6	10°	50°	64.3
98.5	15°	55°	57.4
96.5	20°	60°	50.0
94.0	25°	65°	42.3
90.6	90.6	70°	34.2
30°	86.6	75°	25.9
35°	35°	80°	17.4
81.9	40°	85°	8.7
76.6	45°	90°	0.



3.3 Factors Affecting Thermal Performance of Buildings

Nayak and Prajapati (2006) summarized the factors which affect the thermal performance of a building such as design variables, material properties, weather data and a building's usage data.

3.3.1 Design Variables

a. The Form of Buildings

Buildings are considered the main accountable for indoor thermal conditions because they form the main contact between indoor and outdoor environment. The building form determines the size and the orientation of the exterior envelope exposed to the outdoor environment. Selecting the optimum shape, orientation, and envelope configuration can reduce the energy consumption by about 40% (Wang et al., 2006).

b. Building Orientation

Many factors must be taken into consideration during the selecting of building orientation. They include the expected shading impact and the sun movements according to latitude, time of day and time of year (Goulding et al.,1992).

The building orientation can affect the building thermal performance by minimizing the direct solar radiation into the buildings envelops either building openings or opaque walls (Al-Tamimi et al., 2010). This is important to the Gaza climate as it characterized of sunny days most of the year.

c. The Envelope of the Building

Building envelope has a great effect on both indoor and outdoor space condition (Goulding et al. 1992). It is one of the principal components affect the total heat gain and overall heat transfer coefficient. It was found that the building envelope accounts for 36%, 25% and 43% of the peak cooling load in Hong Kong, Singapore and Saudi Arabia respectively (Al-Tamimi et al., 2010). So, it is important for the building envelopes to have a level of thermal resistance so that avoiding the penetration of water vapor inside the buildings (Matrosov et al., 2007).

d. Shading Devices

Shading devices have a useful impact, especially, in Mediterranean and semi-desert climates. The time of the relative transparency of the materials, and the period of the year can affect the shading (Goulding et al., 1992). In a study of Al-Tamimi and Fadzil (2011), it is concluded that selecting the best shading devices can improve the number of the comfortable hours by about 26% and 4.7% in unventilated and ventilated conditions, respectively in the tropics.

3.3.2 Material Properties

Material properties of buildings components play a fundamental role in controlling the process of heat transfer. Thermal conductivity, thermal resistance, thermal transmittance and density are the most important thermal properties which will be defined as following.

a. Thermal Conductivity λ

The thermal conductivity is a property of the material, which describes "the quantity of heat per unit time in watts, that flows through a 1m thick even layer of material with an area of $1m^2$, across a temperature gradient of 1 K (Kelvin) in the direction of the heat flow" (CSR Hebel Technical Manual, 2006). The less thermal transmission, the lower value thermal conductivity will be (Mahlia *et al.* 2007).

b. Thermal Resistance of a Material, R

The thermal resistance of a material may be defined as "the time required for one unit of heat to pass through unit area of a material of unit thickness when unit temperature difference exists between opposite faces" (Code on Envelope Thermal Performance for Buildings, 1999).

It is the resistance to heat flow between two surfaces at different temperatures. It can be expressed as the R-value which is a function of the material thickness and the reciprocal of its thermal conductivity (CSR Hebel Technical Manual, 2006).

c. Thermal Transmittance, U

It can be defined as "the quantity of heat that flows through a unit area of a building section under steady-state conditions in unit time per unit temperature difference of the air on either side of the section" (Code on Envelope Thermal Performance for Buildings,1999).

The thermal transmittance, U is a direct measure of the thermal insulating ability of a given building component air to air. It is obtained by reciprocating the total thermal resistance of the building component, R (i.e., U = 1/ R) (CSR Hebel Technical Manual, 2006).

d. Density, Porosity

The density, p (kg/m3), is "the mass of a unit volume of the material, comprising the solid itself and the gas- filled pores" (Harmathy, 1988). It plays a great role for the thermal properties; the lighter the material the more insulating and the heavier the more heat storing (Rosenlund, 2000).

3.3.3 Climatic Factors

The climatic factors can affect the design operation of buildings envelop in order to achieve comfort and save energy. It is important to understand the general climate of the region and the microclimate to achieve the desired aim,(Ridley, 1990).

a. Solar Radiation

Solar radiation is the most weather variable influences the air temperatures. It consists of direct radiation (ID) and diffuse radiation disparate by the sky conditions. Also reflections from the ground and adjacent buildings, shading from adjacent buildings and vegetation affect the solar radiation,(Rosenlund, 2000).

b. Winds

Wind affects the convective heat exchanges of a building envelope and the air infiltration (Nayak et al., 2006). It is important to avoid the effect of winter wind which increase the infiltration heat loss and utilizing the summer wind in encouraging ventilation (Ridley, 1990). Topography, vegetation and buildings configuration are factors which affect the wind, (Rosenlund, 2000).

c. Humidity

ASHRAE Standard 55P (2003) defined the relative humidity RH as "the ratio of the partial pressure (or density) of the water vapor in the air to the saturation pressure (or density) of water vapor at the same temperature and the same total pressure". The acceptable rate of humidity differs according to the climate. While a low rate of humidity is preferable in dry climates, it causes discomfort in tropical climate regions, (Biket, 2006).

3.3.4 Building Occupancy and Operations

Buildings produce heat from their occupancy, lights and equipment's. Occupancy densities and types of activities affect the total heat gain. It can be expressive in crowded spaces (Goulding et al., 1992). People give off the heat of metabolism to maintain a constant body temperature. Equipment and electric lights and give off heat to the building equal to the electrical energy they consume (Utzinger et al., 1997).

3.4 Thermal balance of buildings

To decide the thermal situation of a building, first add up all the different sources of heat gain within and around it, and then subtract off all the sources heat loss. If the gains are greater than the losses, then the building will gradually heat up - requiring some sort of helping cooling in order to get a steady internal temperature. Likewise, if losses are greater than gains, the building will gradually cool down - requiring some additional heating.

Thermal balance takes place when the sum of all the different types of heat flow into and out of a building is zero. That is, the building is losing as much heat as it gains. It takes into consideration five components of the heat gain which are conduct through an opaque surface, conduction through glass window, solar radiation through glass window, the internal heat gains and the air exchange via ventilation or infiltration,(Nikpour et al., 2011),see figure (3.2).

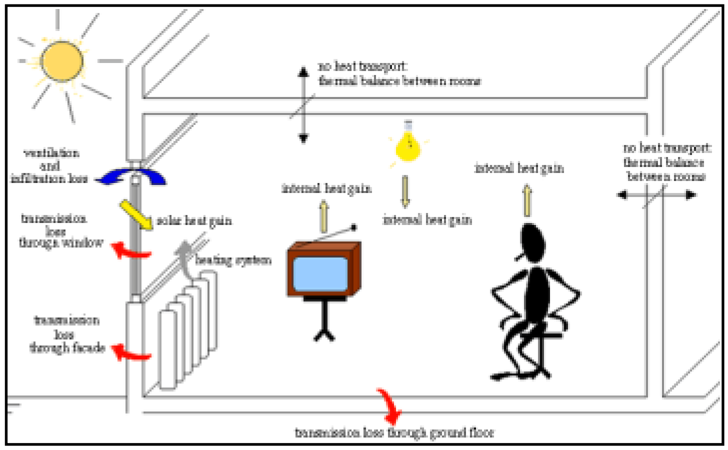


Figure (3. 2) Sources of heat gain and heat loss in buildings
Source: CLEAR comfortable low energy architecture, (2011)

3.5 Thermal Comfort in Buildings

Ampofo (2004) defined the comfort in the building as the range of climate conditions within which the majority of people would not feel thermal discomfort, either hot or cold observed that a comfort in building varies from individual to another depending on age, sex, clothing worn, type of activity performed and geographical location.
Thermal comfort is a vital parameter in passive solar buildings in which solar energy is collected, stored and distributed (Goulding et al. 1992). A group of people, who exposed the same climatic conditions of the same room, may not feel comfort at the same time due to the physical disparity (Çakir, 2006).The researcher agreed with Ampofo definition as it includes all factors of comfort whether the personal factors or the physical ones.

3.5.1 Factors Influencing Human Comfort Inside Buildings

Many variables affect heat dissipation from body, thus thermal comfort. These variables include environmental factors, personal factors, and other contributing factors, (Szokolay, 2008). Basically, the comfortable temperature ranges from 19C° to 28C° to optimize indoor thermal comfort for people. This temperature range is appropriate for the sedentary or near sedentary physical activity levels that are typical of general office work, (Department of Labor, New Zealand, 2007).This section displays two factors which affect the human comfort inside the buildings environmental factors and human factors ,figure (3.3) show these factors.

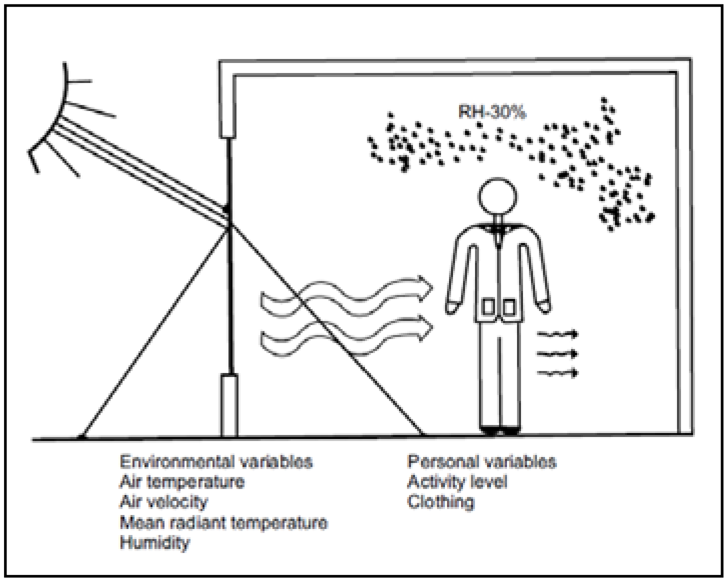


Figure (3. 3)Factors influencing human comfort inside buildings
Source :(Ministry of local government, 2004)

a. Climatic Factors

Climatic factors are the same ones which affect the thermal Performance of buildings as mentioned them before.

b. Personal factors

Thermal discomfort may not cause an immediate health and safety problem, but it will affect morale, and feelings of tiredness and irritability, this may lead to a lack of productivity. There are several personal factors which relevant to thermal comfort, including general state of health. Physical fitness, along with some medication, affects one's ability to adapt to small variations in the surrounding temperature, and so it can affect one's thermal comfort. (Department of Labor, New Zealand, 2007).

- **Metabolic rate (activity)**

Most people daily activity consists of a mixture of specific activities and/or a combination of work and rest periods. A weighted-average metabolic rate may be used, provided that the activities frequently alternate, i.e. several times per hour. The unit used to express the physical activity of humans is the met. Where 1 met = 58.2 $W.m^2$. (CIBSE Guide A, 1999).

- **Clothing**

Clothing is the most controllable factor that assists people to lose body heat when they are feeling warm, and to retain it when we are cold, (Department of Labor, New Zealand, 2007). Clothing level is measured in "col" value, 1 clo = 0.155 $m^2.KW_{-1}$, (CIBSE Guide A, 1999).

3.6 Thermal behavior of courtyard

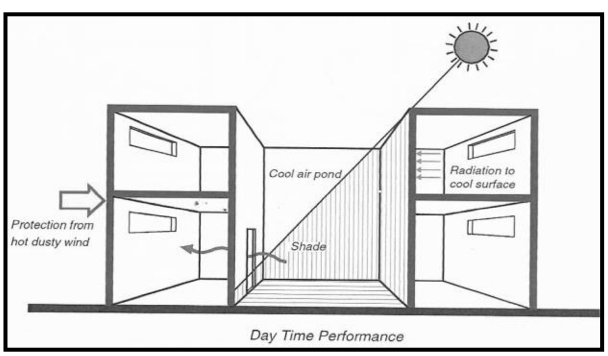
For a long time up to this point the courtyard has been a standout amongst the most claims to fame types of private tasks in warm and dry atmospheres Muhaisen, (2006). The inhabitants of such atmosphere exploit the courtyard to serve as a gatherer of cool air around evening time and a wellspring of shade in the daytime (Safarzadeh et al., 2005).
The Thermal performance of the courtyard house comprises heat exchange processes taking place among the environments of three interrelated spaces; the indoor spaces, the courtyard space and the external open spaces between houses considering the indoor environment, heat are exchanged through:

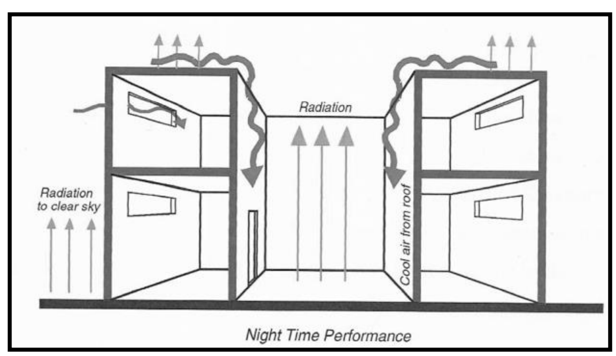
1. The inner envelope.(courtyard walls).
2. The outer envelope (external walls and roof).

The different surfaces of the two envelopes are constantly exposed to the outside air temperature; however their exposure to solar radiation varies with time. This means to control the exposure to solar radiation. In such control, the inner envelope is more critical since most of the openings are located there. Regarding the physical system, which represents the impact of solar radiation upon the indoor space passing through the inner envelope, the two subsystems are identified. The external system deals with:

- The insulation of the courtyard surfaces which is a joint function of the sun's geometry and the courtyard geometry.
- The thermal balance of the surfaces as affected by the incident radiation

The internal system deals with the heat flow taking place through the opaque as well as transparent materials of the envelope. When outdoor conditions are very severe, the system has to resist thermal gains, minimizing hot air infiltration, solar radiation and heat conduction and to thermal losses through earth cooling, ventilation, radiant cooling and evaporative cooling(Scudo,1988), see figure (3.4)





Figure(3. 4) Thermal behavior of courtyard
Source: Scudo(1988)

3.6.1 Thermal Comfort Functions of the Courtyard

Since the 1980s, investigations of warm solace in the open air environment have developed in number as a result of expanded consideration for walkers in urban squares and squares. This prompted an extraordinary number of inquiries about tending to microclimate outline parameters focused around people on foot's warm comfort.(Taleghani, 2013), and the urban courtyard for lodging ventures.

Urban courtyards in lodging tasks are normally encompassed by residences spatially, and socially. Warm solace is influenced by a few elements like building introduction, shadowing, geometry of the yard and the viewpoint degree. Courtyards are created looking into those elements. Additionally, the normal sizes of the courtyards are by and large decided as per the scope. These yards can give security and an agreeable spot for the inhabitants. They are normally planted with trees, and bushes, not just to give agreeable condition and social spot, additionally to shade spaces abutting, and expand the relative dampness of the courtyard; consequently this pondered the encompassing structures. (Khan, 2003).

a. Orientation:

On this subject, courtyard squares were mulled over in a few introductions tending to diverse profits. Herrmann and Matzarakis (2012) mimicked urban yards with distinctive introductions in Freiburg, Germany. They demonstrated that the mean brilliant temperature (Tmrt) was most noteworthy for NS and least for the EW introduction at midday and during the evening. Amid the night, the mean brilliant temperatures were very much alike, however the introduction of the courtyard influences the time of the first increment of Tmrt in the morning, because of immediate sun.

An alternate study was carried out by Yezioro et al. (2006) they made broad study on urban courtyards at a scope of 26–34 moel by utilizing the SHADING project. They presumed that, for cooling purposes, the best bearing of a rectangular courtyard was North– South (NS, i.e. with the more extended veneers on East and West), took after by Nw–se, Ne–sw, EW (in a specific order). They found that the NS course had the most brief length of time of immediate daylight in the inside of the courtyard. This result is as per atmospheres in which less sun is attractive.

Also, the courtyard might be controlled to accomplish the satisfactory introduction in plots that are formed by the lanes arrangements or can't be arranged appropriately. (Koch et al., 2002).

The introduction, as indicated by Koch-Nielsen,(2002) ought to be focused around the building cooperation with the sun and the predominating wind. The best power of sun based radiation is gotten by the flat surfaces, though the east and west-bound surfaces get the most sun oriented radiation among the vertical surfaces. The east-bound vertical surfaces get the radiation in the early morning while the west-bound surfaces get it in the late afternoon.

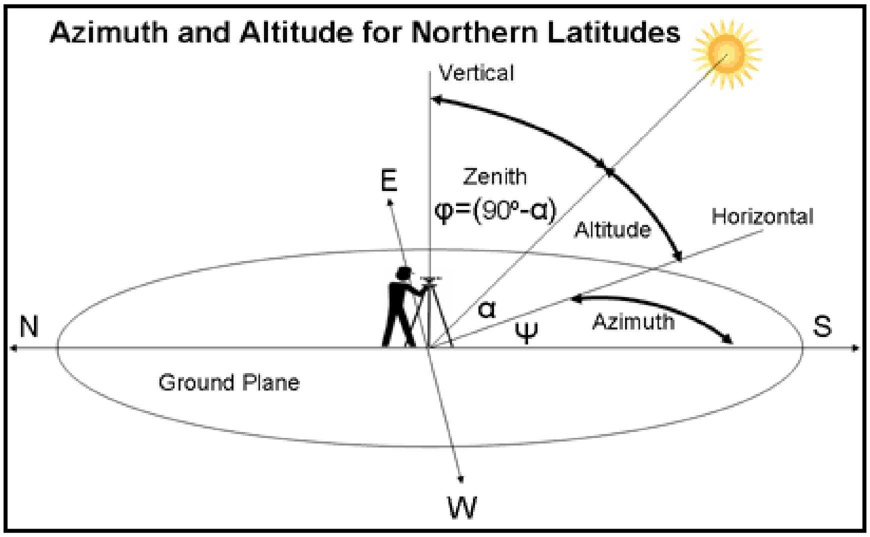
The introduction has additionally steer impact with the ventilation or wind speed. For example, Meir, et al. (1995) has presumed that the right introduction of courtyard can enhance their warm solace; generally, turning them paying little heed to sun based points and wind course may make warm distress. As per climatic conditions for each one region, particularly for the predominant winds development of sun in the bearing and territory of window administered inwards or outwards were mulled over.

b. Insolation

Good sun exposure is essential to the house as long as the dwelling has an appropriate design. Thus the traditional house builder had to take the sun into account from all parts of the house, in all rooms and at different times of the day. Correct orientation required the designer to study the movement of the sun in summer and winter and in relation to plan and sectional arrangement. It was important to ensure that sunshine was a benefit without the harmful effects of excessive temperature and glare. The courtyard has to perform well under the rotation of the sun, see figure (3.5) the succession of the seasons.

The sun projection angles can be measured in the following ways:

- The sunbeam angle, this is the vertical angle between sunbeam and its horizontal shade.
- Sun azimuth angle, this is the angular distance extending from the sunbeam shade to the north in a clockwise movement.
- Knowing the sun projection angles at different times through the equinox and solstice periods allows the architect to anticipate the degree of solar penetration in the different spaces of the house. Generally speaking it is preferable for the orientation of the courtyard to be on the east-west axis, i.e. the longitudinal elevation should be to the north, for the following reasons:
    - The sunlight projection should be towards the longitude elevation (i.e. the south).
    - The southern elevation takes the largest amount of heat in the cold period and lesser amounts in summer because of the high angle of the sun. Hence it benefits from solar gain in winter and can be shaded effectively in high summer (Edward.et al, 2006).



Figure(3. 5) Altitude and azimuth angles
Source : (Szokolay, 2004)

c. Shadowing and shading devices

Urban courtyard speaks to a wellspring of common lighting for the encompassing building and also the conventional courtyard house does. This territory is not presented to the sun's beams even in every hot times because of the accessible trees planted in the yard, which influence emphatically on the encompassing building .This courtyard allows the evacuation of hot air and upkeep of cool air inside the courtyard; and generally keeps the coolness of encompassing spaces (Gedik, 2004). Likewise the shading gadgets are divider insurance systems, which can decrease the sunlight based radiation and glare, and subsequently minimize the hotness pick up into the building show figure (3.5). As formerly said, as to the introduction, the east- and west-bound dividers are presented to the most elevated sun based radiation amid the day. Hence, fitting vertical shading gadgets ought to be connected on the grounds that the sun passes on low plot in the early morning and late evening, where the north- and south-bound dividers are presented to somewhat sun based radiation. In this manner and because of the high sun holy messengers, flat shading gadgets ought to be coordinated as indicated in figure (3.6),(Koch, 2002) On the other hand, shading gadgets ought to be made of light and high-reflectivity materials to keep away from hotness assimilation.

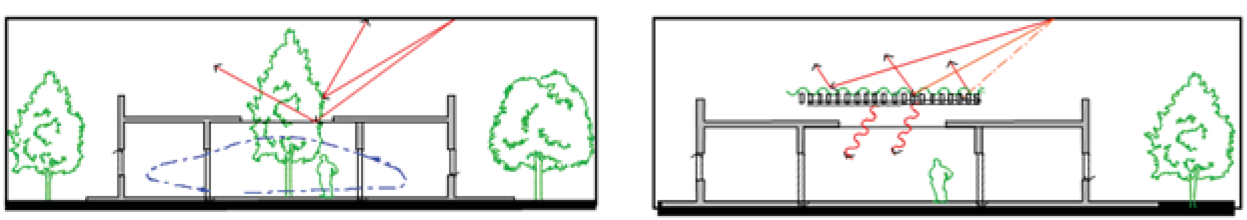


Figure (3. 6) Thermal value of courtyards in enhancing cross ventilation through shadow casting.
Source: (Mikler et al., 2008)with adapted

d. Geometrical parameters of courtyards

The states of courtyards these days have taken more dynamic structures other than the rectilinear states of the conventional ones, because of a few variables, for example, site confinement, and particular capacities. This has brought about formation of new and current shapes exemplified as U, L, T or Y (Saeed, 2007). As indicated by Meir (2000) a great current yards are semi-encased (three or two sided) with great thought on its introduction, as said before to boost its microclimatic execution. On this issue, Steemers et al. (1997) recommend six original nonexclusive urban structures for London and looked at the episode sunlight based radiation, manufactured potential and sunshine affirmation. They presumed that extensive courtyards are earth satisfactory in frosty atmospheres, where under distinctive geometrical conditions they can go about as sun concentrators and hold their protecting impact against chilly winds. Different creators have made comparable perception, for example, Muhaisen and Gadi (2006) they inferred that profound and long courtyard structures brings about less vitality utilization because of the shading impact. Generally the shallow courtyard structures is hence more qualified for frosty atmosphere as it will expand the sunlight based addition and results with less warming loads in winter time. The application of courtyard that slights its essential outline qualities and position would influence its possibilities. The outline variations that are said to influence its execution incorporate its arrangement and viewpoint degree, introduction, limit conditions and level of presentation, and divider sorts (Reynolds, 2002).

e. Airflow and Ventilation

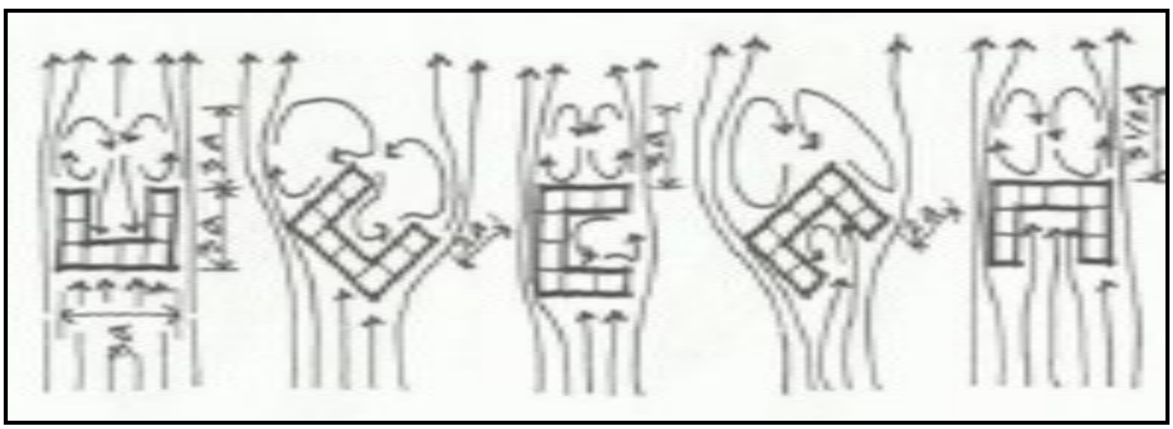
Courtyard manufactured structure is a successful aloof method for cooling in hot bone-dry climatic locales as they describe with substantial diurnal temperature swing. An uprightness of the courtyard configuration is that chilly breeze is accessible paying little heed to wind bearing as the wind will disregard and make low weight in the courtyard.

Regular Ventilation is the methodology by which spaces trade indoor air with outside air without the utilization of any mechanical framework. This could be actuated by wind impacts by which air is determined through or out of the space by means of windows or different openings like louvers, gaps and so forth. Air development can likewise be actuated by lightness coming about because of the contrast between the thickness (because of temperature contrasts) of the quality of the indoor and outside space. The lesser the thickness of the air the higher it will climb. For ventilation openings are not used to expand the diminishment of stickiness in the inside spaces of the ground carpet of the customary inner part courtyard houses in light of the fact that there are no openings outside that guarantee the development of the air (Gedik, 2004).

