Performance Analysis of Solar Gain and Day lighting Effect Using Different Choices of Materials of Double-Skin Facade under Desert Climatic Conditions

تحليل أداء تأثير الكسب الحراري والإضاءة الطبيعية عند استخدام خيارات مختلفة من مواد البناء في نظام البناء بالواجهة الإضافية تحت الظروف المناخية الصحراوية

By: Samar Rafie Shaker Al Tekreeti

2013217254

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Faculty of Engineering & IT

Dissertation Supervisor

Professor Bassam Abu-Hijleh

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Abstract

This study presents a performance analysis of solar gain and day lighting effect using different choices of materials of double-skin facade under desert climatic conditions. In addition, it evaluates the possible positive effects that the use of double skin facades can have on the indoor environment in commercial buildings such as offices. During the working process different literature sources and research about double skin facades and indoor environment conditions are gathered and analyzed. A computer simulation based research will be made in order to compare the theory and get a better insight of how these systems function in practice.

Furthermore, literature is taken into consideration regarding double-skin facades, including its classification and its effectiveness and feasibility in hot and humid climates. The analysis led to many findings and to a section about outer skin materials and effective cavity depth reaching the aim for reduction in cooling load and maximizing daylight penetration at the same time.

A computer simulation software investigation tools, conditions and parameters were set for appropriate grounds of the study. Simulation results were used in comparison with a baseline case and assimilated multiple system into the simulation software to better understand the effect on each selected material.

Results show a range of reduction for each material profile starting from 10% and up to 37 % cooling load consumption savings utilizing double skin facade at the depth of 1.0 meter cavity with an open shaft configuration when using concrete and glass as external skin. The dissertation concludes with limitations and suggestions for future studies.

الملخص

تتناول هذه الدراسة تحليل أداء الكسب الحراري والإضاءة الطبيعية وتأثيرهما نتيجة استخدام خيارات مختلفة من مواد البناء في نظام البناء بالواجهة الإضافية تحت الظروف المناخية الصحراوية. بالإضافة لذلك فإنها تحلل النتائج الإيجابية الممكنة لاستخدام الواجهة الإضافية (المزدوجة) على البيئة الداخلية للمباني التجارية مثل المكاتب. خلال العمل سيتم جمع وتحليل مراجع وبحوث عن الواجهة الإضافية وظروف البيئة الداخلية وسوف يتم عمل بحث نوعي لمقارنة النظرية والحصول على فهم أفضل لكيفية عمل هذه النظم عملياً.

وقد اخذ بعين الاعتبار الأوراق البحثية والمراجع التي تتناول الواجهة الإضافية بما فيها تصنيفها وتأثيرها وجدواها في المناخ الحار والرطب. وتوصل البحث لعدة استكشافات ومنها جزء عن المواد المستخدمة في الواجهة الخارجية وعن البعد المناسب لهذه الواجهة لتعطي الهدف المطلوب لتخفيف الحمل عن نظام التبريد ولزيادة الاستفادة القصوى من ضوء النهار في نفس الوقت.

وقد تم إعداد نظام محاكاة لأدوات وظروف وأطر البحث عن طريق الحاسوب بما يتناسب مع هذه الدراسة. نتائج المحاكاة وضعت كحالة في حد سقفي وجمعت عدة أنظمة في نظام المحاكاة لفهم أفضل لتأثير كل مادة من المواد المختارة.

أظهرت النتائج انخفاض في كل المواد بنسبة تبدأ من 10%-37%في توفير استهلاك التبريد عند استخدام الواجهة الإضافية ببعد 1متر عن المبنى بواجهة مفتوحة عند استعمال الإسمنت والزجاج كواجهة خارجية. وتختم رسالة البحث باقتراحات وتحديات للدراسة في المستقبل.

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To God Almighty, the ultimate source of inspiration and goodness whose diving intervention, knows how to bring out the best in me.

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Chapter | 1

Introduction

1.1 Overview

This chapter will briefly introduce the motivation of this dissertation, which concentrates on the climatic and geographic location and their impact on this study. In addition to introducing an architectural facade system, this could mitigate the desert climatic effect on building cooling load and daylight penetration using this system as a passive design strategy.

The importance of these findings may set standards for building double skin facade in the UAE in particular and for any country that share similar climatical conditions with more understanding about the possibility for the used materials and multiple conditions and parameters can be incorporated to best utilize this practice for new design buildings as well as retrofits projects.

1.2 Double Skin Façade as a Green Building Construction

Frontage or facade is the first noticeable element of any building. This element acts as a medium between the indoor environment and the outdoor environment. What about the Double Skin Façade as a green building construction in desert climate

The climatic conditions in the Gulf area in general and the United Arab Emirates (UAE), in particular are considered hot humid conditions. Building envelopes are protected by the facade from the harsh desert climate. Different approaches and design ideologies influence the architecture movement in the UAE. However, these often face huge environmental issues. Energy consumption for cooling load marks up to almost 60% of the energy consumed to cool the building envelopes and gives a comfortable indoor environment. (Kazim, 2005).

The climate in the United Arab Emirates suffers unpleasantly high temperatures as it can reach 49 C degree during the summer and specially July and August. Humidity adds to heat issues during this period making the outdoor environment very uncomfortable. At this time people often conduct most of their activities indoors.

The construction industry in the UAE had huge movement. The country moved from building typical multi story buildings with concrete skins and aluminum framed windows glazing to skyscrapers with carton wall skin design as per Dubai Chamber of Commerce report (2014). Materials were developed further to deal with the climatic conditions the country suffers. Double skin facade systems provide a 30% reduction in Energy consumption. (Simon, 2013)

As a scientific advancement in architecture, double skin facade (DSF) acknowledges the urgent need for energy efficient system as well as aesthetics in attaining controllable variables for the comfort of building users. Double skin facades also allow building owners to save more as it lessens operational cost, but increases efficiency of building with regard to sustainability and environmental