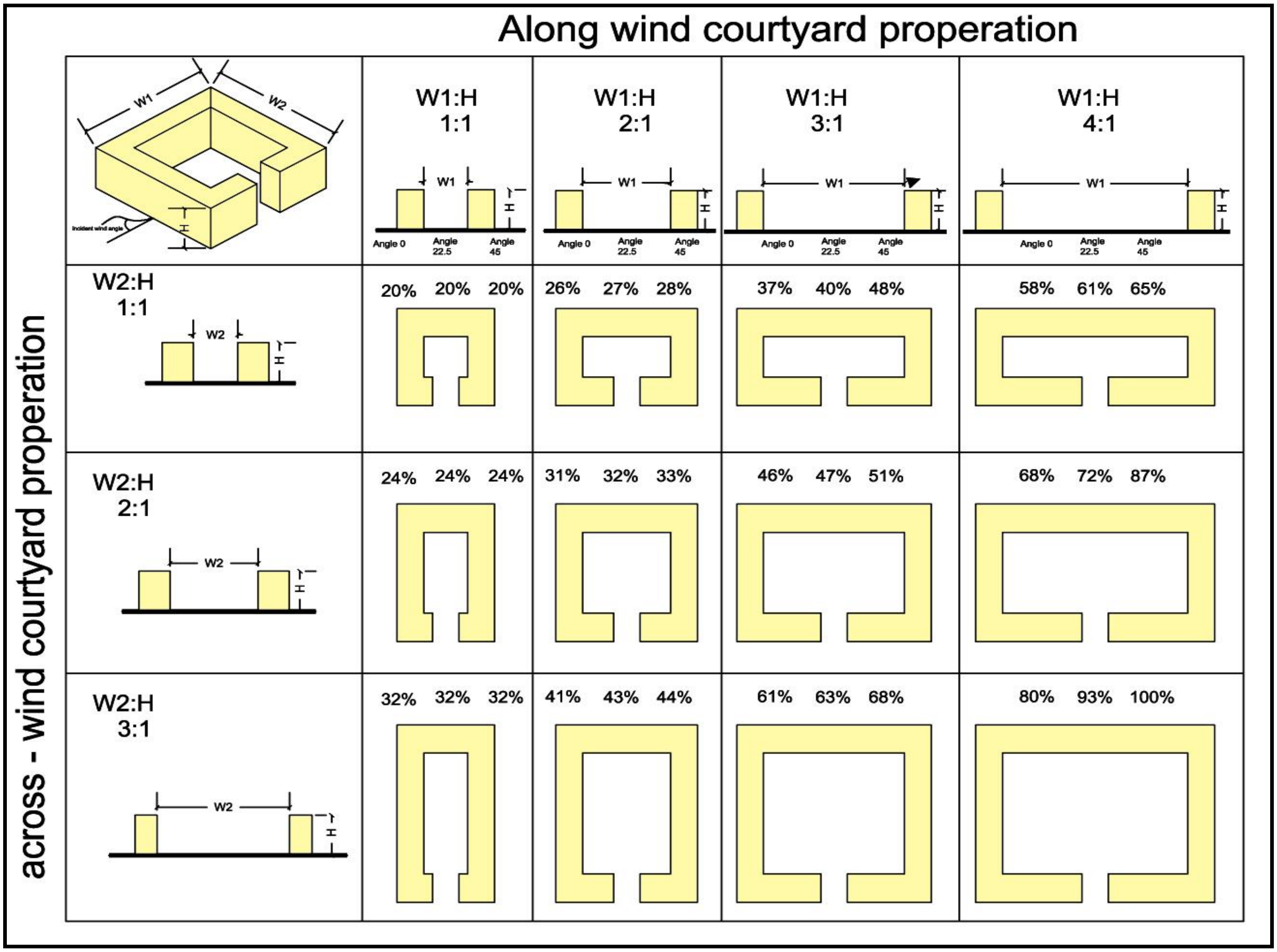
Regular ventilation and wind stream is achievable in two structures; cross ventilation and stack impact. Cross ventilation is a wind-produced weight contrast via air development from the opening over the space. The stack impact is a temperature-created weight contrast by hot air climbing around the top opening permitting chilly air to settle at the base.

Because of sun based radiation, daytime hours the courtyard warms up rapidly making a stack impact because of temperature contrasts. On the other hand, the stack impact might be viable when outside temperatures are cooler than inside with a base contrast of 1.7^{o}c (Kwok ,2007).

Then again, an alternate intend to build the stack impact is by expanding the courtyard stature and by expanding the separation in the middle of high and low ventilation openings. It is in suggestion that the openings are at distinctive statures with a region for the channel and outlet at least 3-5% of the floor zone (Koch ,2002). Cross ventilation increments by substantial opening leeward surface and little opening on the windward surface. Likewise, wind would increment inside the courtyard and cross ventilation would increment by arranging the courtyard 45^{o} from the predominating wind orientation and assembled structure setup impacts air development by the making of swirl zones, see figure (3.7) , Nevertheless, yard measuring for ventilation and putting openings influences the wind speed rate inside the courtyard. Figure (3.8) shows that wide courtyard have high wind speed in rate, yet by expanding the length of the yard the wind rate additionally increments. Restricted and tall courtyard makes wind safe house, (Brown 1985).



Figure(3. 7) Configuration and orientation effect
Source :(Brown 1985).



Figure(3. 8) Sizing courtyard for ventilation
Source :Researcher

3.7 General Guidelines for Improving the Thermal Performance of the urban courtyard elements

The courtyard structure is utilized within diverse climatic areas as a climatic modifier disregarding the distinction in the general methodologies to attain comfort in each of them. Conventional assembled structures in the considered areas demonstrate that yard configuration was adjusted to direct climatic powers and to attain comfort in the diverse atmospheres. This was attained through outlining the courtyard with suitable extents, introduction and medicines of interior surfaces. Amid the icy period, such a space is utilized as a warm cradle, serving to lessen heat misfortunes from the building while amid the warm period; it helps control sunlight based access, going about as a shading segment.

With regard to solar radiation control in the different inspected area, the outline procedure for the warming season ought to mean to concede sun powered addition and, at whatever point conceivable, use intends to store it. In this way, this high temperature can then be dispersed now and again when open air temperatures drop. Solar access is consequently a vital necessity for the warming season. Outline methods for the cooling season ought to go for controlling high temperature additions and disseminating overabundance warm by regular means.

3.7.1 Design Parameters

Geometry, finishing, overhangs and limit medications are considered the principle plan parameters to enhance the courtyard's execution, latent warming depends basically on the accessibility of sun based access. The high temperature put away in the building's structure and in finishing components amid daytime is discharged around evening time by long – wave radiation towards the sky. The rate of this collected hotness misfortune relies on upon the setup. And the thermal properties of the boundaries, as well as on air movement, (Hakmi, 2006).

Vegetation, water bodies, the ground and the building structure might be utilized as high temperature sinks, and hotness could be exchanged by long-wave radiation, vanishing, convection and conduction. Any measure for detached cooling is enhanced with shading. Shading might be attained with the utilization of shelters and finishing, or by the space geometry, which may give dominating by manufactured volume, (Hakmi, 2006).The most relevant strategies to improve comfort in the courtyard space are discussed below.

- **Geometry**

The courtyard geometry has a huge impact on the measure of received sun oriented radiation and wind designs. Geometry is an essential parameter for natural configuration since it changelsess measure for wind and sun based control. Solar penetration in a courtyard form is more controllable than air development. This is on the grounds that the sun powered geometry and radiation are more unsurprising than the wind developments. This makes flexible and adaptable answers for sun based control simpler to work than answers for controlling wind.

Air velocity could be controlled by geometry, arranging or the utilization of different sorts of wind screens. On the other hand, it is vital to verify that ventilation in a courtyard is not totally blocked. Any configuration technique to enhance comfort in courtyard spaces ought to consider sun based control. This incorporates the control of geometry, finishing and the utilization of shading gadgets. The introduction of a courtyard space characterizes the position of the vertical surfaces encasing the structure in connection to the sun. The southern introduction (in the northern half of the globe).Contrasted and different bearings, offers incredible accessibility of solar radiation for the duration of the day and year. Be that as it may, in summer, a southern introduction typically needs extra shading dividers, close-by structures, geology, planting or other urban components. Solar control with arranging and the utilization of shading overhangs are analyzed in the area beneath, (Muhaisen, 2005).

- **Landscaping**

Landscaping is an essential gadget for making the courtyard a more alluring and average space. Landscaping components, pools, fountains, trees, shrubs, flowers, lawns, etc., respectably enhance the courtyard environment, bringing about a noticeable improvement setting for outside exercises. These components likewise help in conveying, reflecting and retaining light. Finishing with vegetation and water surfaces can diminish occurrence sun powered radiation and change the air temperature around the structures, while likewise diminishing the cooling heap of encompassing structures, (Yahia, 2014).

Utilizing plants is an extremely compelling system for adjusting the microclimate and this additionally has a valuable effect on the urban atmosphere. Trees, shrubs, flower-beds, lawns, climbing plants on dividers and pergolas are among the wide assortment of vegetation sorts utilized for finishing. Other than its stylish offer, vegetation can give an average cool shade and serves to build the air relative dampness. The trees and bushes in the urban courtyard give more shade on the floor and, bringing about a lower surface temperature and at last a lower air temperature. In hot humid climates, the adverse effects from increased humidity due to the evapotranspiration process should be taken into consideration, especially when plants are grown near ventilation inlets (Chenvidyakarn, 2007). According to Giridharan (2008) there are four characteristics of vegetation affect both indoor and outdoor thermal conditions in any location which are density of plants, types of plants, size and shape of trees and shrubs, and locations of plants, trees, etc.

- **The Use of Water**

Water has been utilized as a part of transitional spaces for a considerable length of time as a methods for both evaporative and sensible cooling. Fountains, waters ponds, water-films, cascades, lakes, canals, pools, ponds, sprinklers, water-sprayers and other irrigation methods are among the different frameworks utilized, either to improve evaporation or to cool imparting surfaces, Water has an incredible impact on the atmosphere on the grounds that it is constantly transforming starting with one state then onto the next (strong, fluid, gas). As it passes through the hydrological cycle, high temperature is constantly being delivered and assimilated, which has a directing impact on the courtyard microclimate, (Muhaisen, 2005).

- **Canopies**

A canopy is a blanket component or segment utilized for blocking solar radiation and for giving shading. A shading gadget influences the measure of sun powered radiation entering the space and striking the forms interior surfaces. Consequently, it helps lessen hotness picks up from sun oriented radiation, on the other hand, it might additionally diminish the rate at which high temperature picks up as of now inside the space can be dispersed to the sky. The outline parameters of the shading gadget, for example, shape, measurements, situating, material and color, are vital for controlling the ecological execution of the range underneath. The size and state of the cast shadow is affected by the state of the shading component.

Generally the surface temperature amid the day is higher than that of the surrounding air, contingent upon shade. This prompts expanding the forced brilliant high temperature on individuals who stay in the shade, (Muhaisen, 2005).

- **Ground**

The ground of the courtyard space is normally cleared with material, for example, stone or tiles or is secured with grass. The temperature of the ground influences the brilliant expansion in the courtyard space and thus the temperature of the air above, influencing the inhabitant's warm solace. With a crest surrounding air temperature of around 360c, the surface of a traditional brilliantly hued asphalt can achieve temperatures very nearly as high as 450c if presented to sun based radiation while, if shaded, it may stay underneath 350c (Cadima, 2000). For diminishing the ground surface temperature, it is attractive to shade it through space geometry or a shelter component.

Conclusion

This chapter investigated the thermal performance definitions. It illustrated the mechanism of thermal performance, since there are three heat mechanisms which are conduction, convection, and radiation are hired in the passive solar buildings. In addition, the chapter summarized the factors which affect the thermal performance of a building such as design variables, material properties, weather data and a building's usage data.

The chapter outlined the responsive buildings strategies for climate and energy in term of thermal comfort and reducing energy consumption. Generally, human behavior and microclimate in urban spaces is the most important factors that lead the designer to the best techniques of passive solar design. Also, the chapter outlines the thermal behavior of courtyard.

In the end, the chapter displays general guidelines for improving the thermal performance of the urban courtyard elements concerning on the design parameters such as, geometry, landscaping, use of water, canopies, and ground. These elements can integrated into building design and urban courtyard design which contribute effectively to reduce the energy consumption.

4 Chapter 4: Solar Performance of Urban Courtyard

4.1 Introduction

The buildings which form the urban courtyard affect the parameter of the courtyard, so number of buildings and the arrangement of them play a role of specifying the urban courtyard.

In the first section the study concentrated on the most common arrangement of buildings in the housing projects which make urban courtyard at the Gaza Strip. There were six categories, started with three buildings to eight buildings. In order to provide a full understanding to these integrated parameters, this chapter will be divided into 3 sections. The first section will study the amount of incident solar radiation to the overlooking facades and the floor of the courtyard in summer and winter for each category to choose the best model, as it affects the thermal condition of the buildings overlooking the urban courtyard.

The second section will study the amount of incident solar radiation per m^2 (facades and floor of courtyard) for the best models by calculating of each categories to compare between them then choose the best one. To validate the result of the best model the percent of sunlit at the building's facades and the floor of courtyard will be calculated by using ECOTECT program and IES software.

The third section will study the effect of orientation for the best model by calculating the amount of incident solar radiation when changing the orientation of the model to select the best orientation.

4.2 Tools and validity

Energy simulation tools are increasingly used for the analysis of energy performance of the buildings and the thermal comfort of their occupants. Today, multiple tools are available and they differ in many ways; in their thermodynamic models, their graphical user interfaces, their purpose of use, their life-cycle applicability, and their ability to exchange data with other software applications. Choosing simulations tools for any study depends on the objectives of this study. The current study used two popular simulation tools namely IES and ECOTECT; as they provide the required results in this study.

Urban courtyard with different configurations was analyzed energetically. The incident solar radiation has been calculated for each model by ECOTECT. Then, the sunlit for the best model of each category was calculated by ECOTECT and IES to choose the best model. The results were evaluated in order to optimize the thermal behavior of the best models.

Integrated Environmental Solutions (IES) program is used in this study to simulate how the building will perform from an energy perspective over a whole year. In addition, ECOTECT program is used to validate the results.

4.2.1 ECOTECT program

ECOTECT is one of the few tools in which performance analysis is simple, accurate and most important, visually responsive. It is a software package with a unique approach to conceptual building design. It couples an intuitive 3-D design interface with a comprehensive set of performance analysis functions and interactive information displays. ECOTECT offers a wide range of internal analysis functions which can be used at any time while modeling. These provide almost instantaneous feedback on parameters such as sun penetration; potential solar gains, thermal performance, internal light levels, reverberation times and even fabric costs. ECOTECT calculate the total amount of solar radiation falling on selected surfaces for each month of the year (Marsh, 2003).

ECOTECT Analysis offers several simulation applications during the earliest stages of design including:

- Calculate annual, monthly, daily, and hourly total energy use of the model.
- Analyze effects of infiltration.
- Display the sun's position and path relative to the model at any time.
- Display and animate complex shadows and reflections.
- Generate interactive sun.
- Calculate the incident solar radiation on any surface and its percentage shading,
- Work out daylight factors and artificial lighting levels either spatially or at any point.
- Calculate monthly heat loads and hourly temperature graphs for any zone.
- Generate full schedules of material costs and environmental impact.
- Read and write a wide range of CAD and analysis file formats.

4.2.2 IES virtual environment

The Virtual Environment is an integrated suite of applications linked by a Common User Interface (CUI) and a single Integrated Data Model (IDM). This means that all the applications have a consistent "look and feel" and that data input for one application can be used by the others. It includes several tools such as Sun Cast for solar shading analysis, Apache for thermal simulation, Radiance for lighting simulation, and other applications.

Apache tool is used in this study which is the thermal simulation engine in IES Virtual Environment, (VE-Pro User Guide- IES Virtual Environment 6.4, 2011). It performs a dynamic thermal simulation using hourly weather data. It can Link data with the other ISE tools and it includes a wide range of applications which are:

- Thermal performance analysis.
- Building fabric design.
- Occupant comfort analysis.
- Natural ventilation studies.
- Façade analysis.
- Energy consumption prediction.

- Plant design and sizing.
- Mixed-mode design.
- Carbon emissions.

4.3 Study Parameters

This section investigated the incident solar radiation (total monthly) by using the ECOTECT program. This calculates the total amount of solar radiation falling on selected surfaces for each month of the year. Geometric overshadowing, reflective effects and available radiation are calculated separately for each day within the month. This calculation will obviously take around 30 times longer that the average daily calculation and display a graph similar to the Average Daily graph see figure (4.1).

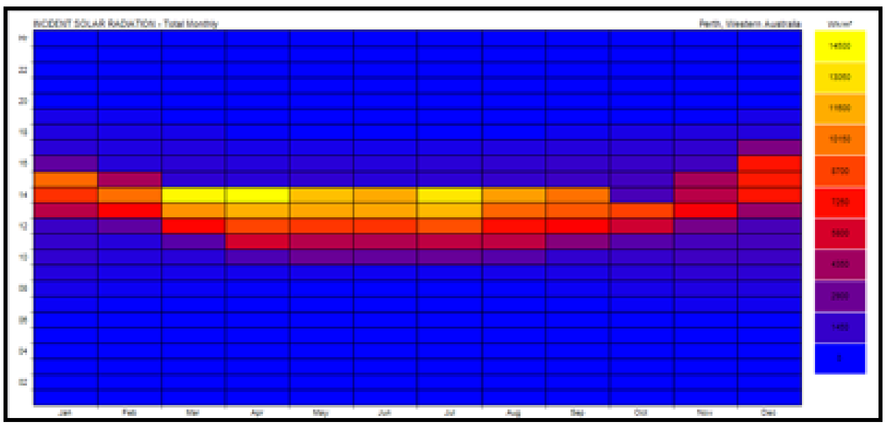


Figure (4. 1) Totally Monthly Solar Exposure in ECOTECT
Source: ECOTECT Tutorial

Interacting parameters in any thermal analysis are numerous. These parameters in the current study include climate, building configurations, urban courtyard. The study investigated realistic cases in the housing projects at Gaza Strip. Therefore Building parameters and climatic data are assumed to be fixed, and the arrangements of the building are variable (number of buildings) to calculate the buildings solar performance.

4.3.1 Climatic Parameters

Climate weather data files for specific city represent the usage of climatic parameters in any simulation analysis. These files were arranged by World Metrological Organization region and country (WMO). The weather data file consists of group of location and climatic information included latitude, longitude, WMO station identifier, climate type, summer and winter dates for hot weeks and cold weeks, and other climatic parameters such as temperature, humidity, wind speed, and solar radiation, (U.S. Department of Energy , 2012).

Weather data file is available now in many formats that represent the type of analysis package and software. Weather data formats include Energy Plus data file (WEA) that is used by ECOTECT, (U.S. Department of Energy, 2012).
Because of the unavailability of weather data file for the Gaza Strip in any formats, the climatic weather data file for Tel Avive, “Isreal” (Bit Dagan) is used in ECOTECT software. The effect of coastal climate of Mediterranean Sea for Gaza and Tel Avive is similar. It lies on 32 latitude and 34.8 longitudes. Where the weather data file for Tel Avive, “Isreal” (Sde-Dov) is used in IES as it part of the site and location of the software. It lies on 32.10 latitude and 34.78 longitudes.

4.3.2 Building Parameters

Most of the previous studies on the thermal performance present relatively accurate results, as they depend on a simulation programs, but these results in many cases are hard to apply in reality. Thus, the study investigates real cases of housing projects in the Gaza Strip, in order to implement the results in reality.
Residential buildings in the Gaza Strip have different configurations in terms of areas, heights, types, and volume. Basically, the current study estimates the housing projects at the Gaza Strip which contain urban courtyard, and intercepts the most common of urban courtyards in these projects. So, the study assumes some features to make a scene for the comparison between the various models which depend on the average of the most models. Thus, the study assumes the following:

- **Building area**

After making a survey to the most housing projects, it perceived that most of the buildings included two apartments in the floor with area of 150 m^2 (15*10). So the building area is 300m^2 (30*10). The apartment is provided to accommodate six members, which reflects the average Palestinian family size, (PCBS, 2012).

- **Building height**

Building heights in the housing projects are ranging between 5 floors to 8 floors. According to MPWH most of housing projects contain of 5 floors, accordingly the study assumes building height is 5 * 3.2 m (16m).

- **Setback between buildings**

According to MPWH the setback between buildings is not less than 2 meters for single houses. Setbacks in the housing projects are ranging between 4 to 8 meters. The study assumed the average setback where it was 6 meters.

- **Orientation**

As indicated before that buildings take the same orientation of the streets which is (north eastern- south western) and (north western- south eastern).The study assumed an impartial orientation (the long side parallel to the north). Also most models are symmetrical in the arrangement of building around courtyard, so they can get an equal solar radiation for both sides see figure (4.2).

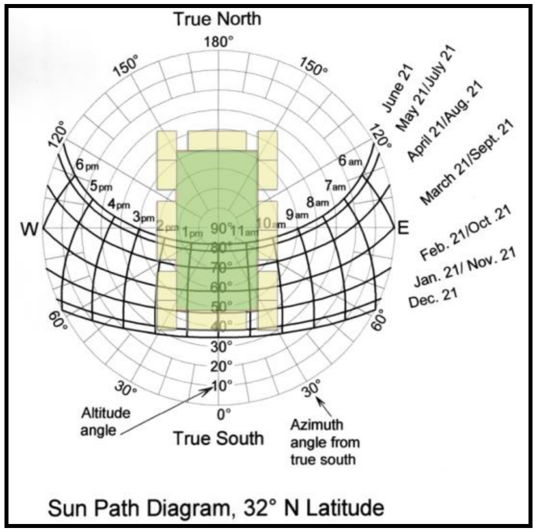


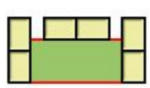
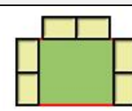
Figure (4. 2) A Stereographic sun-path diagram for Latitude 36°
Source: (Szokolay, 2004) with adapted

4.3.3 Urban courtyard parameters

As mentioned before that the study investigates the most common realistic models from the housing projects, therefor urban courtyard have various models as shown in table (4.1).Every model has abbreviation code consist of 3 letters:

- (A) Refers to number of apartments.
- (B) Refers to number of buildings.
- (C) Refers to closed courtyard.
- (S) refers to semi closed courtyard.

Table (4. 1) Study models of urban courtyards plans in the housing projects

CODE	**2A-3B-S1**	**2A-3B-S2**
PLAN		
Urban Courtyard Parameters(P)	124	128
P/Height(H)	7.75	8

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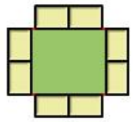
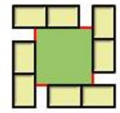
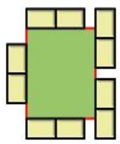
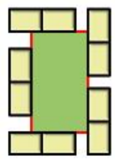
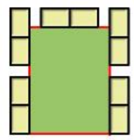
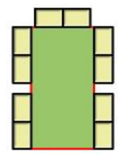
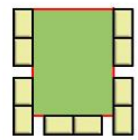
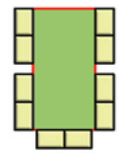
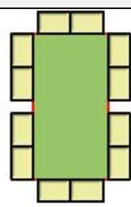
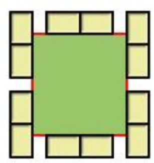
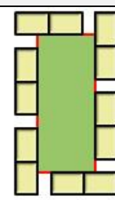
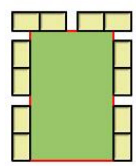
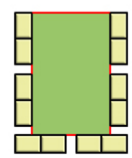
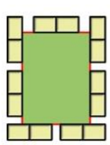
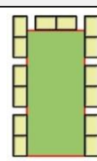
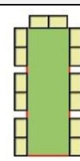
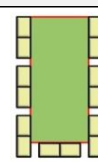
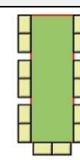
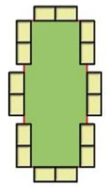
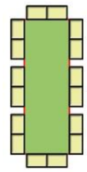
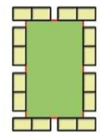
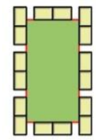
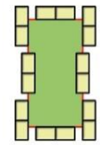
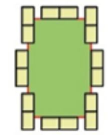
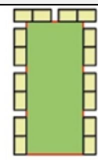
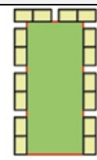
PLAN		
(P)	128	104
P/H	8	6.5

CODE	2A-5B-C1	2A-5B-C2	2A-5B-S1	2A-5B-S2	2A-5B-S3	2A-5B-S4
PLAN						
(P)	197	143	197	200	197	200
P/H	10.19	8.94	12.31	12.5	12.31	12.5

CODE	2A-6B-C1	2A-6B-C2	2A-6B-C3	2A-6B-S1	2A-6B-S2
PLAN					
(P)	200	176	196	235	235
P/H	12.5	11	12.25	14.68	14.68

CODE	2A-7B-C1	2A-7B-S1	2A-7B-S2	2A-7B-S3	2A-7B-S4
PLAN					
(P)	215	267	274	267	274
P/H	13.43	16.68	17.12	16.68	17.12

CODE	2A-8B-C1	2A-8B-C2	2A-8B-C3	2A-8B-C4	2A-8B-C5	2A-8B-C6
PLAN						
(P)	292	272	246	278	289	268
P/H	18.25	17	15.37	17.37	18.06	16.75
CODE	2A-8B-S1	2A-8B-S2				
PLAN						
(P)	307	307				
P/H	19.18	19.18				

4.4 Solar radiation investigation

The Gaza strip has a relatively high solar radiation. It has approximately 2861 of sunshine hours across the year with an average solar radiation of (5.33) kWh/m² (Palestinian Energy Authority, 2010). This refers to its location near the hot dry region of the world.
In this section the study calculates the total incident solar radiation for the three months of summer and that of winter for each model. The calculations consisted two parts, the overlooking facades to the urban courtyard and the ground of urban courtyard itself. Afterwards, a comparison has been made between the percentages of incident solar radiation for the alternatives models to choose the best arrangement.

4.5 Simulation results

Simulations were performed using ECOTECT software. The 3D models were created , then the solar radiation analysis were performed using *sun exposure* application .The simulation results were expressed in terms of total months of incident (in Wh)and (Wh/m^2) at summer months and winter. The main principles in passive design strategies is to avoid unwanted heat gain in summer and increasing the heat gain and avoid heat loss in winter (Evans, 2007). The simulation results assumed that the lowest value of incident in summer is 0% and highest value in winter is 100%.
There were 6 categories of urban courtyard according to the number of the buildings around it.

4.5.1 Total incident at the three buildings (3B) formed courtyard

There were two models of urban courtyard consist of 3buildings, see figure (4.3).
The results indicated that the total incident of solar radiation for 2A-3B-S1model at façades in summer increased about 26%, where the total incident in winter for 2A-3B-S2 model decreased about 23%.

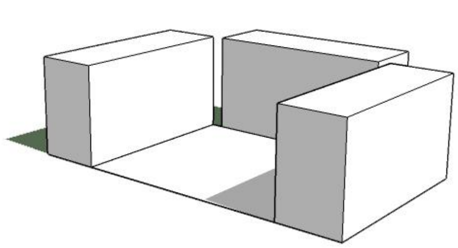
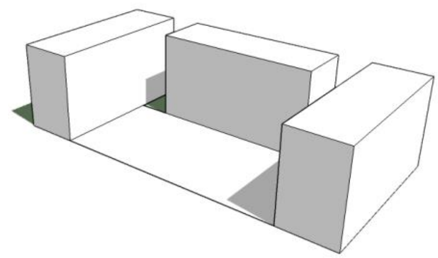
	
Model 2A-3B-S1	Model 2A-3B-S2

Figure (4. 3) Perspectives of 3B models

It was evident that there was a slight difference between the two models reached to about 3%.See fig (4.4).The simulation results for the floor of the same models indicated that incident solar radiation for 2A-3B-S2 model increased about 7% in summer and the optimum percent of incident in winter, See figure (4.5). It is clear that 2A-3B-S2 model is better than the other one.

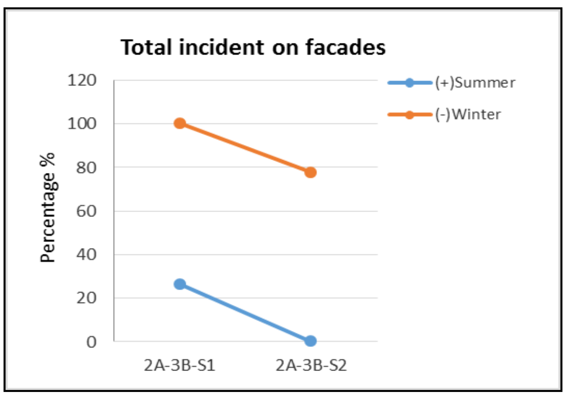


Figure (4. 4) Total incident radiation in the facades (3B)

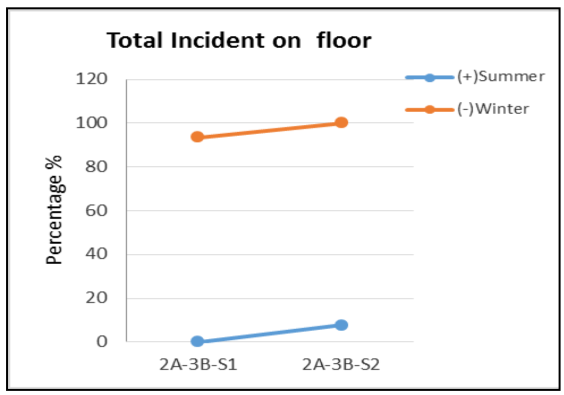


Figure (4. 5) Total incident radiation on the floor (3B)

4.5.2 4B urban courtyard

There were two models of urban courtyard consist of 4 buildings, see figure (4.6). The results indicated that the total incident for 2A-4B-C1model on facades in summer increased about 26%, where the total incident in winter for 2A-3B-C2 model decreased about 22.5%.

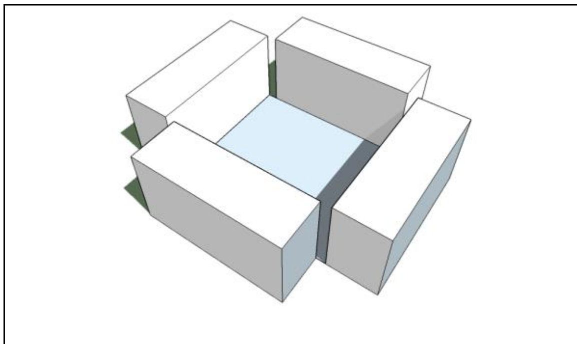
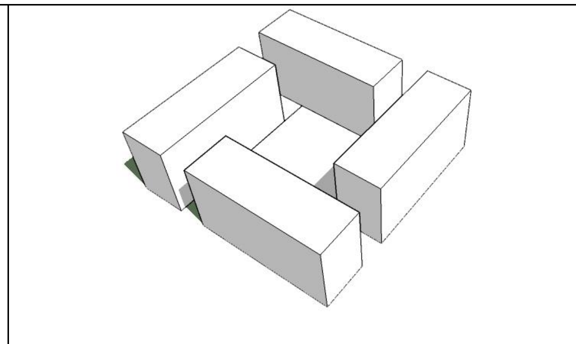
	
Model 2A-4B-C1	Model 2A-4B-C2

Figure (4. 6) Perspectives of 4B models

It was evident that there was a slight difference between the two models reached to about 3%, see figure (4.7).

The simulation results for the incident solar radiation on the floor for the same models indicated that total incident for model 2A-4B-C1increased about 7% in summer where it was the optimum percent of incident in winter see figure (4.8). This increasing was due to the shading for the adjacent buildings at 2A-4B-C2 model. It is clear that 2A-4B-C2 model is better than the other one.

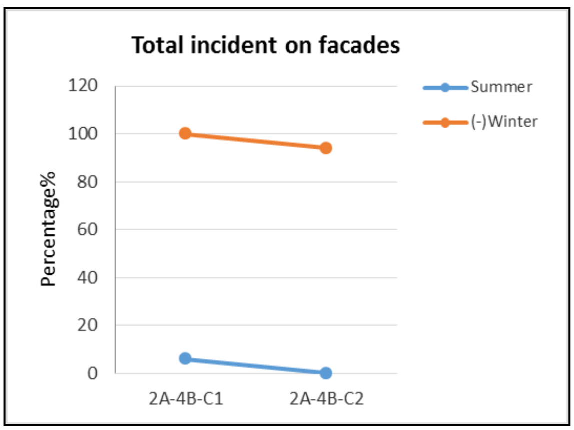


Figure (4. 7) Total incident radiation on the facades (4B)

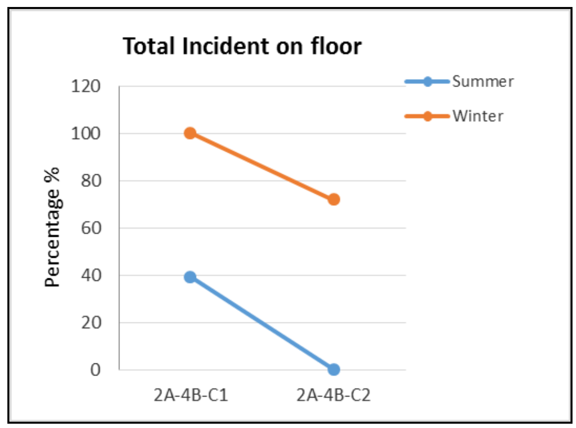


Figure (4. 8) Total incident radiation on the floor (4B)

4.5.3 5B urban courtyard

There were six models of urban courtyard consisting of 5 buildings ranging between closed and semi closed courtyards, see figure (4.9). It was clear from the results that total incident solar radiation for closed courtyards was less than the semi closed ones in summer; this refers to the open side as it allows the solar radiation to get in the courtyard, subsequently expose facades and floor to solar radiation.

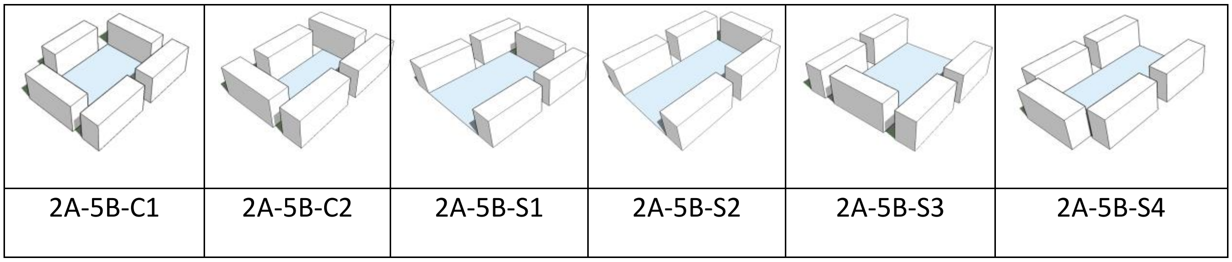


Figure (4. 9) Perspectives of 5B models

In summer, the results showed that 2A-SB-S1 model recorded the highest percentage of incident solar radiation compared to the optimum with 31%. This percentage was due to the open side of the courtyard and the large sunny area increasing as followed comparing them with the optimum percentage:

25% for 2A-5B-S2 model, 23% for 2A-5B-S4 model and 18% for 2A-5B-S3 model

Where as in 2A-SB-C2 model where it had closed courtyard, recorded the optimum incident solar radiation and 2A-SB-C1 model followed it.

In winter, the semi-closed courtyard for 2A-SB-S2 model had the optimum percentage of solar radiation. This gradually decreased in 2A-SB-S1 model by about 3%.Also; it decreased about 24% in 2A-SB-C1 model and about 37% for 2A-SB-C2 model. While for 2A-SB-S2 and 2A-SB-S1 models, the results were the worst. The low percentages were due to the open side of courtyard, which was opposite to the sun path; of the facades. The other models which had semi-closed courtyards; the percentages of incident radiation were the highest, see the figure (4.10).The simulation results for the floor of the same models showed that 2A-SB-C2 had the optimum percentage of incident radiation in summer, where 2A-SB-S2 model had the same results in winter. Taking into consideration the percentage of increase, which was 87% for 2A-SB-S2 model in summer, whereas it was 7% decrease for 2A-SB-C2 model in winter, see figure (4.11). In other models, the percentages increased and decreased between those two models. So, it is advisable to choose 2A-SB-C2 model to be the optimum percentage of incident solar radiation for this category.

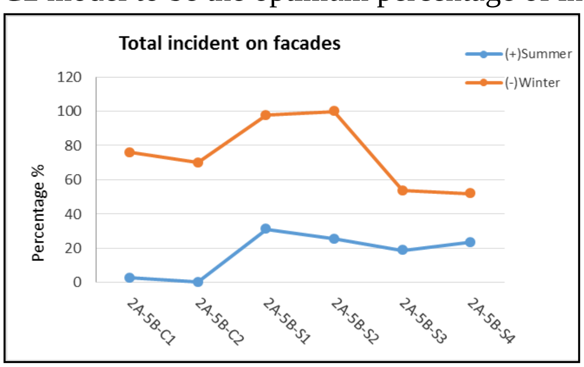


Figure (4. 10) Total incident radiation on the facades (5B)

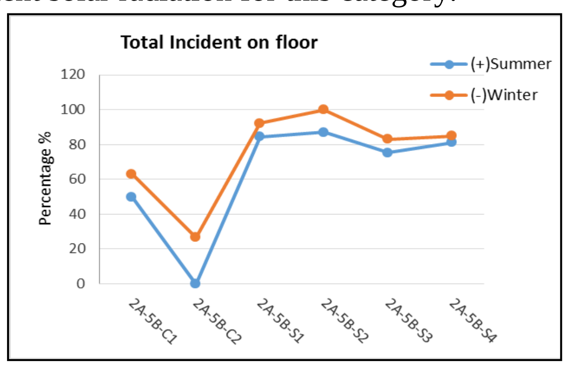


Figure (4.11) Total incident radiation on the floor (5B)

4.5.4 6B urban courtyard

There were five models of urban courtyard consisting of 6 buildings ranging between closed and semi closed courtyards, see figure (4.12). As the previous category, it was clear from the results that total incident for closed courtyards were better than the semi closed ones, this referred to the open side where it allowed the solar radiation to get in the courtyard, subsequently, facades and floor of courtyard were exposed to solar radiation.

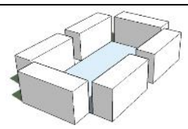
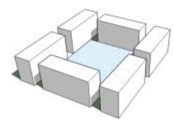
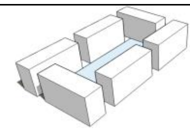
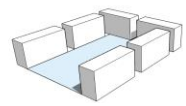
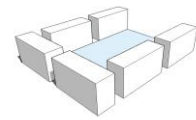
				
2A-6B-C1	2A-6B-C2	2A-6B-C3	2A-6B-S1	2A-6B-S2

Figure (4. 12) Perspectives of 6B models

In summer, the results indicated that the percentage of incident solar radiation for 2A-6B-S1 model on facades comparing with the optimum percentage was the highest percentage, where it was by about 25%. This referred to the open side of the courtyard. This percentage was due to the open side of the courtyard and the large sunny area of the facades, see figure (4.13).

It was clear that percentage of incident radiation for 2A-6B-S2 model followed it. As it was about 13% .The difference between the percentages for the previous models was because of changing the orientation of the open side toward the sun path. Furthermore, 2A-6B-C2 model had the optimum percentage of incident. 2A-6B-C3 model followed it with increasing about 3%, then model 2A-6B-C1with increasing about 10%.

In winter, the semi closed courtyard for 2A-6B-S1 model had the optimum percentage of incident radiation. Gradually, the percentage decreased for 2A-6B-C2 model, as it was about 31 %. It decreased about 33% for 2A-6B-C1 model, and 30 % for model 2A-6B-C2, comparing them with the optimum percentage. 2A-5B-S2 model received the lowest solar radiation, as the percentage decreased about 55.1%. This was due to the open side of the courtyard that faced the sun path.

The simulation results for the floor of the same models indicated as shown in figure (4.14) that the percentages of incident solar radiation for the closed courtyards were better than the semi closed ones, but vice versa in winter, since 2A-6B-C3 model had the optimum percentage of incident radiation, the parentage for 2A-6B-C2 model increased about 26%, and 2A-6B-C1 model increased about 47%. The percentage of incident radiation for model 2A-6B-C3 increased just 3% from the optimum percentage on facades, and it had the optimum percentage of incident radiation on floor. Thus it’s advisable to select 2A-6B-C3 model to be the optimum for this category.

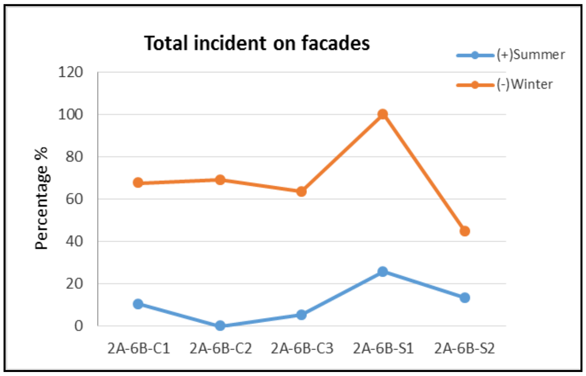


Figure (4. 13) Total incident radiation on the facades (6B)

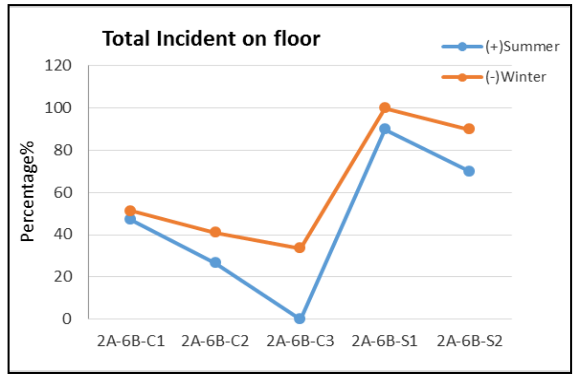


Figure (4.14) Total incident radiation on the floor (6B)

4.5.5 7B urban courtyard

There were five models of urban courtyard consisting of 7 buildings one of them was closed and the others were semi closed courtyards, see figure (4.15).

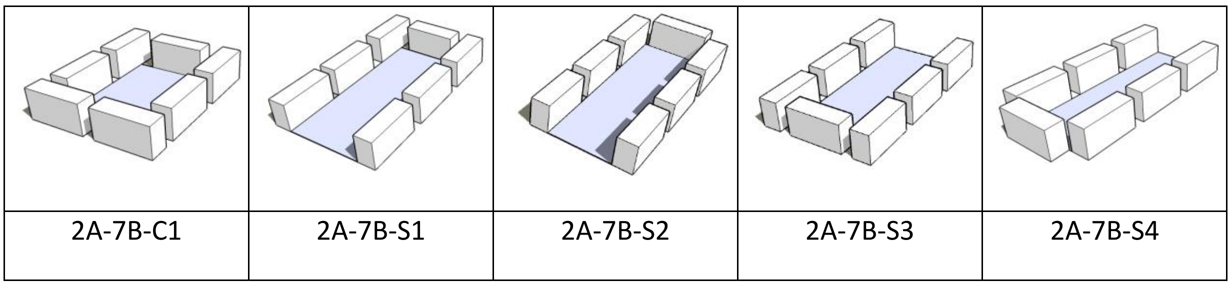


Figure (4. 15) Perspectives of 7B Models

As mentioned before in the previous categories that closed courtyards were better than the semi closed ones. In summer, there was one closed model with the optimum percentage of incident solar radiation on facades and floor, but in winter, this percentage decreased about 25% on facades and 38% on floor. This makes 2A-7B-C1 model has the optimum percentage of incident radiation; see figure (4.16), and (4.17).

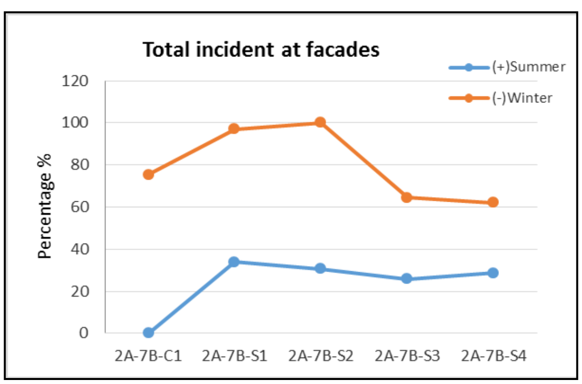


Figure (4. 16) Total incident radiation on the facades (7B)

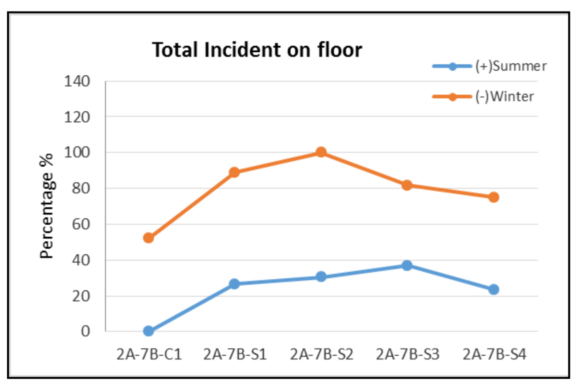


Figure (4. 17) Total incident radiation on the floor (7B)

4.5.6 8B urban courtyard

According to the large number of the buildings that create the courtyard, there were many alternatives models of urban courtyards. There were 8 models most of them are closed, see figure (4.18).

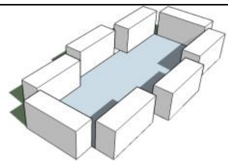
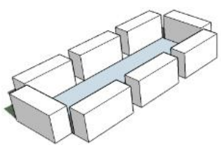
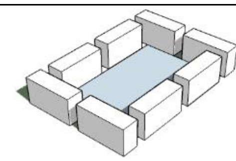
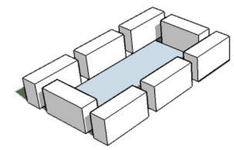
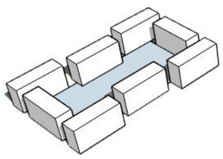
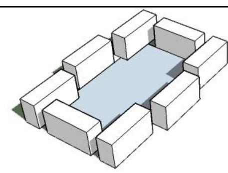
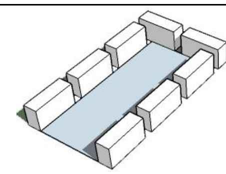
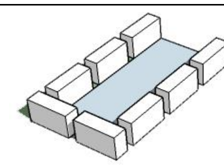
			
2A-8B-C1	2A-8B-C2	2A-8B-C3	2A-8B-C4
			
2A-8B-C5	2A-8B-C6	2A-8B-S1	2A-8B-S2

Figure (4. 18) Perspectives of 8B Models

As shown in figure (4.19), in summer, the results indicated that the total incident radiation for 2A-8B-S1 model on facades received the highest percentage, where it was about 28% compared with the optimum percentage. This referred to the open side of the courtyard, as it exposed to the sun radiation, and the large sunny area of the facades. It was apparent that the percentage of incident radiation for 2A-8B-S2 model followed it, where it was about 19.5% .Furthermore; 2A-8B-C4 model received the optimum percentage of incident radiation, followed by 2A-8B-C5 model with increasing about 8.8%, then 2A-8B-C3 model with increasing about 9.46%, 2A-8B-C6 model with increasing of 10.2%, 2A-8B-C2 model with increasing of 16.4%, finally, 2A-8B-C1 model with increasing about 17.1%. Clearly there were slight differences between them. This was due to the slight difference between the facade's areas which faced the sun radiation.

In winter, the percentage of incident radiation for the semi closed courtyard for 2A-6B-S1 model had the optimum percentage. Gradually, this percentage decreased for 2A-8B-C4 model about21 %. 2A-8B-C3 model decreased about 24.7% and 25.3 % for 2A-8B-C6 model; 2A-8B-C1 and 2A-8B-C2 models almost decreased the same percentage about 26.6%. 2A-5B-S2 model received the lowest percentage of incident solar radiation; this was due to the open side of the courtyard that faced the sun path as it was by about 44.3% comparing with optimum percentage.

The same simulation was done for the floor of the same models. As shown in figure (4.20). 2A-8A-6B-C5 model received the optimum percentage of incident radiation, while the percentage of incident radiation for 2A-8A-6B-C1, 2A-8A-6B-C2, 2A-8A-6B-C3 and 2A-8A-6B-C4 models increased about(46.8%,40.1%,58.2%,23.1%, respectively) compering them with the optimum percentage .The highest percentages of incident radiation were received by 2A-8B-S1and 2A-8B-S1 models. This was due to the open side as mentioned before.

So, according to the percentage of incident radiation on facades and floor for each model, it is clear that 2A-8B-C4 model is the best one.

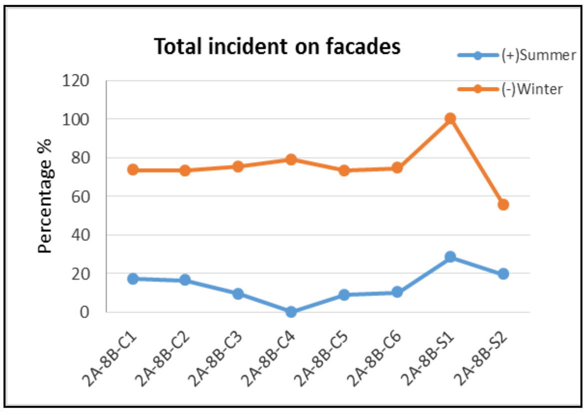


Figure (4. 19) Total incident radiation on the facades (8B)

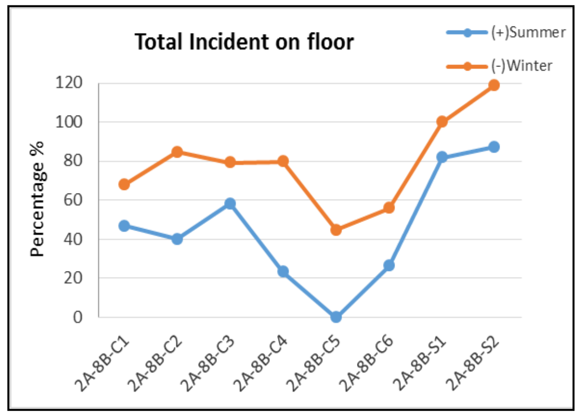
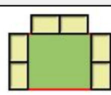
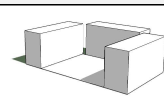
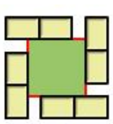
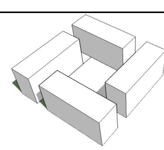


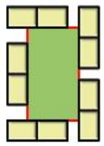
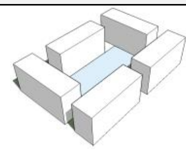
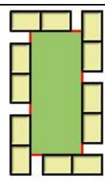
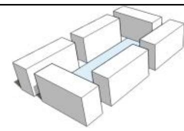
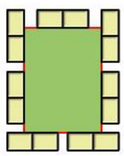
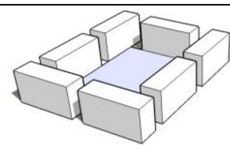
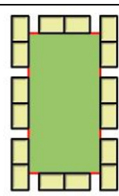
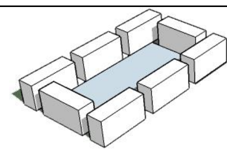
Figure (4. 20) Total incident radiation on the floor (8B)

4.6 Comparison between the best models of each category

According to the previous investigation in the total incident of solar radiation for all categories of urban courtyards, the best model of each category was chosen to make a comparison between them. Those models illustrated in the following table (4.2).

Table (4. 2) Best model of urban courtyard for each category

Type	Urban courtyard plan	Perspective	Urban courtyard parameters(P)	Urban courtyard dimensions	W/L	P/H H=16M
3B			124M	30*34	1.13	7.75
4B			104M	26*26	1	6.5

Type	Urban courtyard plan	Perspective	Urban courtyard parameters(P)	Urban courtyard dimensions	W/L	P/H H=16M
5B			143M	46*25	0.54	8.9
6B			196M	62*26	0.42	12.25
7B			215M	62*46	0.74	13.43
8B			278M	82*42	0.51	17.37

To make a comparison between the models; the incident solar radiation per meter square Wh/m^2 were calculated for each model on facades and floors.

4.6.1 Selecting the best model of each category

In summer, the results indicated that 3B model recorded the highest percentage of incident solar radiation per m^2 with increased by about 36% comparing with the optimum percentage. This was referred to the open side of the courtyard as it mentioned before. It was clear that the percentage of incident radiation for 4B model was the optimum on facades, while the percentage of incident radiation per m^2 for 5B, 6B, 7B and model 8B models increased (14.8%, 22.3%, 17% and 19.5% respectively). Cleary, there was gradually increasing of the incident radiation percentage paralleled with the parameter of the urban courtyard as shown in figure (4.21).

In winter, the results were different, since 3B received the optimum percentage of incident radiation Wh/m^2, gradually the percentage decreased for 8B model by about 29.2 %, 7B model decreased about 37.4%, 38.3 % for 6B model, 38.4 % for 3B model, and finally it

decreased 38% for 5B model. Evidently, there was a slight difference between the models; this was referred to the ratio between the parameter of the courtyard to the height of building as it shown in the table (4.3).
The simulation results for the percentage of incident radiation per m^2 for the floors of the same models recorded that 8B received the optimum percentage in summer, where the percentage increased for 3B, 4B, 5B, 6B, 7B models by about (26.6%, 5.2%, 4.0%, 10%, 12.0%, and 14.9% respectively).
In winter, the percentage of incident radiation per m^2 for 3B model received the optimum. But, in winter, it received the highest percentage of incident radiation on facades. So, it can't be chosen. Other models, the percentages of incident radiation were decreased comparing them with the optimum percentage respectively (47.6%, 52.6%, 35.9%, 33.1%, 26.6%) for models (4B, 5B, 6B, 7B, 8B), see figure (4.22).

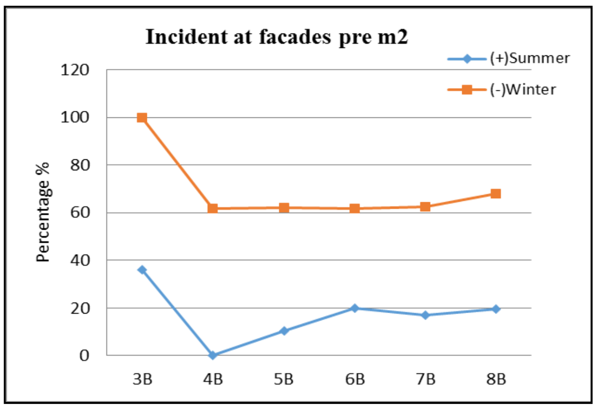


Figure (4. 21) Total incident radiation on facades per m^2

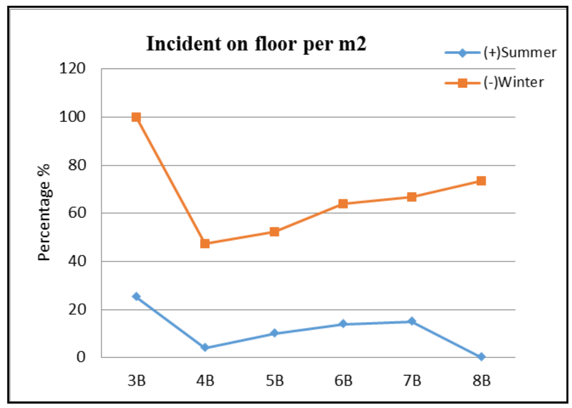


Figure (4. 22) Total incident radiation on floor per m^2

Taking into consideration the percentage of decreasing in summer and increasing in winter on facades and floors of each model, it became clear that there were three options to choose between them, which were 5B, 8B and 4B models. The following table (4.4) showed the difference between the percentages of incident radiation per m^2 for the three models.

Table (4. 3) The percent of incident per m2 for the best three models.

code type	Percent of incident solar radiation on Facades		Percent of incident solar radiation on Floor	
	Summer	Winter	Summer	Winter
4B	0	38.4%	4%	47.6%
8B	19.6%	68%	0	26.6%
5B	10.2%	70%	10%	52.6%

Although the percentage of incident radiation per m^2 on facades for 4B model was the optimum percentage in summer, and 8B model had the optimum percentage on floor, but they had the lowest percentage of incident radiation per m^2 in winter. Moreover, model 5B had the average percentage of incident radiation per m^2 on facades and floor in summer and winter with slight difference of percentage.

As shown in figure (4.23) in the morning, the urban courtyard was shaded in the hottest day (21^{st} of June) from the east side. On the other hand, the eastern façades which were overlooking the courtyard had self-shading from the east. Also, the northern and southern facades had self-shading. Furthermore, most short facades had self-shading from the adjacent buildings. Otherwise, figure (4.24) showed the shading for the hottest day in the afternoon, where the courtyard's floor was almost shaded from the overlooking buildings. Also, most of facades' buildings had self-shading.

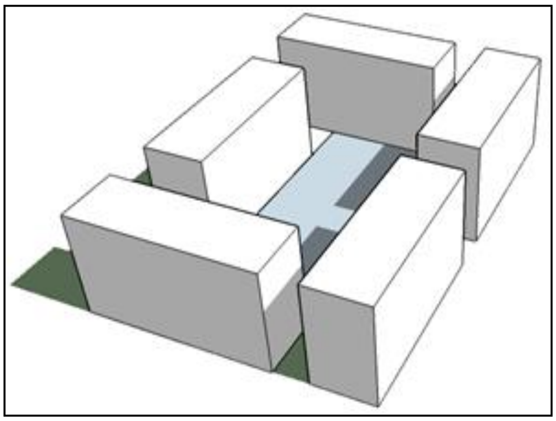


Figure (4. 23) Shading in the morning 21^{st} of June

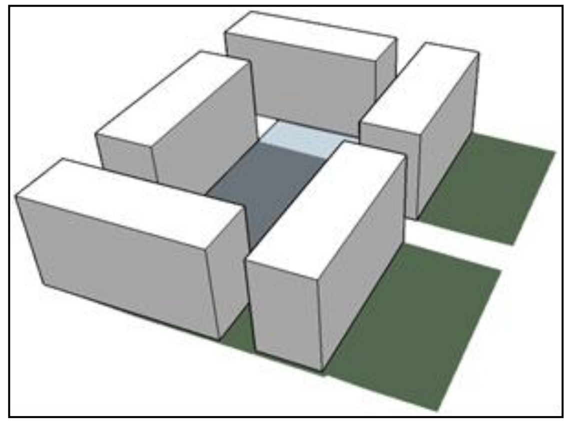


Figure (4. 24) Shading in the afternoon 21^{st} June

Figure (4.25) showed shading behavior of urban courtyard in the morning of the 21^{st} of December. It was clear that most facades of the buildings in the morning were exposed to the sunshine. As known, increasing the surface area exposed to the incident solar radiation leads to lower heating loads in winter. Figure (4.26) showed the shading behavior for the same model in the afternoon, it was clear that the long overlooking facades exposed to the solar radiation, while the short ones had self-shading.

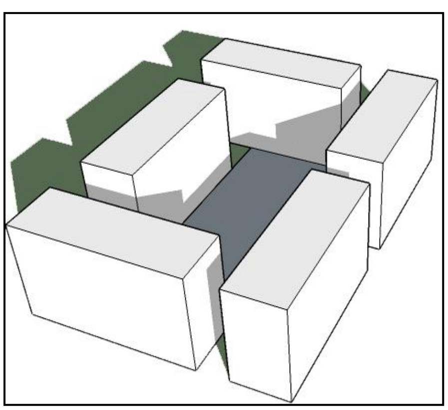


Figure (4. 25) Shading in the morning of 21st December

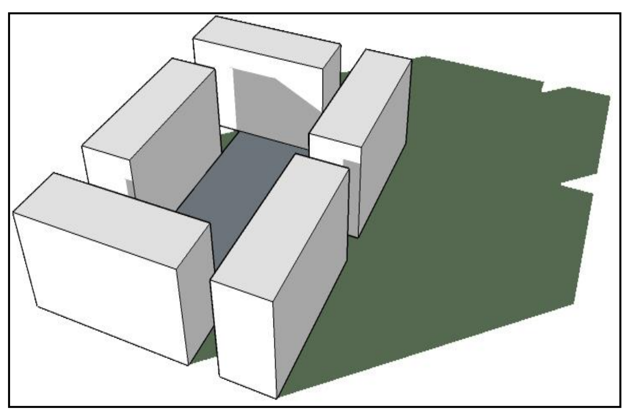


Figure (4. 26) Shading in the afternoon of 21st December

It’s advisable to select the model 5B to be the best model of all categories, as it had the optimum percentage of incident solar radiation on facades and floor of urban courtyard, thus, affects the thermal performance of the buildings effectively.
According to Edwards (2006) he stated that the most widely recognized extents of width to length proportions of the courtyard are: 1:1.8 and 1:3.6, which depend basically on the sun, way. Noticed that 5B model has the ratio of width to length is 1:1.84, this result come in line with the previous studies.

4.6.2 Sunlit area for the best models of each category

To make a validation to the previous result, a series of images have been created by Sun Cast to visualize where the shadows are cast onto the models surfaces at specific months of the year. These months are June and December. Percentage of sunlit area at facades and floors for the six models were calculated by ECOTECT and IES.
In summer, by using IES simulation, 8B model had the highest percentage of sunlit area where it was 45.1% from the total facades area. Otherwise the sunlit area for the same model by using ECOTECT was 47% of the total facades area, see figures (4.27) and (4.28).
The models which had semi closed courtyard, 7B and 3B models, the percentages of sunlit area by using IES software were (42.9%, 41.2% respectively). While, by using ECOTECT software they were 45% for 7B model and 43% for 3B model.
However, 4B and 5B models had the optimum percentages of sunlit area, as they received the lowest percentage of sunlit area, which was 38% of the total facades area by using IES software and 41% by using ECOTECTE software.
In winter, 3B by using IES and ECOTECT software had the optimum percentage of sunlit area. This referred to the open side of the courtyard. Other models followed it with slight differences.

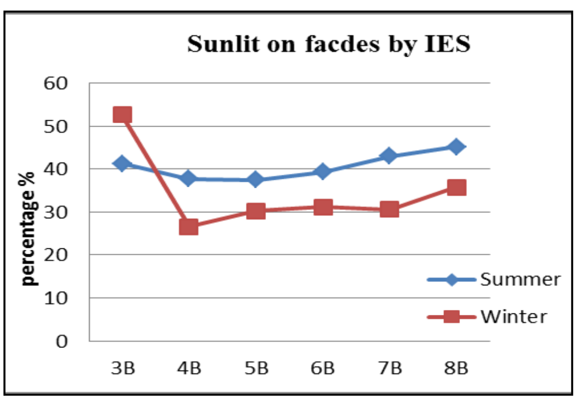


Figure (4. 27) Sunlit area percentage on facades by IES

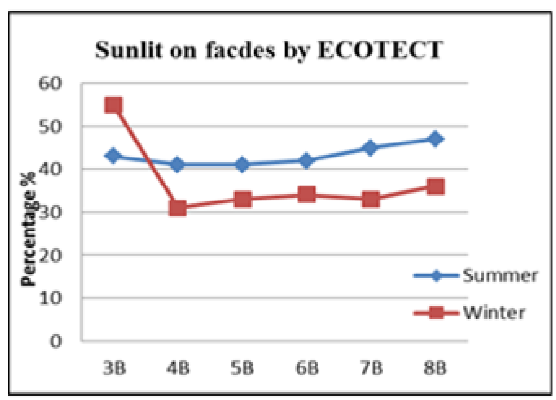


Figure (4. 28) Sunlit area percentage on facades by ECOTECT

The same simulation was done to the floors of the courtyards, see figure (4.29) and (4.30). In summer, the results recorded that 5B model had the optimum percentage of the sunlit area by using IES software, as it was 12.2% from the total facades’ area. While 3B model had the highest percentage of sunlit area as it was 59.2%. Other models the percentages of sunlit area increased and decreased between those two models.

By using ECOTECT software, the optimum percentage of sunlit area was for 4B model, where it was 40% of the total floor's area. 5B model followed it, as it was 42% of total floor's area.

The discrepancy in results between ECOTECT and IES can be explained as a result of different load calculation techniques and assumptions.

Taking into consideration the percentage of sunlit area in summer and winter on facades and floors for each model, it becomes clear that model 5B has the optimum percentage of sunlit area.

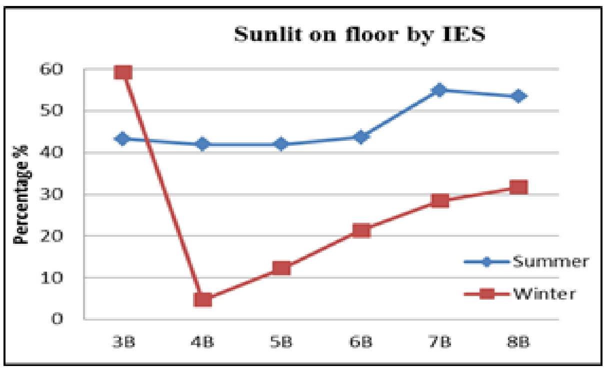


Figure (4. 29) Sunlit area percentage on floor by IES

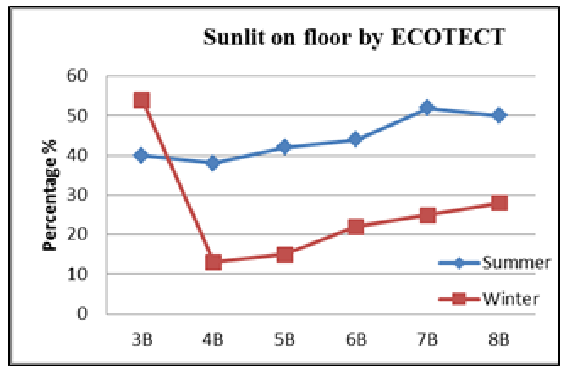
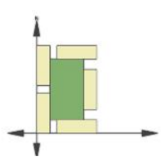
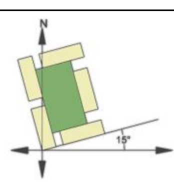


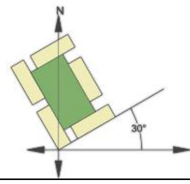
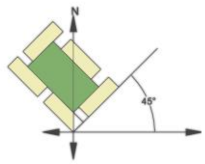
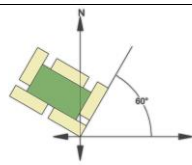
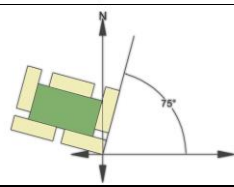
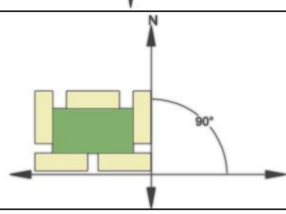
Figure (4.30) Sunlit area percentage on floor by ECOTECT

4.6.3 Effect of orientation on the best model (5B)

Six values of orientation were considered by changing the orientation of the simulated model to have the ability to change the required energy, as it affects the amounts of solar radiation falling on the building surface and floor of courtyard, see table (4.5).

Table (4. 4) Effecting of change the orientation for the simulated model

Degree	PLAN	Incident Radiation at Facades		Incident Radiation at Floor	
		At summer	At winter	At summer	At winter
0 degree		13%	24.6%	39.1%	43.4%
15 degree		15.4%	21.8%	28.5%	100%

Degree	PLAN	Incident Radiation at Facades		Incident Radiation at Floor	
		At summer	At winter	At summer	At winter
30 degree		22.5%	12.6%	15.3%	58.1%
45 degree		17.3%	11.2%	0.0%	58.3%
60 degree		14.0%	2.8%	28.2%	16.9%
75 degree		1.7%	4.0%	36.0%	27.5%
90 degree		0.0%	100%	32.9%	43.1%

The study assumed the long axis of all the models' was along north - south. The orientation change 15 degrees, frequently, until reached 90 degrees. The result indicated that the total incident solar radiation which was received at 0 degree increased regularly until reached the max at 45 degrees. The values were (13%, 15.4%, 22.5%, and 17.3% respectively), see figure (4.31). Contrarily, orientation of 60 to 90 degrees, the percentage of incident solar radiation decreased until reaching the optimum percentage at 90 degrees. The percentages were (14.0%, 1.7%, and 0.0% respectively).

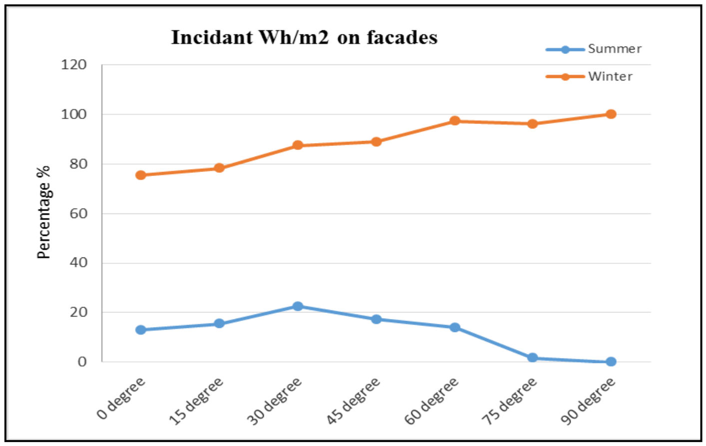


Figure (4. 31) Incident solar radiation on facades per m2

As shown in figure (4.32) the total incident radiation percentage in summer at 0 degree decreased gradually, until reached the optimum percentage at 45 degrees. The percentages were (39.1%, 28.5%, and 15.7%, respectively. But, the percentage of incident radiation increased gradually at 60 d to 90 degrees .On the other hand, the optimum percentage of incident radiation was at 0 degree in winter. This percentage decreased regularly from the optimum percentage until reached 45 degrees. The percentages were (35%, 58.1%, and 58.8% respectively). The same trend can be observed at orientation from 60 to 90 degrees. The percentages were (16.9%, 27.5%, and 32% respectively). Noticing that at 90 degrees recorded the optimum percentage.

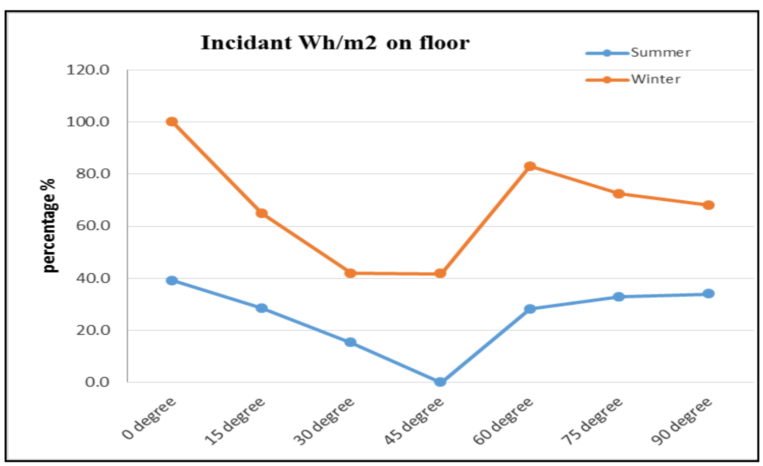
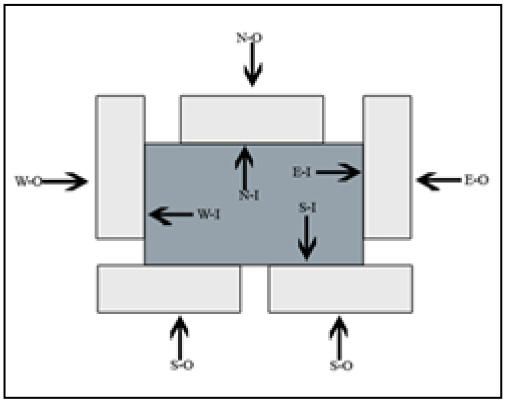


Figure (4. 32) Incident solar radiation on floor per m2

In order to understand the cause of result, the facades named according to their orientation and its direction from the courtyard (inner facades –I) and (outer facades _ O).



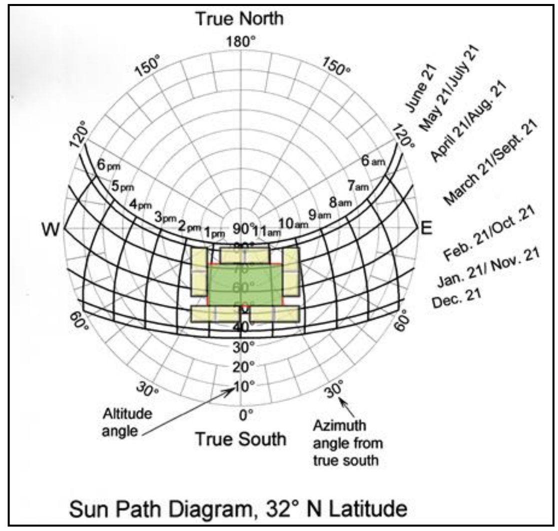
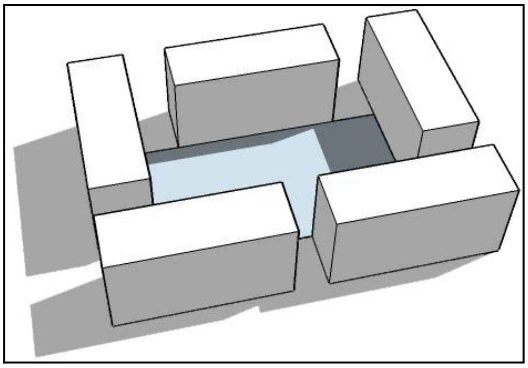


Figure (4. 33) Abbreviation code for facades **Figure (4. 34) A Stereographic sun-pathdiagram for Latitude 32°**
Source: (Szokolay, 2004) with adaption

Every façade has abbreviation code consist of 2 letters, see figure (4.32):
(EO) eastern outer façade and (EI) eastern inner façade.
(WO) western outer façade and (WI) western inner façade.
(NO) northern outer façade, and (NI) northern inner façade.
(SO) southern outer façade, and (SI) southern inner façade.

Figure (4.34) shows the sun path during the year for the study model. As seen, summer altitude allows for effective shading. As shown in figure (4.35), in the morning of 21st of June (EO) facades and (WI) facades are exposed to solar radiation, while other facades have self-shading. Clearly, the facades areas which are exposed the sun are less than the shaded ones. At the midday of 21st of June the long facades are exposed to solar radiation, since (SO) and (NI) are exposed it. This radiation is semi perpendicular to the facades, which means; it doesn't inter to the depth of the building .It affects the thermal performance of the building. On another hand, (SI) and (NO) facades have self-shading. In the afternoon of the same day, (EI) and (WO) facades are exposed to solar radiation as shown in figure (4.36). The short side of the urban courtyard is exposed to solar radiation, while the long side almost has self-shading during the day. Hence, decreasing the surface area exposed to the solar radiation leads to lower cooling loads in summer (if any needed).



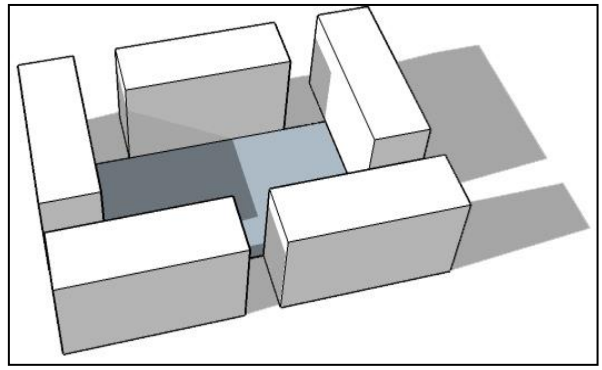
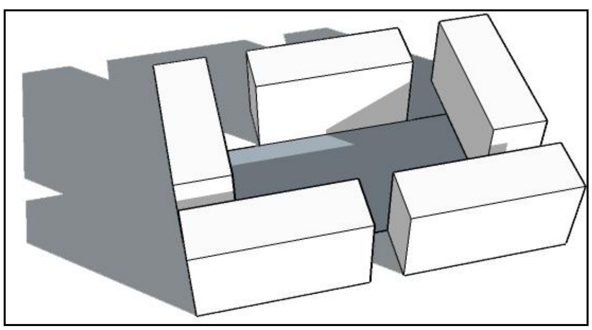


Figure (4. 35) Shading in the morning of 21st of June **Figure (4. 36) Shading in the afternoon of 21st of June**

In winter, the lowest angle of the sun projection is on 21st December. This angle allows more solar radiation to be gained by the courtyard and the overlooking facades. As shown in figure (4.37), most buildings' facades are exposed to solar radiation. As, in the afternoon, the long side of the urban courtyard is exposed to solar radiation, see figure (4.38), while the short side has self-shading. Hence, increasing the surface area exposed to the solar radiation leads to lower heating loads in winter (if any needed).



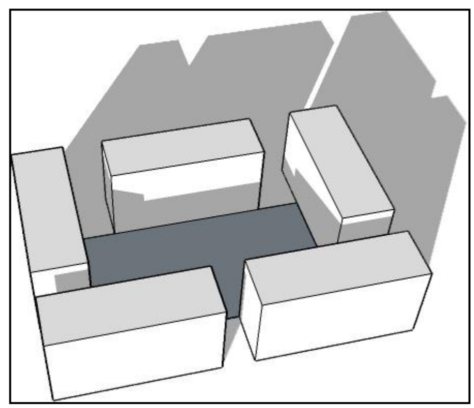


Figure (4. 37) Shading in the morning of 21st of December **Figure (4. 38) Shading in the afternoon of 21st of December**

Conclusion

This chapter dealt with the most common urban courtyard in the housing projects in the Gaza Strip; where these urban courtyards are divided into six categories according to the number of buildings available around the courtyard. Many researches indicated that the incident solar radiation falling on the building is the factor that has the largest impact on the thermal response of the building. So, in order to make a comparison between those urban courtyards; a simulation was done to estimate the incident solar radiation on the facades and the floors of the courtyards. Iin order to choose the best model of all categories; the sunlit percentage for the best model of each category was done by the IES software; and the result was validated by the ECOTECT software. The results concluded that 5B(urban courtyard formed by 5 buildings) has the best percentage of incident solar radiation; the result came in line with previous studies that are linked with the best parameter of courtyard as the proportions of the courtyard is 1:1.84, with parameter of 143m and the ratio between the parameter and the height buildings is 8.94.

The thermal performance of the urban courtyard is integrated with other design parameters such as orientation. Therefore a calculation of incident solar radiation per m^2 was done for variation of orientation. The results concluded that urban courtyard oriented east and west are preferable.

5 Chapter 5: Effect of Urban Courtyard on the Thermal Performance of Buildings

5.1 Introduction

It has been derived from the previous chapter that the amount of solar radiation affects the thermal performance of a building. The thesis mainly focuses on solar and thermal performance of the overlooking buildings to achieve the best model of an urban courtyard. This can be achieved by choosing the best orientation and landscaping of the courtyard.

IES software will be the main software for simulation in this chapter, while final results will be validated by ECOTECT. This chapter will be divided into three sections to provide a full understanding of the thermal performance of the urban courtyard.

The first section introduces a study of the thermal performance of the six categories as a validation of the previous results .Therefore, it uses the IES software to calculate the heating and cooling loads for each model to compare between them and select the best one.

The second section makes a comparison between the thermal performance of building around the best model and the same buildings which form a linear shape to verify the effect of the courtyard on the thermal performance of the buildings.

The third section studies the thermal performance of each building in the best model to select the best building , then it studies this building in details by calculating the heating and cooling loads of each floor after that it selects the best flat in that building.

5.2 Thermal Analysis Parameters

For the purpose of thermal analysis by IES or ECOTECT, table (5.1) shows a group of essential parameters that must be filled in the two models. For further details see appendix (A).

Table (5. 1) Thermal analysis parameter

	ECOTECT software	**IES software**
Location and Site Data		
Location		
Weather File Data	Tel Avive, Isreal (Bit Dagan)	Tel Avive, Isreal (Sde-Dov)
Latitude	32N	32.10 N
Longitude	34.8 E	34.78 E
Site Data		
Ground reflectance	0.2	
Terrain types	Suburbs	Urban
Wind exposure	Normal	Normal
Thermal Condition		
HVAC System	Full Air Conditioning	Full Air Conditioning
Thermostat Range	18.0 C^0- 26. C^0	18.0 C^0- 26.0 C^0
Heating set point	18.0C^0	18.0 C^0
Cooling set point	26. C^0	26.0 C^0

Domestic Hot Water DHW Consumption	0.0	0.0
Use of the building/ Hours of Operation	On continuously	On continuously
Model settings		
Solar reflected fraction	-	0.05
Furniture mass factor	-	1.00
Design condition		
Clothing (clo)	1.0	-
Humidity	60.0	-
Air speed	0.5 m/s	-
Lighting level	300 lux	300 lux
Occupancy	0	0
Internal heat gain		
Sensible gain	0	0
Latent gain	0	0
Infiltration rate		
Air change rate	0	0
Wind Sensitivity	0	0
Construction		
Exterior walls		
U-value	1.77	1.9487
Roof		
U-value	0.896	0.9165
Ground-contact/exposed		
U-value	0.88	0.7059
Window		
U-value	6.0	5.5617

In addition, the building has no shading devices, no special finishes, and no available thermal insulation. Besides, windows area is about 10-15% of walls area, (Neufert et al., 2000), see figure (5.1).

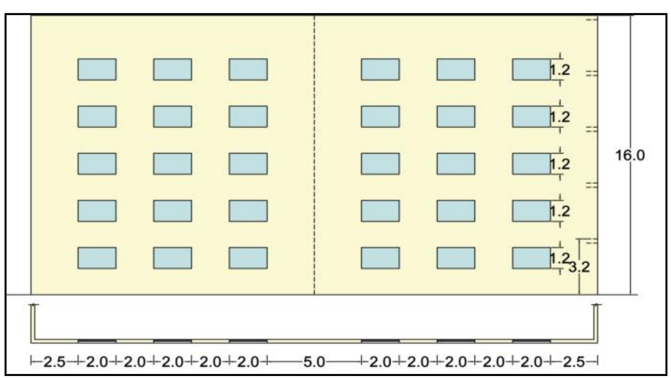


Figure (5. 1) Sample of the buildings elevation

5.3 Investigation on thermal performance of the best models

As mentioned in the previous chapter, there is a relation between the solar radiation and the thermal condition at the building. This study is an attempt to investigate the thermal performance of the best model of each category to affirm the preceding results of choosing the optimum model. The study examines the heating and cooling loads per m^3 for each model.

5.3.1 Simulation results

Simulations were performed using IES software. The 3D models were created, see figure (5.2), then the total heating and cooling loads analysis was performed using *ApacheSim.*The simulation results were expressed in terms of the total loads (in MWh).

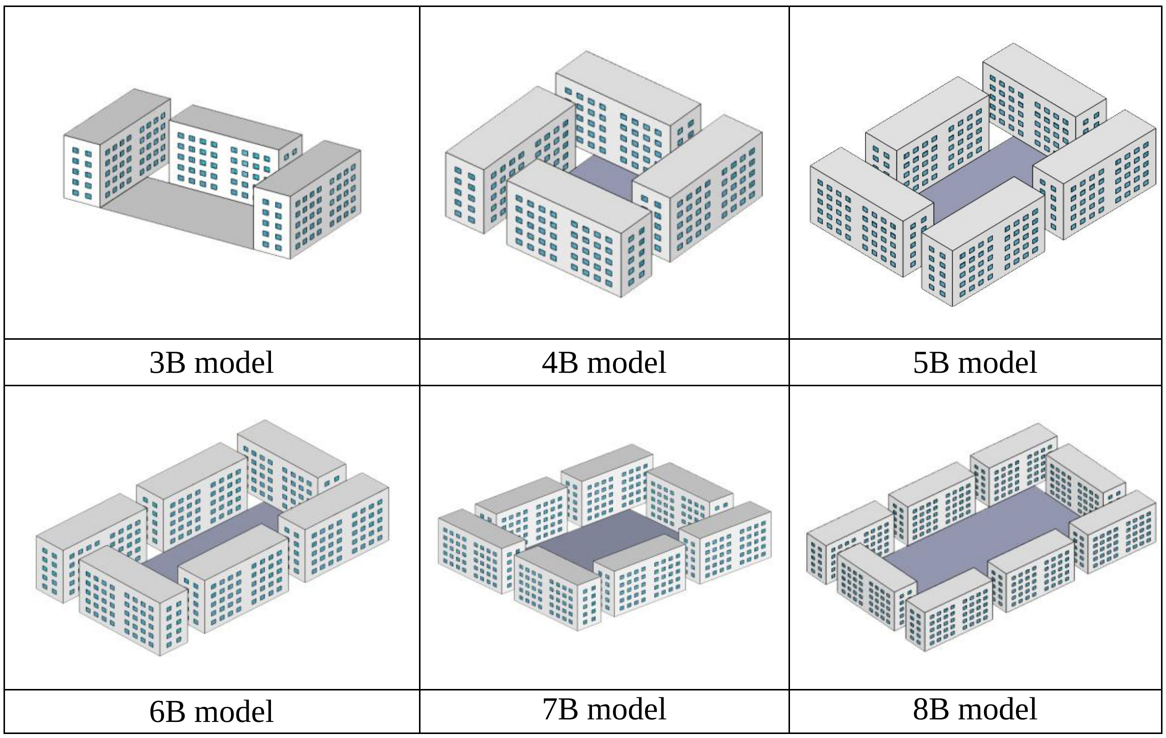


Figure (5. 2) Perspective of alternative models

The results indicated that the total heating loads per m^3 for 5B model was the optimum. Gradually, the percentage increased for model 3B to about 24.8 %, model 7B increased to about 25.3%, model 8B increased to about 25,8% and 26.4 % for model 6B, but Model 4B was the worst as it increased to about 33.6 %, see figure (5.3). This was due to the ratio between the parameter and the height of buildings.

On the other hand, the results indicated that the total cooling loads for 7B was the best. It can be seen that there were slight differences between the models, as model 5B increased by 0.18%, model 6B increased by 0.61%, and model 8B increased by 1.9%, where model 3B and 4B were the worst as they increased by 2.75%.

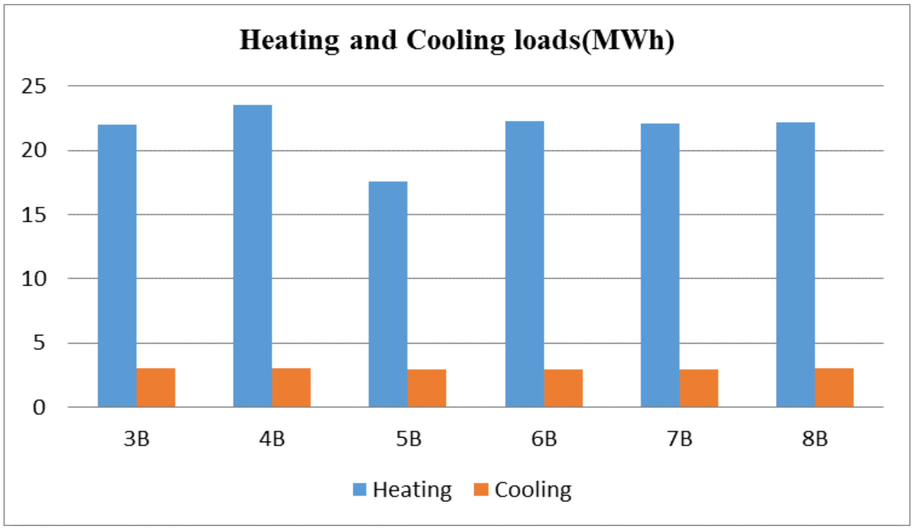


Figure (5. 3) Heating and cooling loads for the best models

Cleary, all models are better in summer than winter as the cooling loads are lower than the heating loads in general.

According to the results of the total heating and cooling, model 5B is advisable to be select as the best model. These results affirm the previous outcomes which were antecedently figured out.

5.4 Effect of orientation on the thermal performance of the buildings for the best model

Simulations were performed using IES software. The 3D models were created, then the total heating and cooling loads analysis was performed using *ApacheSim* . The simulation results assumed that the lowest value of the total heating and cooling loads (MWh) is the optimum.

Six values of orientation considered by changing the orientation of the simulated model were seen to have the ability to change the required energy as it affects the thermal performance of the building. The study assumed that long axis of all the models is along the north-south, see figure (5.4).

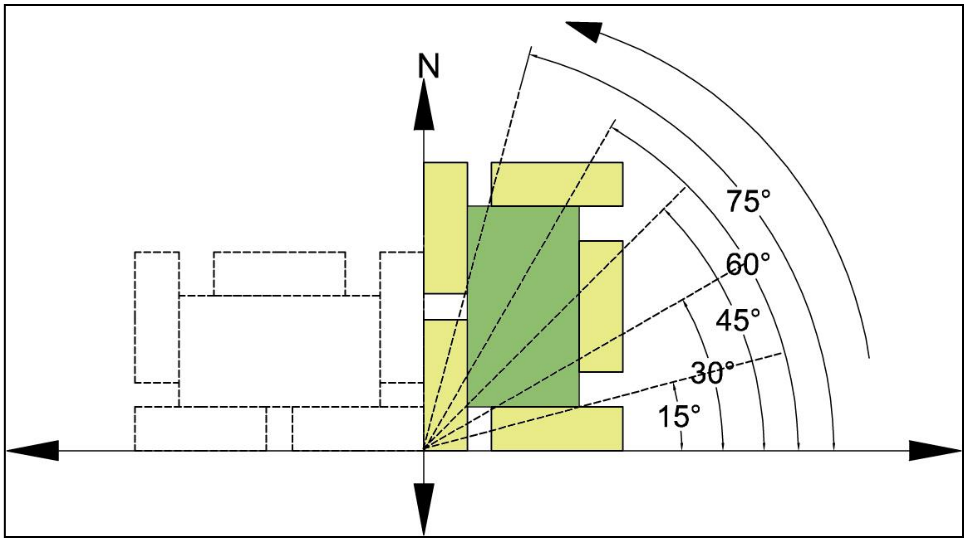


Figure (5. 4) Values of orientation of the study model

The orientation changed by 15 degrees frequently until it reached 90 degrees. The result indicated that the total heating loads at 0 degree increased regularly until it reached 45 degree. The values were (0.98%, 1.14%, 1.47%, and 1.59% respectively), see figure (5.5).The same trend can be observed at the orientation 60 degrees until 90 degrees, but the percentage decreased until it reached the optimum percentage at 90 degrees. The values were (1.0%, 0.34%, and 0.0%) respectively. Clearly, it took the same trend at summer by noticing the percentage of cooling loads but with a higher percent. This trend affirms the result of the effect of orientation on the incident of solar radiation as shown in fig (4.31) in the previous chapter.

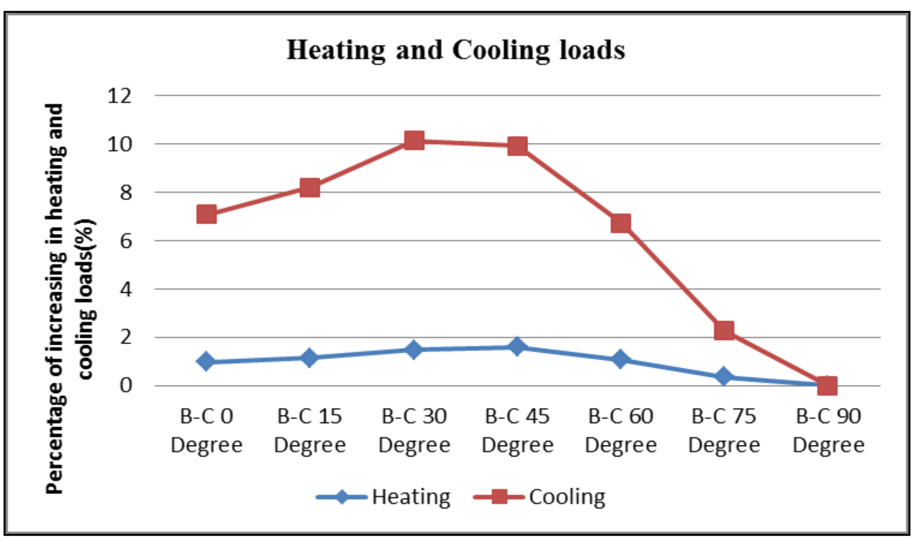
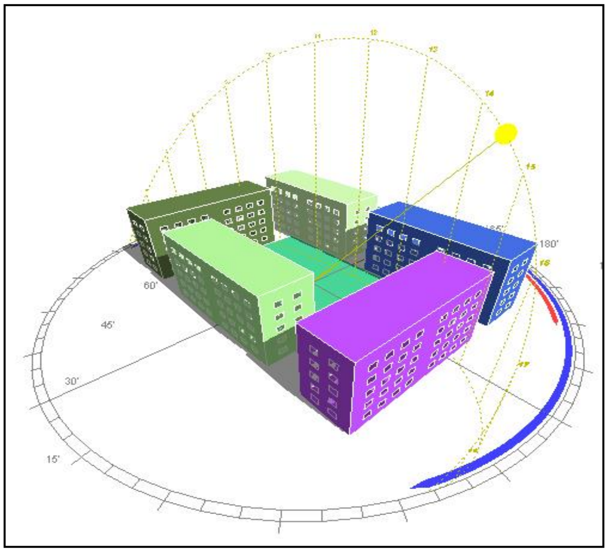


Figure (5. 5) Heating and cooling loads for buildings arrangement around courtyard

Therefore, the best orientation is along east, west as the side of the courtyard takes the same axes. A considerable amount of incident solar radiation is absorbed by roof in summer, and much of it is absorbed by southern façade in winter. This can be explained as the sun altitude angle is low in the midday of winter that enables south facade to capture desirable solar radiation resulting in decreasing heating loads. But during summer sun altitude angel is high enough that reduces incident solar radiation on southern façade. The amount of incident solar radiation on the building facade depends on the azimuth on the wall and the orientation angle of the building, see figure (5.6).On the opposite of southern facades (inner facades) have self-shading.



Figure(5. 6) Sun path for model 5B

5.5 Comparing the thermal performance of linear building model

The study assumes two linear models with the north side are parallel to the long axis of the buildings to compare the best one with the courtyard model.

Simulations were performed using the IES software. The 3D models were created for five buildings forming a line. Model (A) shows the buildings laid parallel to each other at a long side. See fig (5.7), where model (B) buildings are laid parallel at a short side, see fig (5.8).

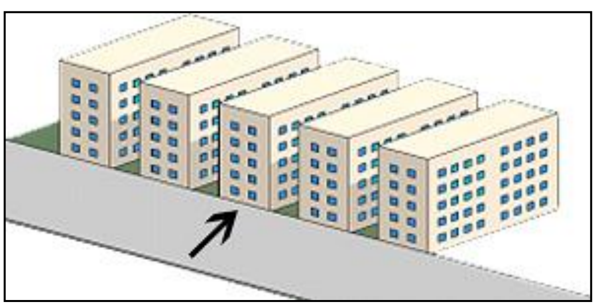


Figure (5. 7) Perspective of linear arrangement (A)

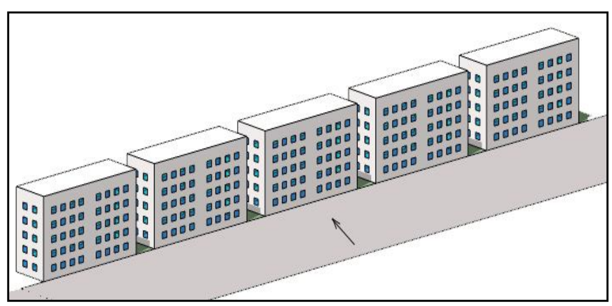
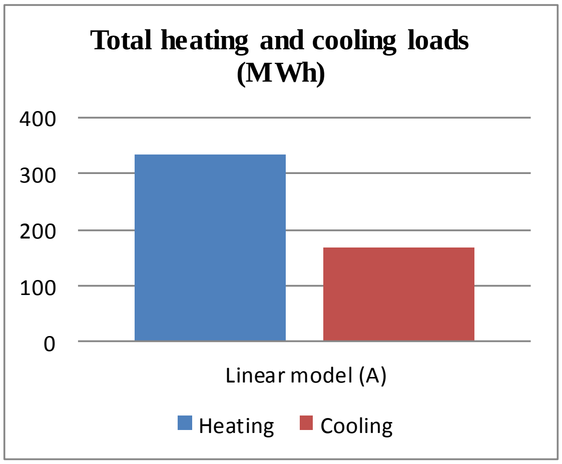


Figure (5.8) Perspective of linear arrangement(B)

The results indicated that the total heating loads for model (B) was the best, while in model (A), they increased by about 5.2%, see figure (5.9). This was because the long facades for all buildings of model (B) were exposed to the sun. And short facades had self-shading. On the other hand, the total cooling loads for model (A) was the best, since in model (B), the total increased by about 27.8%, see figure (5.10).
Also long facades had self-shading in the morning and afternoon. In general, the total loads for model (A) are less than model (B). So model (A) is better than model (B).



Figure(5. 9) Total heating and cooling loads for linear model(A)

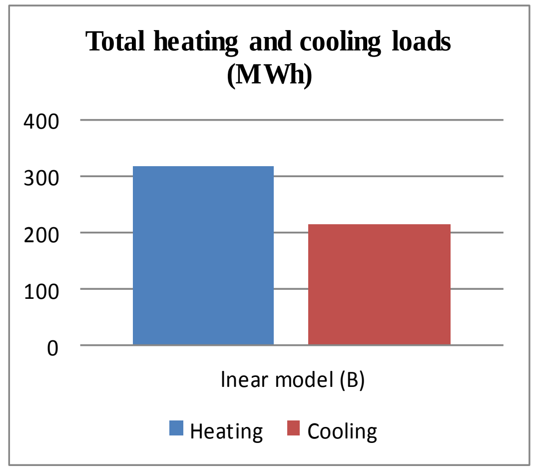


Figure (5. 10) Total heating and cooling loads for linear model (B)

5.6 Comparing the thermal performance of linear model with courtyard model

Simulations were performed using the IES software. The 3D models were created to five buildings forming a line. It was assumed that buildings lay on 30 m street to avoid the semi open courtyard arrangement. See figure (5.11). Then the total heating and cooling loads analysis was performed using *ApacheSim*. Afterwards, the result was compared to the best model of the urban courtyard. Six values of orientation were considered by changing the orientation of the linear model. It was seen to have the ability to change the required energy as it affected the thermal performance of the buildings. The study assumed that long axis of all the models is along north-south. The same was done for the linear arrangement. Then the orientation changed by 15 degrees frequently until it reached 90 degrees, see figure (5.12).

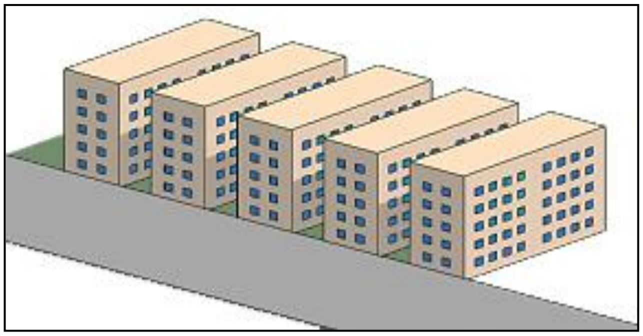


Figure (5. 11) Perspective of linear arrangement

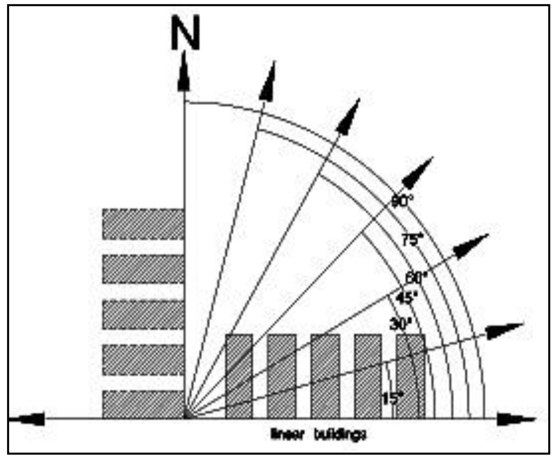
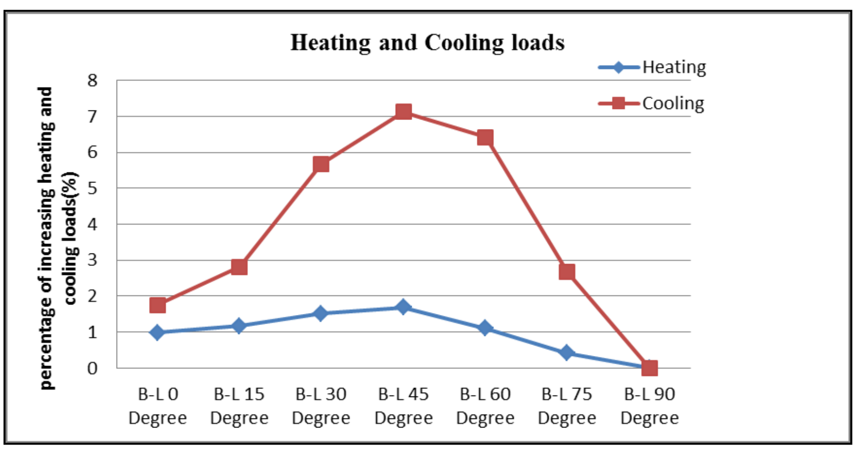


Figure (5. 12) Values of orientation

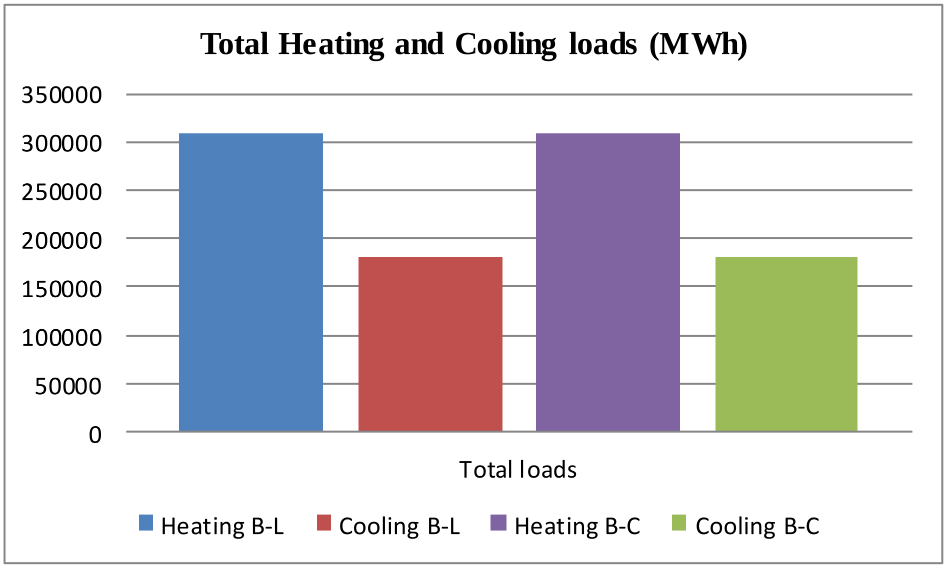
The result indicated that the total heating loads at 0 degree increased regularly until it reached the max at 45 degrees. The values were (0.98%, 1.16%, 1.51%, and 1.68%) respectively. See figure (5.13). The same trend can be observed at an orientation of 60 degrees until 90 degrees; however, the percentage decreased until it reached the optimum percentage at 90 degrees. The values were (1.1%, 0.41%, and 0.0%) respectively. Clearly, it took the same trend at summer by noticing the percentage of cooling loads but with a higher percentage.

To clearly investigate orientation East-West achieves the lowest required energy. Notice that the result took the same trend as well as the buildings available around courtyard. This can be explained as the sun altitude angle is high in the midday of summer that reduce incident solar radiation on southern façade, On the other hand the sun altitude angle is low in the midday of winter that enable south facade to capture desirable solar radiation making it perfect to decrease the cooling loads.



Figure(5. 13) Heating and Cooling loads for linear arrangement

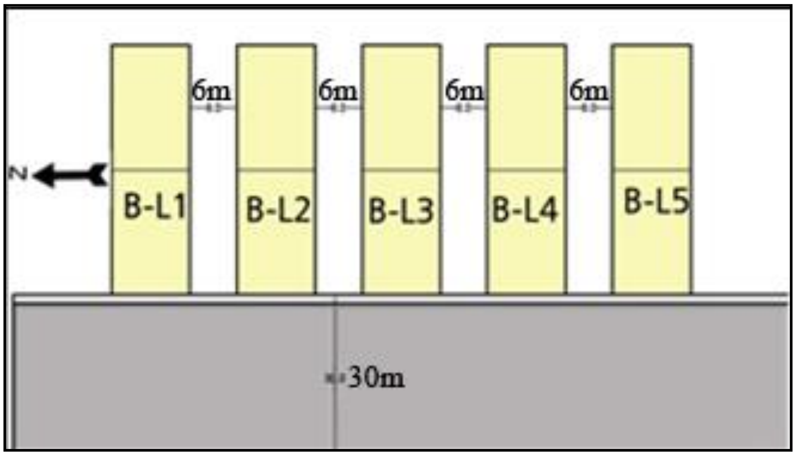
Based on the previous results, a comparison between the best orientations of the courtyard model and the best one of the linear model was done.
The result indicated that the total heating loads for the courtyard model are lower than the linear model. The same result was found for the total cooling loads.
The result indicated that the total heating loads for the linear model increased by about 6.8% and the total cooling loads increased by about 10.1%. See figure (5.14).
This means that courtyard model is better than the linear one .The result verified the effect of the courtyard on the thermal performance of the buildings.



Figure(5. 14) Total heating and cooling loads for courtyard and linear models

5.7 Thermal performance of each building at linear model

In order to understand the thermal performance of the buildings, the researcher had the code (B-L) for linear model. See figure (5.15).



Figure(5. 15) Plan of linear model arrangement

The best building in winter was building (B-L5) as the long facade of the building lay in the southern side, as it was exposed the solar radiation at midday Moreover, the same thing happened to the short facades since they were exposed to solar radiation in the morning and afternoon, see figure (5.16).

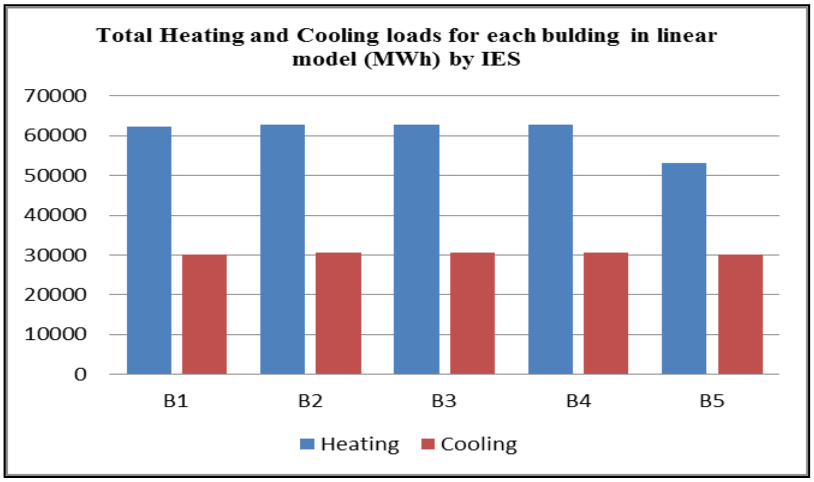


Figure (5. 16)Total Heating and Cooling loads for each building in linear model by IES

Building B-L5 is also the best in summer since the long facades are (north –south). The northern facade has a self-shading effect. On the contrary, the opposite façade has a few effect of solar radiation since the sun altitude angel is high enough which reduces incident solar radiation on southern façade at midday. The buildings in between B-L2_B-L4 almost have the same loads in summer, as they increased by about 1.9%, where it increased by about 0.4% for B-L1. In general, the amount loads of cooling is less than heating, which means that this arrangement is better in summer; this was due to the amount of incident solar radiation on the building façade as it depends on the azimuth in the facades, beside the self-shading of the southern facades and the self-shading of the north facades reduce the heating loads in summer. See figure (5.17) and figure (5.18).

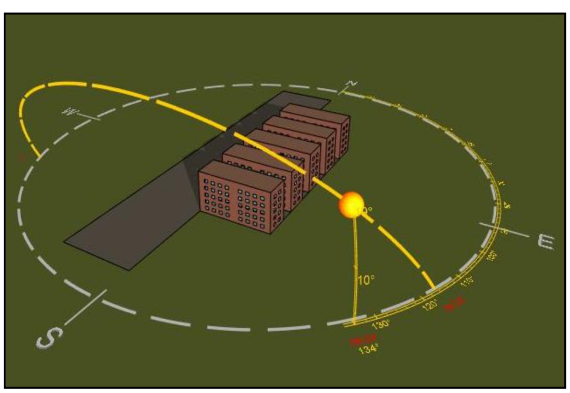


Figure (5. 17) South facades at summer afternoon

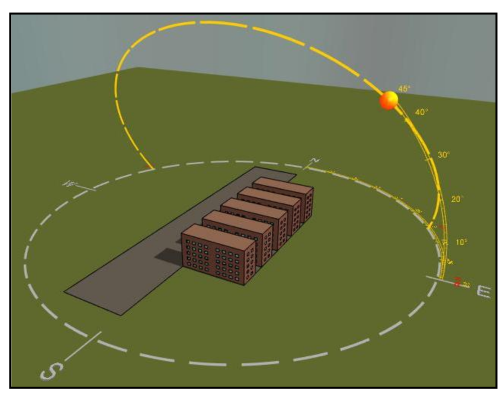
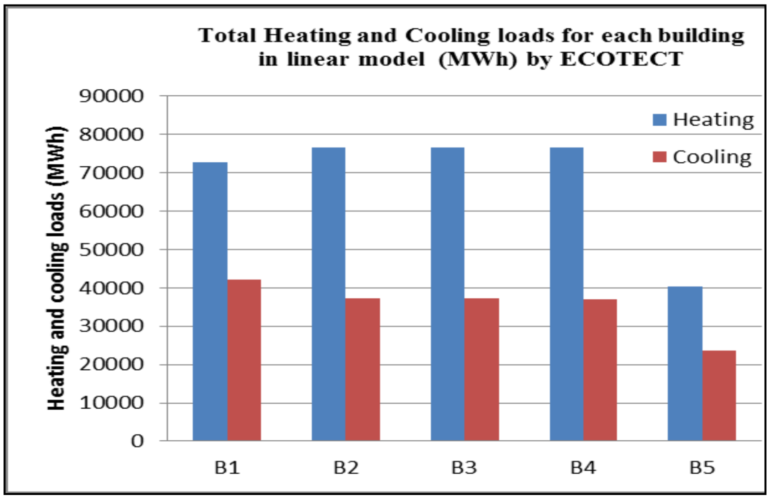


Figure (5.18)South facades at winter afternoon

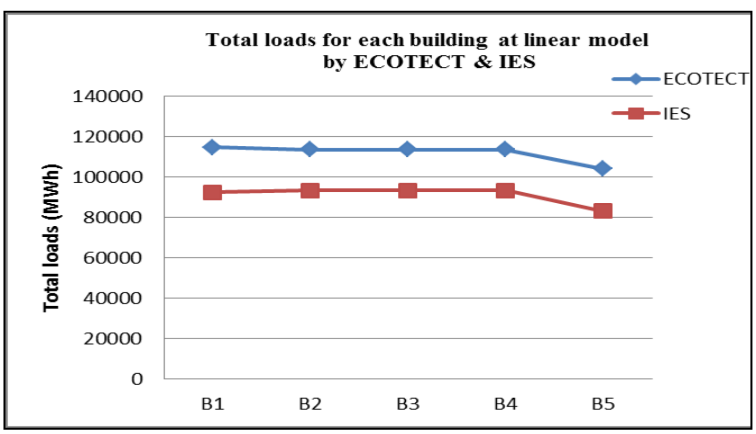
5.7.1 Validation of the best building at linear model

As mentioned in the previous section, building B-L 5 was the best in thermal performance. To affirm this result, a simulation at ECOTECT software was done for the model to calculate the heating and cooling loads. The results indicated that the best building was B45 in winter and summer as it had the lowest heating loads and cooling loads followed by B1, then the rest of buildings had the same percentage of increasing as they have the same circumstances. See figure (5.19).



Figure(5. 19) Total loads for each building in linear model by ECOTECT

Taking into consideration the total amount of heating and cooling for each building simulated by ECOTECT software or simulated by IES software, it became clear that building B5 is the best one. The simulation had the same trend at ECOTECT and IES software with slight difference which is referred to the different load calculation techniques and assumptions. This affirms that building B4 has the best thermal performance, see figure (5.20).



Figure(5. 20) Total loads for each building in linear model by ECOTECT and IES

5.8 Thermal performance of each building at courtyard model

In order to understand the thermal performance of the buildings, each building had a code (B-C) for the courtyard model, see figure (5.21).

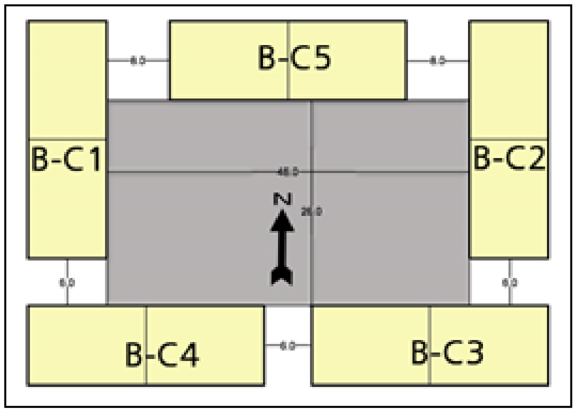


Figure (5. 21) Plan of courtyard model arrangement

The best building in winter (less heating loads) was building B-C4; as the long facade of the building laid in the southern side where incident solar radiation is absorbed in winter .This can be explained as the sun altitude angle is low in the midday of winter that enable south facade to capture desirable solar radiation. The same thing applies on the short facades since they are exposed to the solar radiation in the morning and afternoon. As shown in figure (5.22) the result indicated that the amount of heating loads for building B-C3 increased by about 0.1%. The slight difference was due to the same orientation and conditions of building B-C4 and B-C3. Although Building B-C5 had the same orientation, the amount of heating loads increased by about 5.9%. This was due to the shading on the short facades from the adjacent buildings. Buildings B-C2 and B-C3 increased by about 9%. On the other hand, building B-C5 is the optimum in summer because the long facades are (north –south), as known during summer sun altitude angel is high enough that reduce incident solar radiation on southern façade.

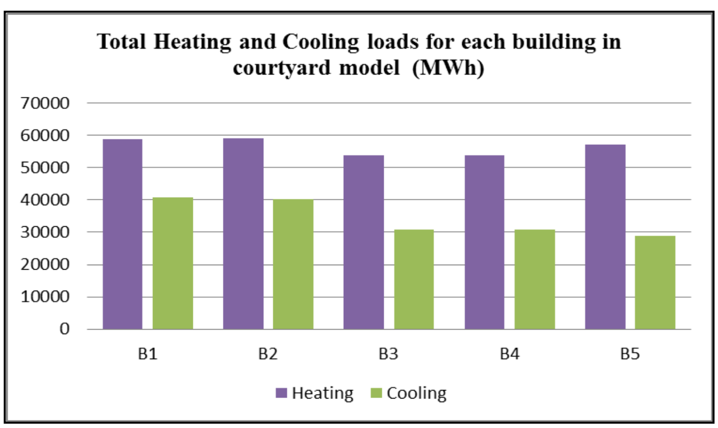


Figure (5. 22) Total Heating and Cooling loads for each building in courtyard model by IES

Also northern facades had a self-shading. The heating loads for building B-C4 increased by about 5.8%, and it increased by about 6.1% for building B-C3. However, the heating loads for building B-C1 and B-C2 were the highest, as they increased by 39.2% and 40.1% respectively. This was due to the orientation of those buildings since the long facades were exposed to the solar radiation in the morning and afternoon. Keeping in consideration the total amount of heating and cooling for each building, it became clear that building B-C4 is the optimum one. The following table (5.2) shows loads for each building respectively

Table (5. 2) loads for each building respectively

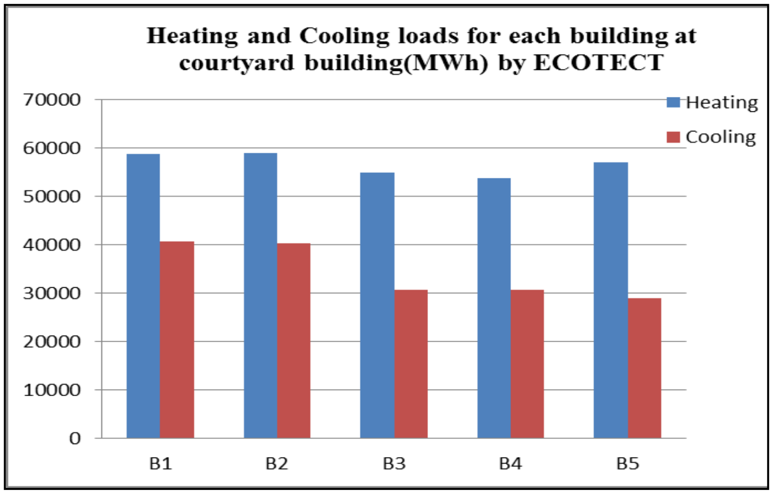
	1 (The lowest loads)	2	3	4	5 (the highest loads)
Heating loads	B4	B3	B5	B1	B2
Cooling loads	B5	B4	B3	B2	B1
Total loads	B4	B3	B5	B2	B1

5.8.1 Validation of the best building at courtyard model

As mentioned in the previous section, building B-C4 was the optimum in thermal performance. To affirm this result, a simulation using ECOTECT software was done for the model to calculate the heating and cooling loads.

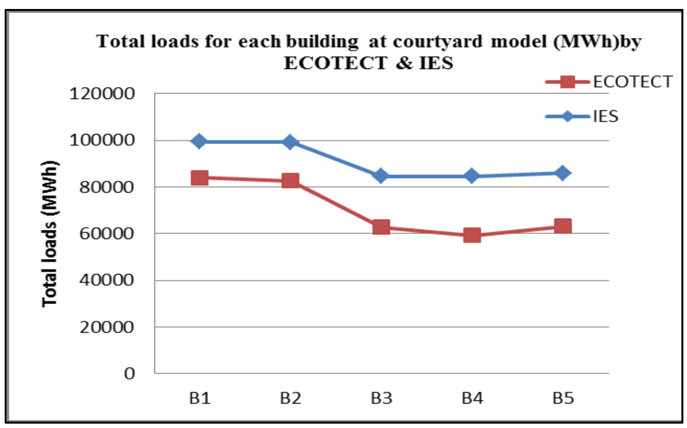
The results indicated that the optimum building was B4 in winter as it had the lowest heating loads followed by B3, where the total heating loads increased by about 5.6%. The slight difference between the two buildings was because they had the same orientation. The total heating loads for building B5 increased by about 11.6%. However, building B1 and B2 had the highest loads; as the total cooling loads increased by (35.9% and 33.2%) respectively, because most of their facades were shaded in the morning and the afternoon. See figure (5.23). In summer, building B5 was the optimum, where cooling loads for building B4 increased by about 1.3%. There was a slight difference between them; that was because they took the same orientation.

Building B3 loads increased by about 8.3%, buildings B1 and B2 increased by about (52.4%, 50.9%) respectively. This was due to the orientation of those buildings since the long facades were exposed to the solar radiation in the morning and the afternoon.



Figure(5. 23) Heating and Cooling loads for each building in courtyard model by ECOTECT

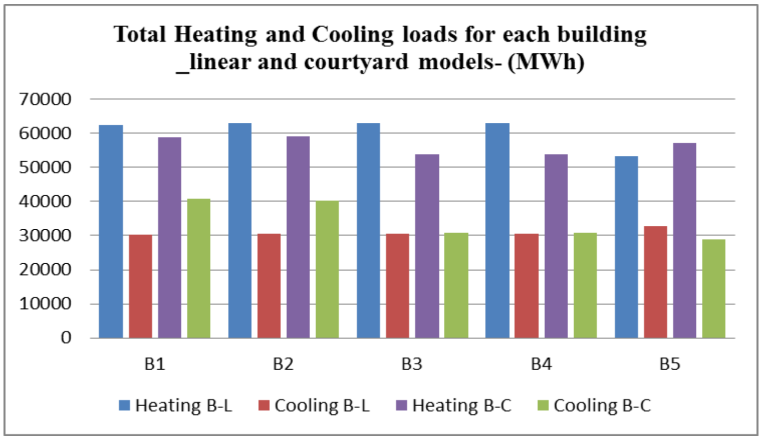
Taking into consideration the total amount of heating and cooling for each building simulated by ECOTECT software or simulated by IES software, it became clear that building B4 is the optimum one. Notice that simulation had the same trend at ECOTECT and IES software with slight difference .This is returned to the different of thermal properties of the building materials installed in each model, which are not considered in simulation.This affirms that building B4 has the best thermal performance, see figure (5.24).



Figure(5. 24) Total loads for each building at courtyard model by ECOTECT and IES

5.9 Comparing the thermal performance of each building in linear model with courtyard model

The results indicated that the total loads for the courtyard model was less than the linear model. On the contrary, it was noticed that the total amount of heating loads for building B-L5 was better than buildings (B-C1, B-C2, and B-C5); however, the buildings (B-L1 to B-L4) had an amount of loads more than all the buildings at courtyard model, see figure (5.25). On the other hand, the amount of cooling loads for building B-L1 was better than the amount loads for buildings (B-C1, B-C2, and B-C3). This was due to the reason mentioned above.



Figure(5. 25) Heating and Cooling loads for each building in courtyard and linear models

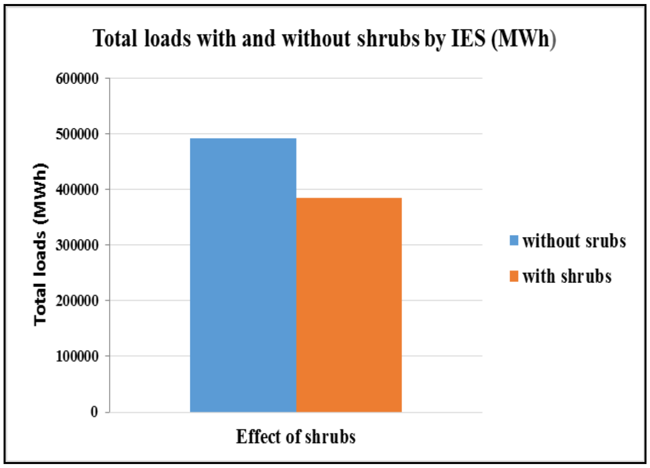
The Previous results indicated that the urban courtyard effects on the thermal performance of the building overlooking it. By decreasing the cooling loads in summer and increasing them in winter according to the amount of incident solar radiation on the building facade depends on the azimuth on the wall and the orientation angle of the buildings.

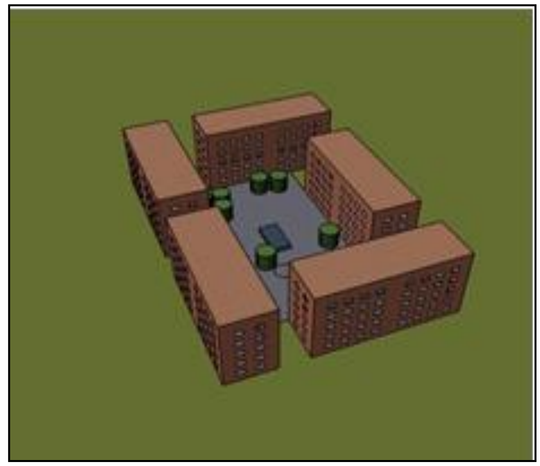
5.10 Effect of vegetation on the thermal performance of urban courtyard

Trees provide multiple benefits for environment and human. Proper trees care and management programs are important to the sustainability of urban context as well as at the urban courtyard. To improve that, the study assumed planting some small deciduous trees in order not to block the solar radiation in winter. Then the researcher calculated the total loads for the overlooking buildings, and then conducted a comparison with the similar buildings without shrubs.

The calculation was done using IES software and ECOTECT software to achieve validity.

As shown in the figure (5.26) by using IES software, the total loads for the overlooking buildings with Planting shrubs in the courtyard was less than the same buildings in courtyard without shrubs.

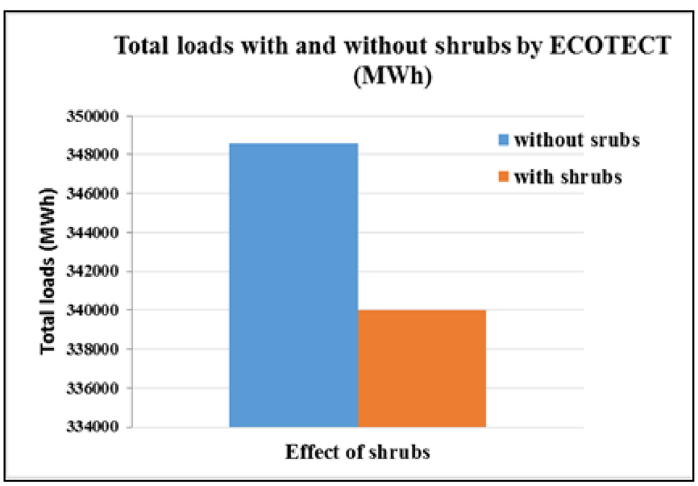


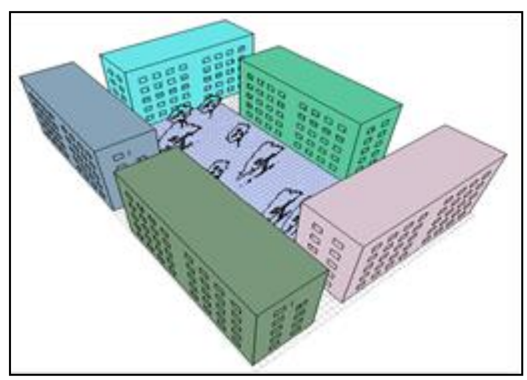


Figure(5. 26) Effect of shrubs on the total loads of buildings by IES

This can be explained as the reduction in Insolation leads to the reduction in surface gain. Scientifically, heat transfer happens between building envelop and surrounding environment by conduction, convection, radiation, and evaporation. When solar radiation reach building envelop, the heat conduction through building elements (walls, roofs, ceilings, windows, and doors) happens directly. When a higher temperature zone get in contact with lower temperature zone, fast molecular movement is occurred from hot to cold, (Szokolay, 2008). Therefore, when tree blocks solar radiation (in summer), temperature is reduced directly and the transfer movement reduces as well.

The same result was obtained by using ECOTECT software when planted some trees in the courtyard as the total loads became less, see figure (5.27).

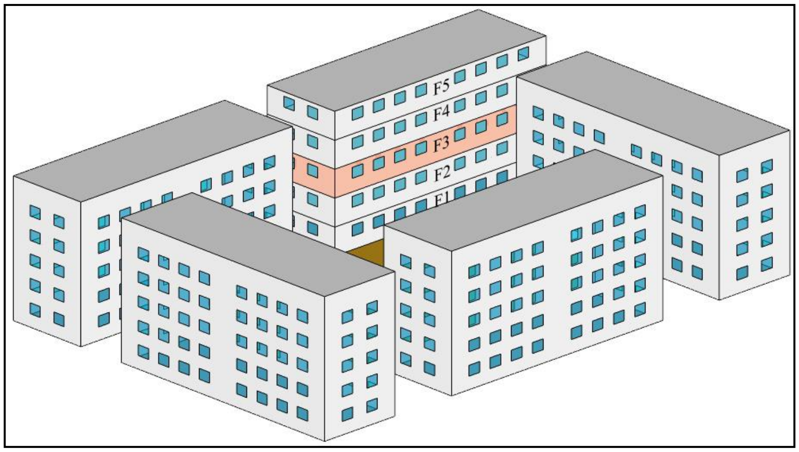




Figure(5. 27) Effect of shrubs on the total loads of buildings by ECOTECT

5.11 Comparison between the floors in the best building

A simulation was done by IES software for the best building B4 to select the optimum floor. Each floor has abbreviation (F) and the floor's number see figure (5.28).

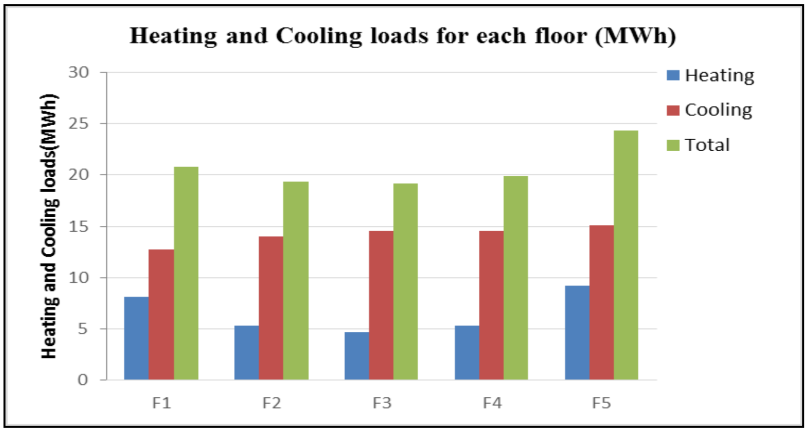


Figure(5. 28) prespictive for ecach floor at the best building

The results indicated that the third floor has the optimum total loads. As shown in figure (5.29) in summer the ground floor had the lowest loads, since the sun altitude angel is high enough that reduce incident solar radiation to reach inside the ground floor. The second floor followed it with increasing of cooling loads by about 10.2%, then the third and fourth with an increase by about (13.8%,and 14.4%) respectively. The highest loads were for the last floor as they increased by about 18.5%. This can be explained as the roof is exposed to the solar radiation most of the day.

In winter third floor had the lowest heating loads, followed by the second and fourth floors with an increase by about (13.2% and 13.8) respectively, the highest heating loads was for the ground floor with increased by about 97.6%.

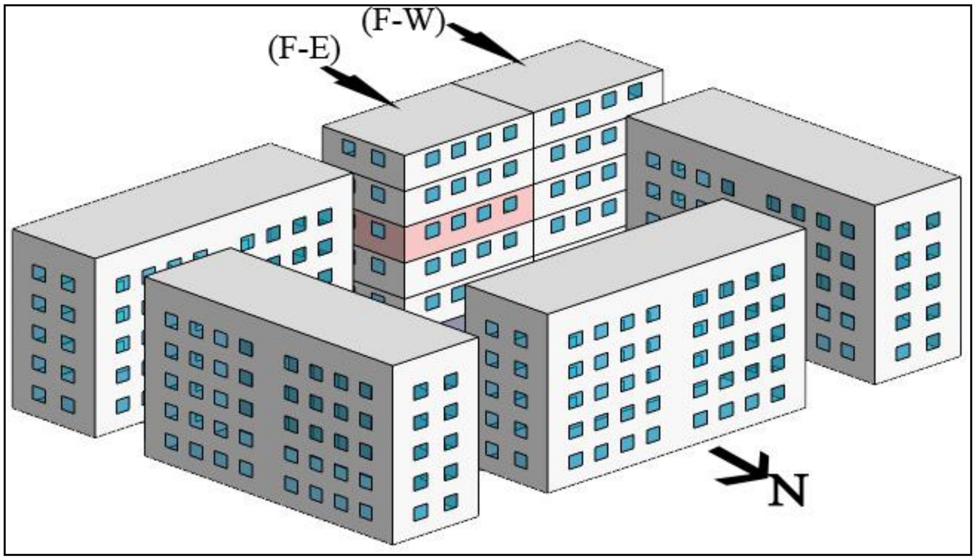
In general the total loads for the third floor was the lowest as it has the best condition in summer and winter.



Figure(5. 29) Total loads of each Floor in the best building

5.12 Comparison between each flat in the best floor

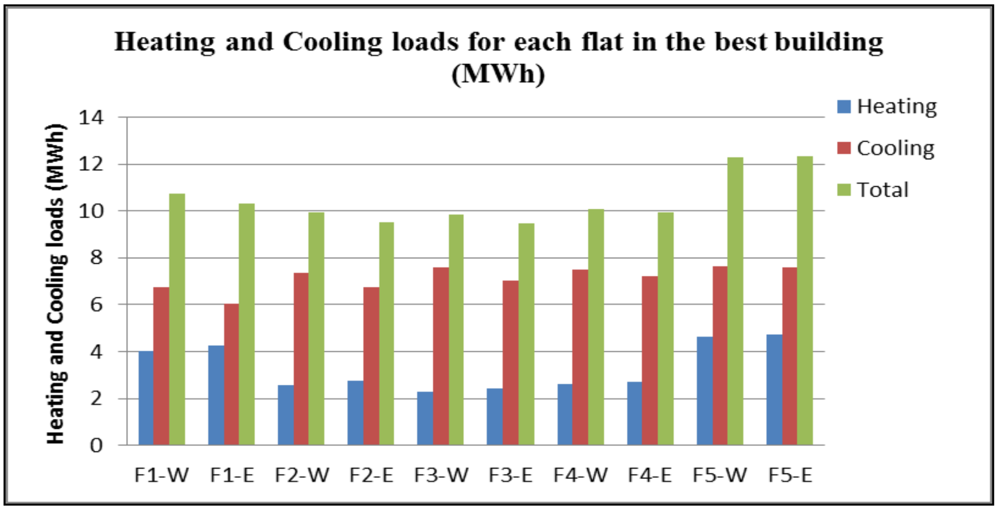
A simulation was done by IES software for the study model to select the best apartment. The eastern apartment took abbreviation (F-E), while the western one took abbreviation (F-W), see figure (5.30).



Figure(5. 30) perspective to the each flat at the best building

As shown in figure (5.31) in summer the eastern apartment at the ground floor had the lowest loads, as the sun altitude angel is high enough which reduces the ability of incident solar radiation to reach inside the ground floor especially from east side. In winter the western apartment at the third floor had the lowest heating loads.

Generally, the western apartments in winter are better than the eastern ones, as solar radiation in the afternoon is more effect from the morning time, moreover incident solar radiation is absorbed in winter .This can be explained as the sun altitude angle is low in the midday of winter that enable south facade to capture more solar radiation.
Otherwise the eastern apartments are the best in summer, as they don’t have western facades while the long facades of the building laid in the southern side where they have low effect of solar radiation since the sun altitude angel is high enough that reduce incident solar radiation at midday, and the northern facades have self-shading.



Figure(5. 31) Total loads of each Floor in the best building

According to the lowest energy consumption for each apartment, it can be concluded that the western apartment at the third floor is the best one.

Conclousin:

This chapter dealt with the best urban courtyard in the context of the housing projects according to the results discussed in the previous chapter.

Firstly, it investigated the best model of urban courtyard in the housing projects according to energy consumption by using IES software and ECOTECT as a validation tool. It investigated the effect of urban courtyard model and linear model on energy consumption to affirm that urban courtyard had effect on the thermal performance of the building. After that it discussed the effect of orientation on the thermal performance of the buildings. It concluded that the urban courtyard along east and west are the best orientation.

It also discussed the effect of vegetation on the total energy consumption; the results concluded that planting some shrubs make the energy consumption less. After that it investigated the best building according to its total loads in summer and winter, the result indicted that the south-eastern building had the less total loads. Finally, it investigated the optimum floor in the best building, where it was at third floor. As mentioned in the previous chapter, every floor contained two apartments, so that it investigated the best apartment and the result indicated that the western apartment is better than the eastern.

6 Chapter 6: Conclusions

6.1 Introduction

The world is undergoing a significant challenge displayed through the lack of the conventional energy and the environmental problems related to the increase in energy consumption .Consequently, this threat is linked with climate change, global warming and unexpected phenomena such as urban heat island. Most cities planners and scientists have been troubled with this change, thus need and comfort of people. The lack of conventional energy and environment pollution is another challenge that related directly and indirectly with increasing CO2 emissions from fossil fuels. Essentially, the buildings are the big contributor to these problems; hence cooling in summer and heating in winter are the largest consumers of energy in the buildings.

Corresponding with the rare conditions of the Gaza Strip, energy demand increases as the populations, services, and welfare increase. Furthermore, residential buildings in the Gaza Strip are the largest consumers of energy for the purpose of cooling, heating, lightening and others. The conflict with the shortage of energy in the Gaza Strip makes the imported fossil fuels the main source of energy. Between political conditions and increasing energy consumption, the Gaza Strip suffers from lack of thermal comfort and healthy environment. However, the building's design in the Gaza Strip doesn't take sufficient account to the climatic factor especially the solar radiation. Hence, this study came to overview the environmental design in the Gaza Strip's buildings especially in the new housing projects. Solar energy is studies to be the main renewable source of energy available in the Gaza Strip with an average duration of solar radiation, which can be useful for many applications.

Urban courtyard design is one of the most direct and efficient method of passive solar design served for the purpose of energy saving. It takes responsibility for many benefits for surrounding buildings. The main solution for energy and pollution issues, choosing the right dimension and orientation of urban courtyards is the solution. It focused on the most common models of urban courtyard in the housing projects at Gaza Strip, and classified them according to the number of overlooking buildings. Accordingly, parametrical studies were hold using the simulation programs ECOTECT and IES to investigate the effect of urban courtyards on the thermal performance and energy consumption of the overlooking buildings. For that reason, the study was divided into two parts. The first section concerned on understanding the thermal effect of courtyards, proportions, ratios and the thermal performance. This part dealt with realistic urban courtyards in housing projects of Gaza Strip and investigated the best model. On the other hand, the second section of the study was focused on the effect of best model of urban courtyard on the thermal performance of the surrounding buildings

The building orientation is another aspect affecting the relation between the buildings' facades and the incident solar radiation falling on them. Consequently, it is affecting the energy consumption for cooling and heating. The main findings of the theoretical study are:

- Solar radiation is the most weather variable influences the air temperatures and affected by the reflections from the ground and adjacent buildings, shading from adjacent buildings and vegetation.

- Buildings are considered the most significant energy consumers, so there are several attempts to solve the energy problem through design low energy building which is known as energy efficient building design.

- Thermal comfort in the buildings environment can be accomplished by incorporating passive solar design techniques in the early phase of design and construction, then lead to reduce air temperature and energy consumption without increasing pollution and costs.

- The urban courtyard parameter and configuration play a great role in determining the amount of solar radiation received by the building's surface which affects the thermal performance inside buildings.

- Building envelope has a great influence on the total heat gain and overall heat transfer coefficient.

- The energy simulation programs can be considered as a reliable analytical method for building energy research and for evaluation of architectural design in early stages.

- The total heating energy needed to provide comfort throughout the year in the climatic condition of the Gaza Strip which is located in hot humid region is greatly less than the required cooling energy.

- Orientation of urban courtyards was taken into consideration in some projects, but in some cases the access to the lot of land affected the orientation and buildings take the same orientation of land plots due to the decrease in land area.

- It has been found that the long axis of the building should be elongated along the east-west direction, as it causes the low energy consumption.

- Urban courtyards at housing projects in the Gaza Strip don't pay a special attention to the climatic factors. Several shapes and proportions were found in the buildings which affect the amount of solar radiation

- A rectangular shape of courtyard with ratio of 1:1.8(W:L) is recommended in order to reduce the cooling and heating requirements with a possibility to enhance its heating performance .

- The urban courtyard along east and west are the best orientation to achieve the optimum thermal performance of the buildings

- Vegetation effect on the total energy consumption; as planting some shrubs make the energy consumption less.

- The optimum building according to its thermal performance was the south-eastern building as it had the less total loads.

- The optimum floor was the third one, as the building consists of five floors.

- The best apartment was the western in the third floor, as each floor consists of two apartments.

- It is important to eliminate the thermal transfer rate between the building envelop and surrounding environment in ways of conduction, convection and radiation in order to maintain the thermal balance.

6.2 Recommendation

- After conducting the current study that focused on finding out the best structure of urban courtyard for the purpose of energy conservation, valuable recommendations were developed to the municipalities, community, planners and engineers, which can be summarized as to:

- For the purpose of achieving thermal comfort in summer and winter, courtyard arrangements are more recommended than the linear arrangements.

- It is recommended to utilize the advantages of urban courtyard arrangements of building in achieving the less energy consumption.

- The closed urban courtyard is more preferable than the semi closed ones in achieving the thermal comfort inside buildings.

- It is recommended to avoid the bad effect of the north- south orientation of the urban courtyard by makes it the short side of the courtyard.

- Promote the concept of urban courtyard in the housing projects due to its proven benefit in energy saving.

- Utilize the advantages and benefits of trees in the urban courtyard for the purpose of energy saving and thermal comfort in the surrounding buildings.
- Design energy efficient buildings, by utilization surrounding courtyard with good manner such as water, shading device and other elements in term of climatic factors.
- It is recommended that the Land Authority and the Stakeholders take into consideration the relation between street and courtyard orientation.
- Renewable energy sources which are available in the Gaza strip, such as solar should be considered as a potential and clear alternative to solve the problem of energy shortage.
- Because the residential sector consumes the large part of the energy in the Gaza Strip, this sector should be the focus to develop plans and strategies for reducing energy demand, by using urban courtyards with the optimum parameter.
- Benefit from the successful experiences that are managed and organized by other countries in energy efficient building and renewable energy techniques.
- Increasing the awareness of architects about the importance of integrating energy efficient building techniques during the different design stages.
- Directing the officials in government to the necessary of developing regulations and standards which ensure the use of energy-efficient principles in housing projects design.
- Using media and school education to help in increasing the awareness of general public about the dimensions of energy problem and the means of energy conservation which can contribute in the solution.
- Develop the existing building laws and legislations in a way that promote energy efficiency in residential buildings. This includes granting licenses and permits.
- It is necessary to utilize renewable energy sources in buildings in order to mitigate the environmental problems and the ever increase in using the conventional sources of energy.
- Sufficient account must be taken in the Mediterranean climate especially to type and configuration of the urban courtyard, as the solar radiation is the most important parameter in this climate.

6.3 Limitations of Results:

As a final remark, there are some limitations of the results:

- The study was based on the Mediterranean climate of the Gaza Strip and the simulation used Tal -Aviv weather data.
- The results achieved from the study come from the thermal point view, because the simulation examined the solar radiation. Other environmental variables such as ventilation, day lighting, urban heat island effect, sky view factor, land and resources weren't considered. In real cases simulation, all of these factors have to be considered in a compromise manner to achieve the best outline.
- Assumptions associated with the use of ECOTECT and Design Builder such as internal gains and load calculation technique.
- Although two simulation programs have been used, a physical or field investigation is recommended for further validation.

6.4 Future studies

- Role of urban courtyards on the thermal performance according to the height of the building.
- Study on thermal performance of other shape of urban courtyards such as, L shape, circular trapezoid, pentagon, hexagon, heptagon, and other shapes, in buildings.
- Study elements of urban courtyards and their effect on the thermal performance.

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Appendix

ECOTECT Setting:

Location and site data

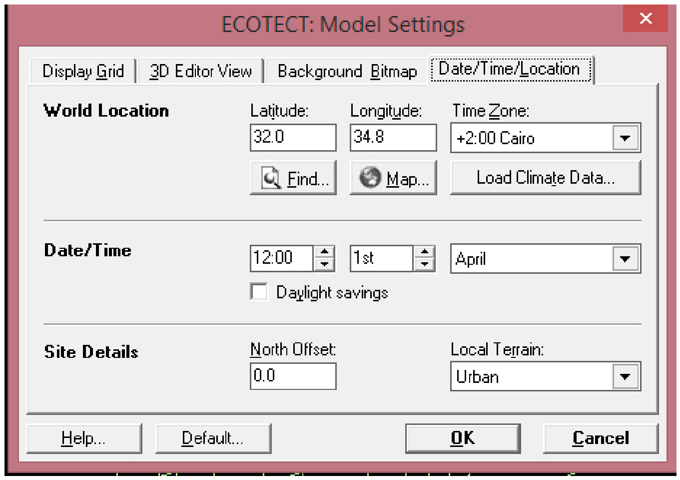


Figure1 : Location and Site Data in ECOTECT

Thermal properties for zones in ECOTECT:

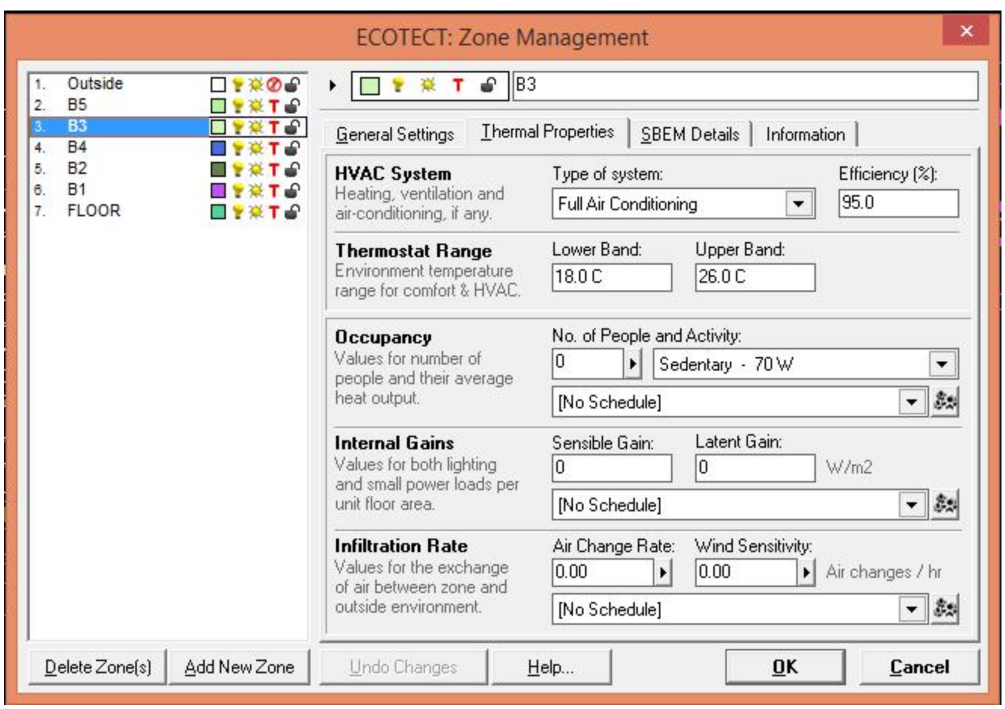


Figure2 : Thermal properties for zones in ECOTECT

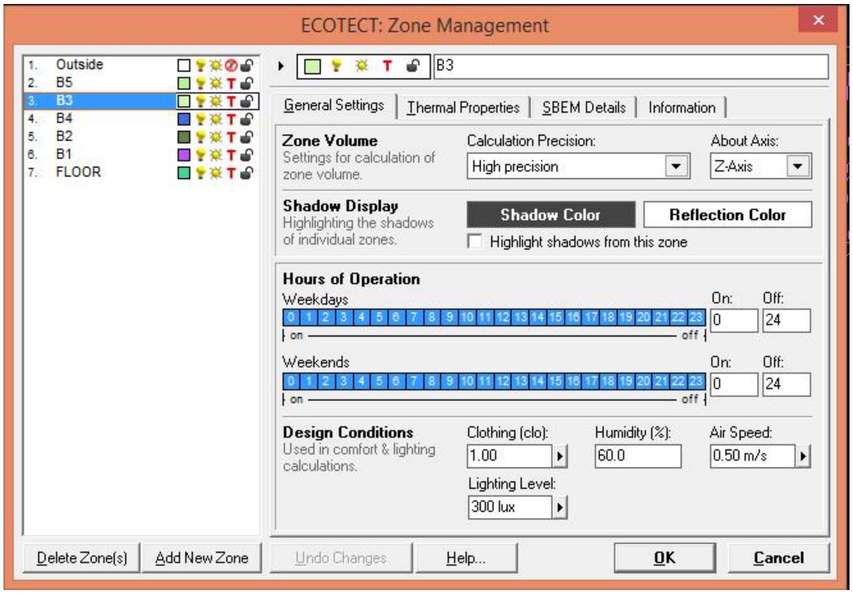


Figure3 : General Settings for Zones in ECOTECT

Materials Assignment in ECOTECT:

Thermal properties for zones in ECOTECT

Materials Assignment in ECOTECT

Walls: U-value= 1.77 W/m² °K and Thermal Lag= 4 hrs, see figures (4) and (5).

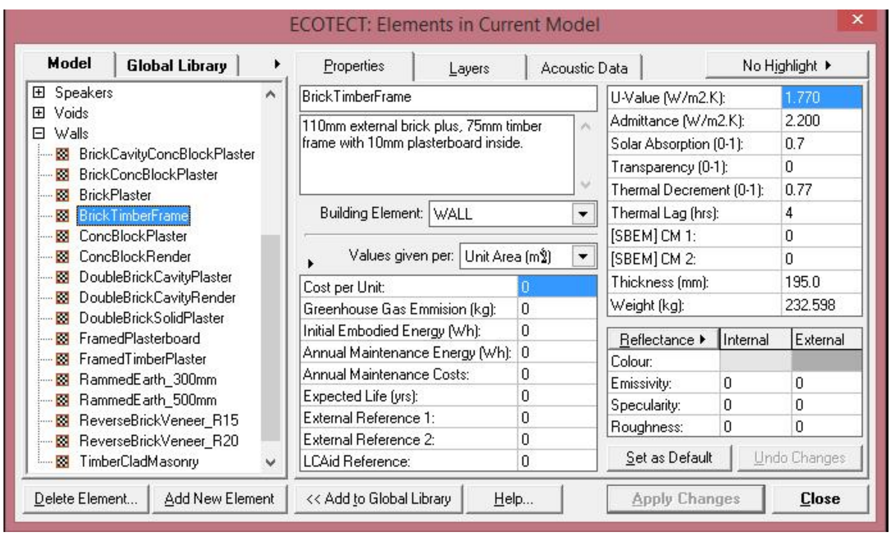


Figure4 : Properties of walls material in ECOTECT

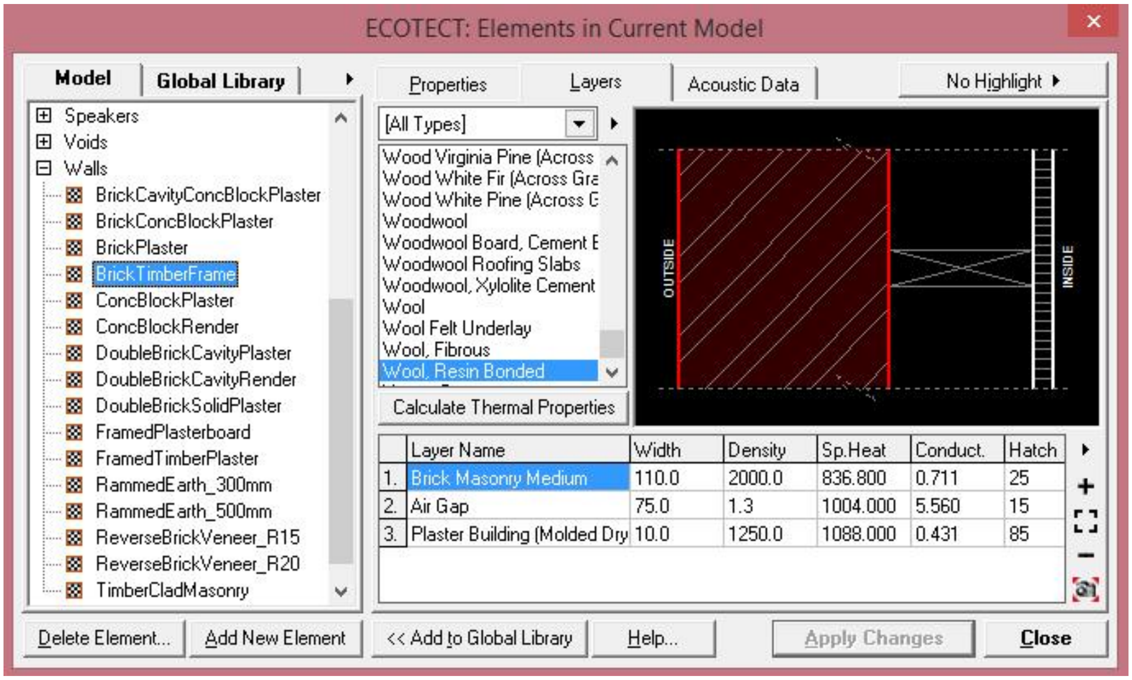


Figure5 : Layers of walls material in ECOTECT

Roof: ConcreteRoof_Asphalt1 with U-value= 0.896 W/m² °K and Thermal Lag= 7 hrs, see figure (6) and figure (7).

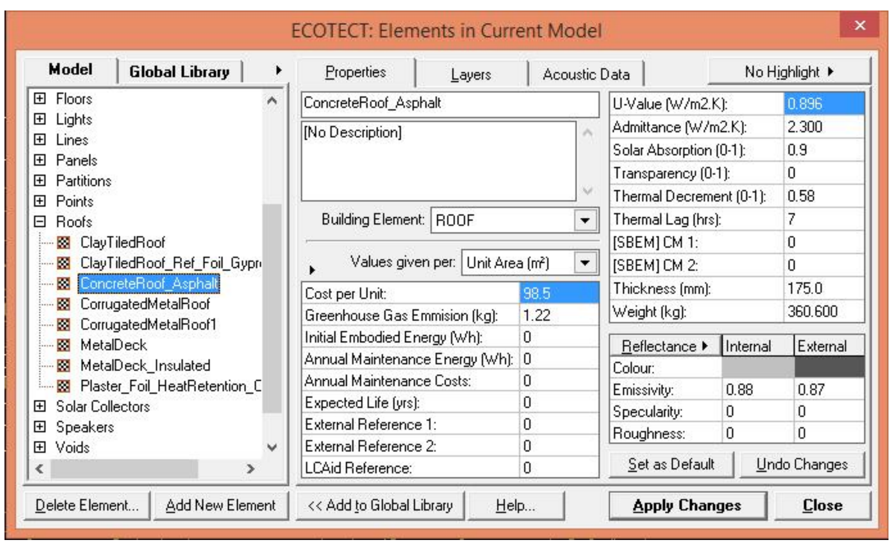


Figure6 : Properties of roof material in ECOTECT

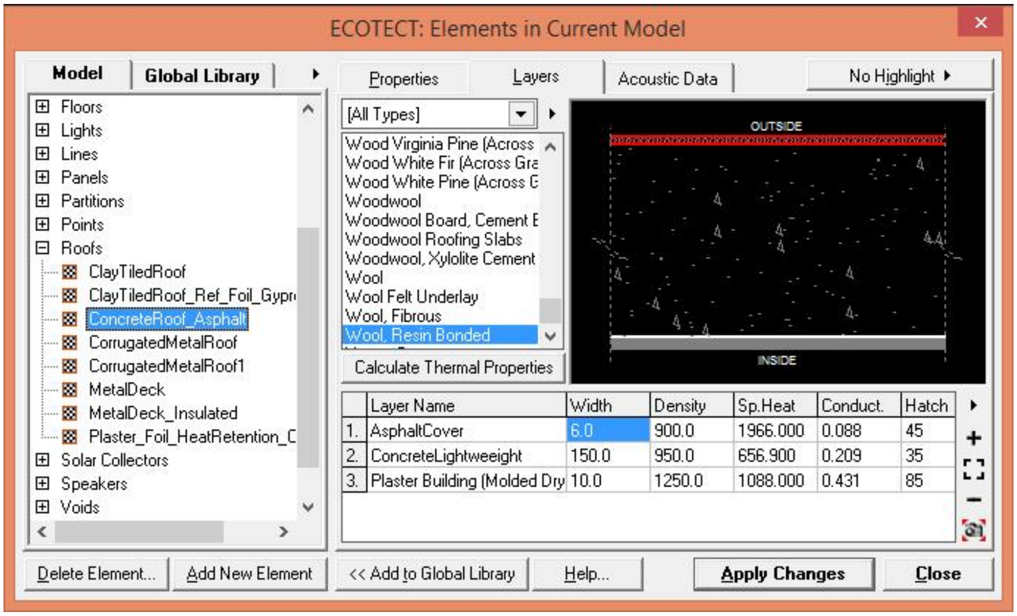


Figure7 : Layers of walls material in ECOTECT

Ground: ConcSlab_On Ground with U-value= 0.88 W/m² °K , see figure (9) and (10).

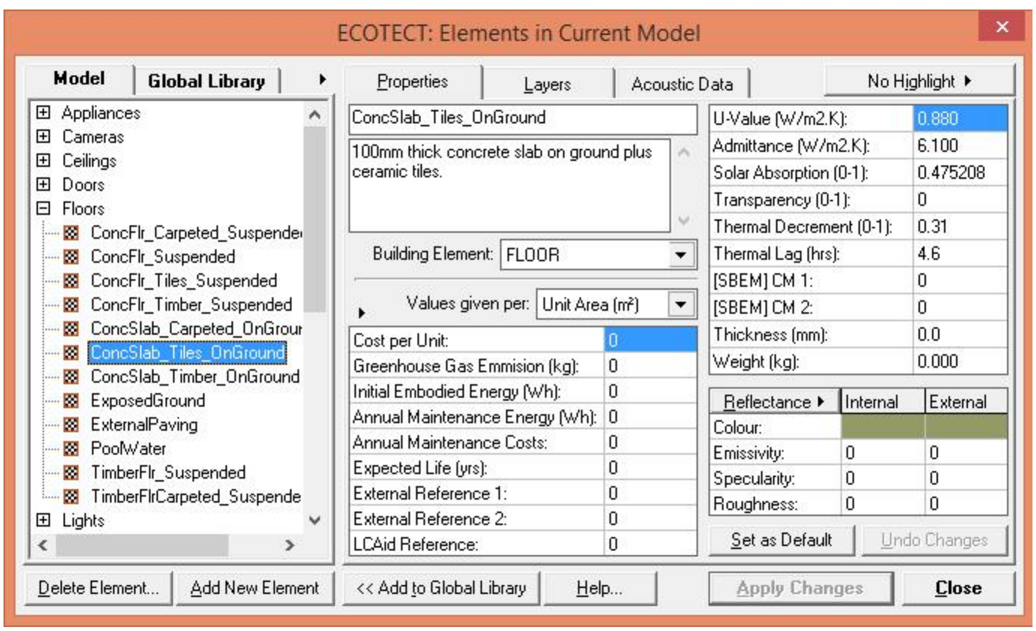


Figure8 : Properties of roof material in ECOTECT

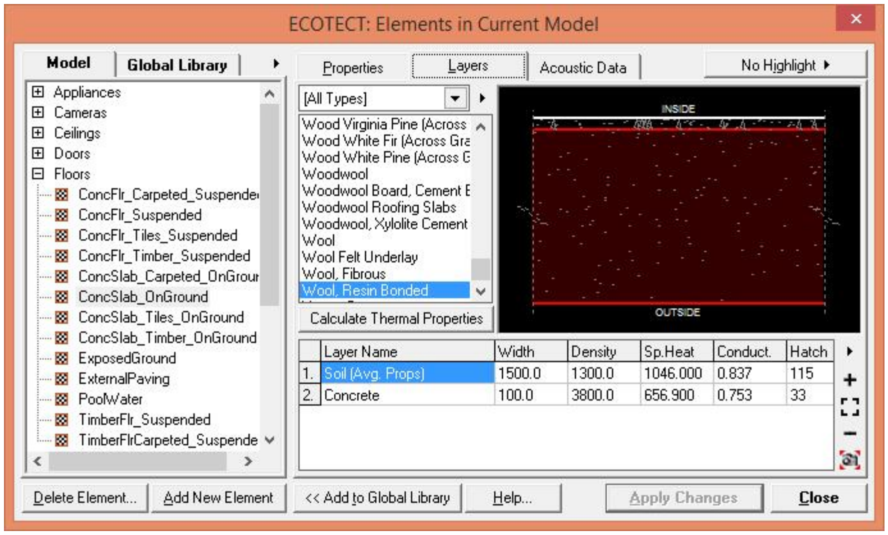


Figure9 : Layers of walls material in ECOTECT

IES Setting:

Location and site data

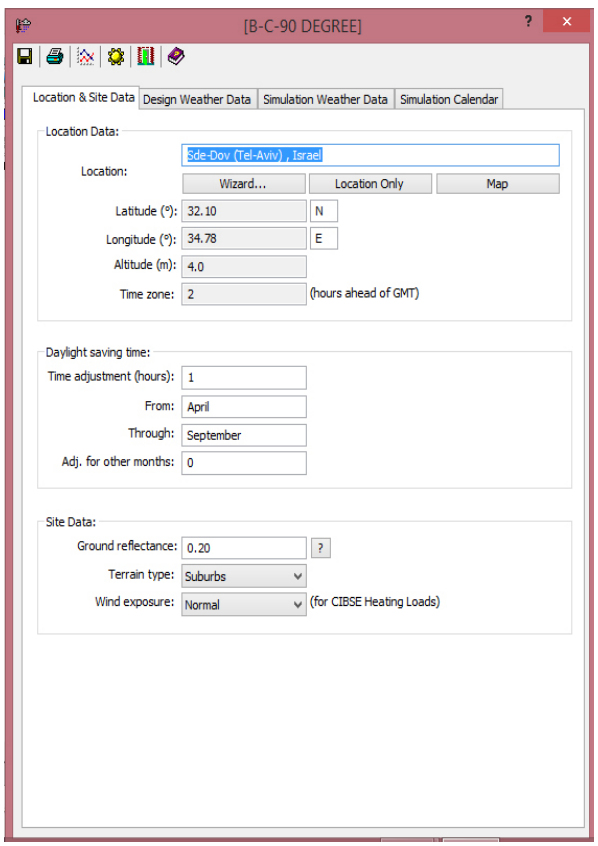


Figure10 : Location and site data

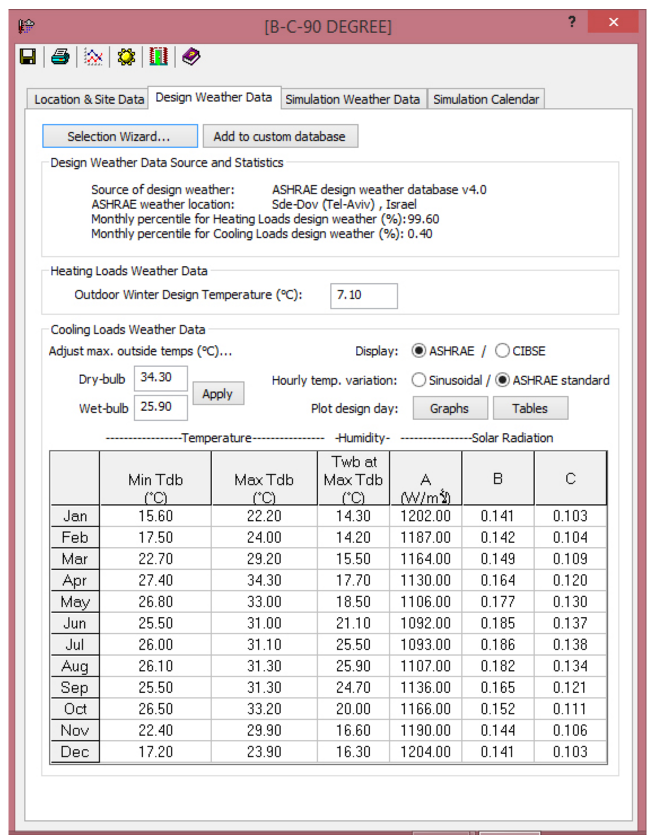


Figure11 : Design weather data

Setting of SunCast

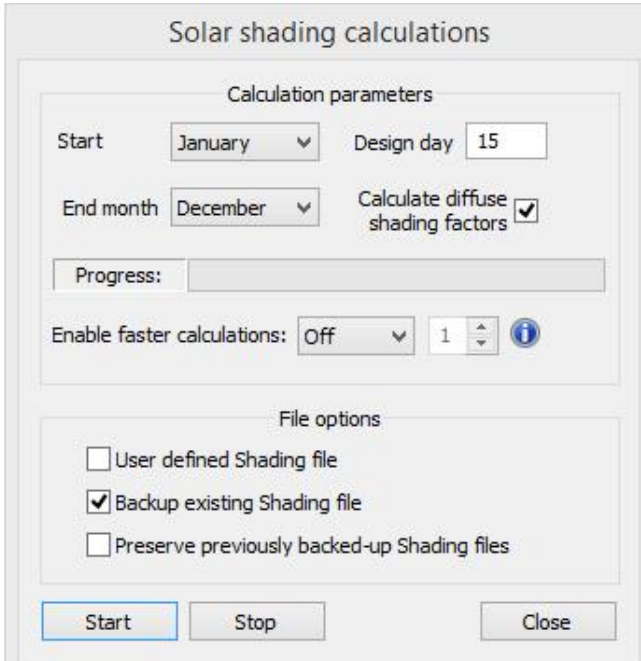


Figure12 : Setting of SunCast

- **Setting of ApacheSim**

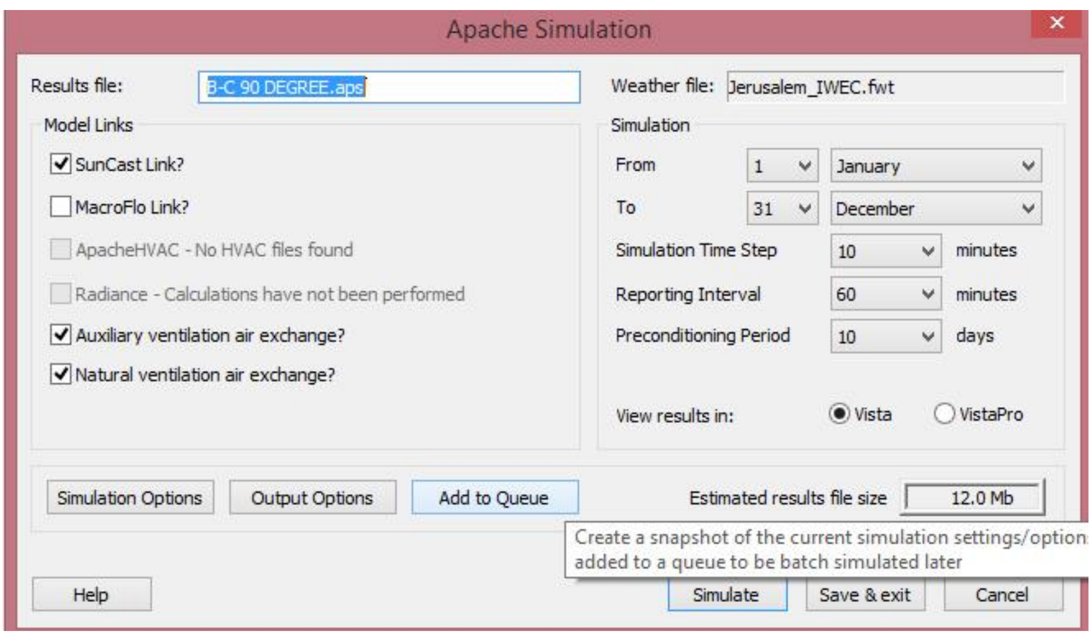


Figure13 : Setting of ApacheSim (dynamic simulation)

- **Building Template Manager**

Thermal condition

Room condition

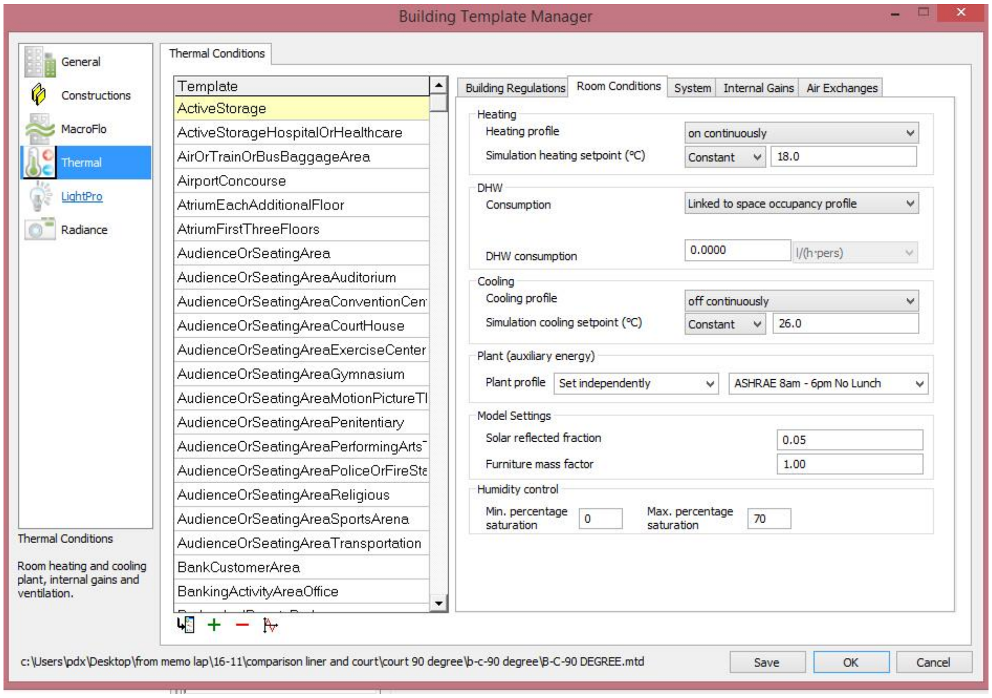


Figure14 : Room Thermal condition in IES

- **Construction in IES**

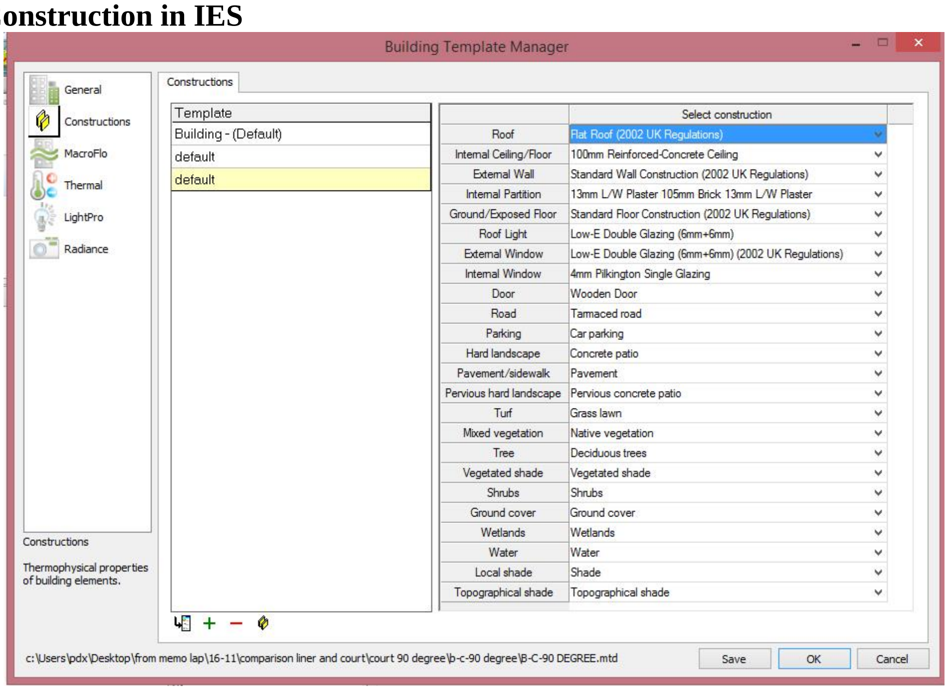
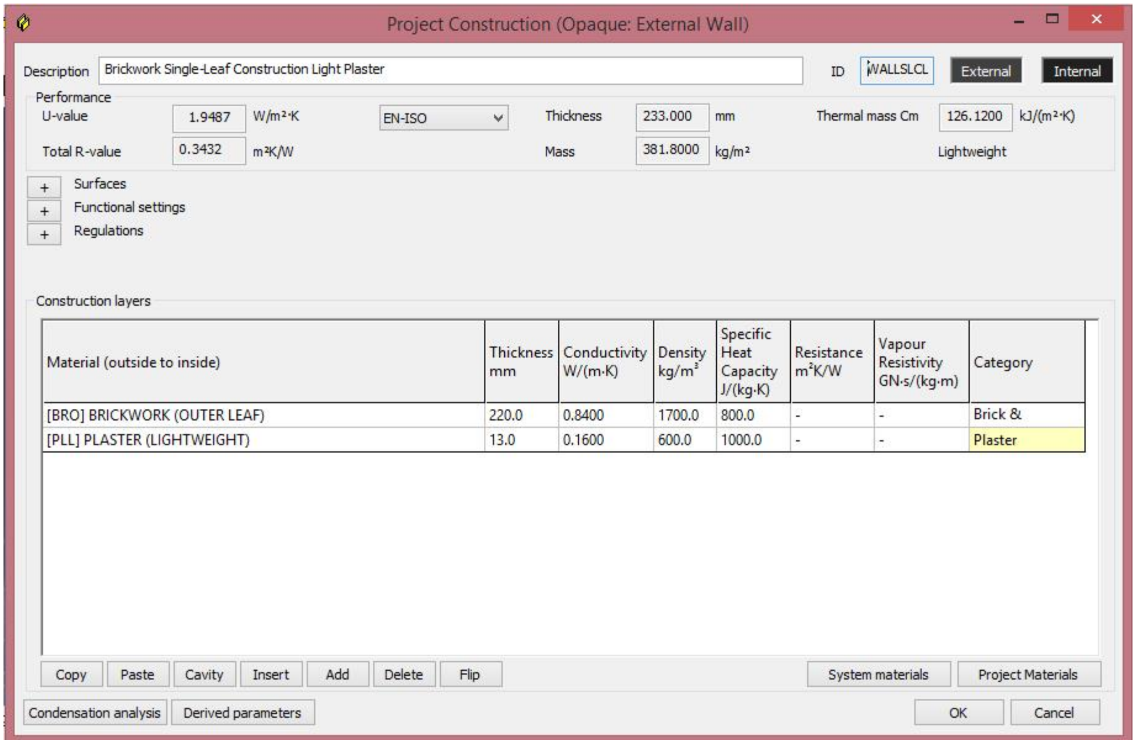


Figure15 : Construction in IES

- **Apache construction database**

External wall: brickwork single-leaf construction light plaster



Project Construction (Opaque: External Wall)

Description: Brickwork Single-Leaf Construction Light Plaster — ID: WALLSLCL — External — Internal

Performance
U-value 1.9487 W/m²·K — EN-ISO — Thickness 233.000 mm — Thermal mass Cm 126.1200 kJ/(m²·K)
Total R-value 0.3432 m²K/W — Mass 381.8000 kg/m² — Lightweight

+ Surfaces
+ Functional settings
+ Regulations

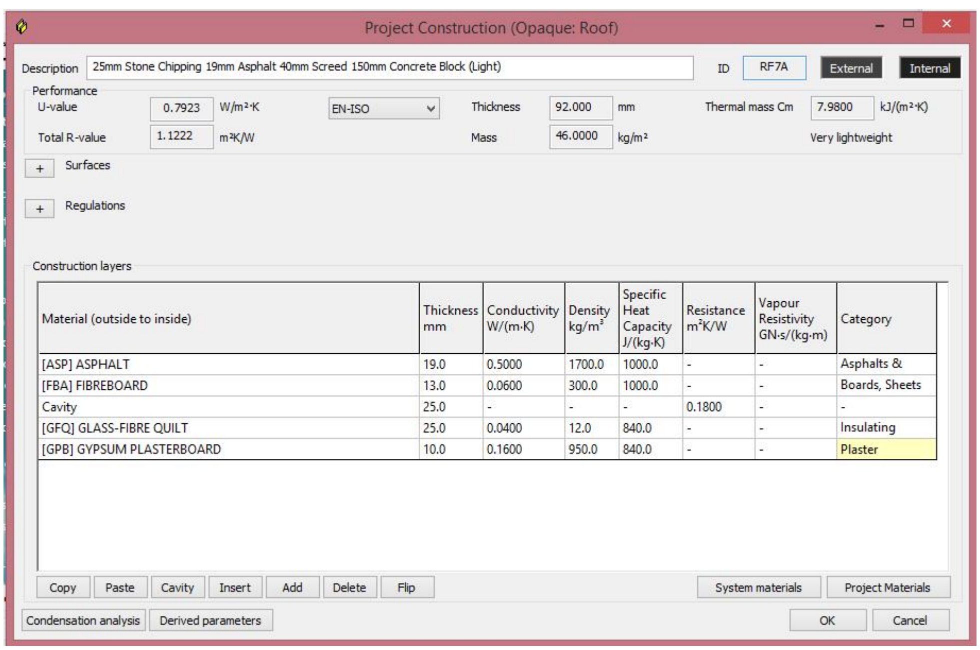
Construction layers

Material (outside to inside)	Thickness mm	Conductivity W/(m·K)	Density kg/m³	Specific Heat Capacity J/(kg·K)	Resistance m²K/W	Vapour Resistivity GN·s/(kg·m)	Category
[BRO] BRICKWORK (OUTER LEAF)	220.0	0.8400	1700.0	800.0	-	-	Brick &
[PLL] PLASTER (LIGHTWEIGHT)	13.0	0.1600	600.0	1000.0	-	-	Plaster

Copy — Paste — Cavity — Insert — Add — Delete — Flip — System materials — Project Materials
Condensation analysis — Derived parameters — OK — Cancel

Figure16 : Layers of walls material in IES

Roof: 25mm stc 19mm asp 40mm sc 150mm cbl



Project Construction (Opaque: Roof)

Description: 25mm Stone Chipping 19mm Asphalt 40mm Screed 150mm Concrete Block (Light) — ID: RF7A — External — Internal

Performance
U-value 0.7923 W/m²·K — EN-ISO — Thickness 92.000 mm — Thermal mass Cm 7.9800 kJ/(m²·K)
Total R-value 1.1222 m²K/W — Mass 46.0000 kg/m² — Very lightweight

+ Surfaces
+ Regulations

Construction layers

Material (outside to inside)	Thickness mm	Conductivity W/(m·K)	Density kg/m³	Specific Heat Capacity J/(kg·K)	Resistance m²K/W	Vapour Resistivity GN·s/(kg·m)	Category
[ASP] ASPHALT	19.0	0.5000	1700.0	1000.0	-	-	Asphalts &
[FBA] FIBREBOARD	13.0	0.0600	300.0	1000.0	-	-	Boards, Sheets
Cavity	25.0	-	-	-	0.1800	-	-
[GFQ] GLASS-FIBRE QUILT	25.0	0.0400	12.0	840.0	-	-	Insulating
[GPB] GYPSUM PLASTERBOARD	10.0	0.1600	950.0	840.0	-	-	Plaster

Copy — Paste — Cavity — Insert — Add — Delete — Flip — System materials — Project Materials
Condensation analysis — Derived parameters — OK — Cancel

Figure17 : Layers of roof material in IES

- **Apache variables**

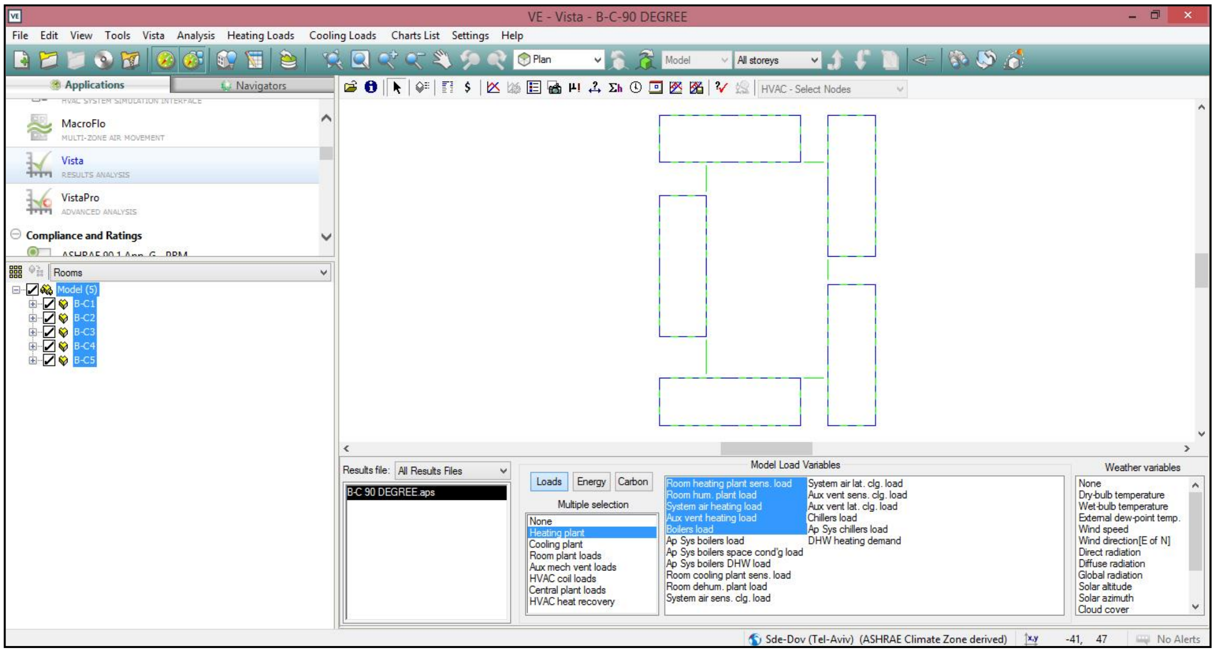


Figure18 :Apache variables for the study model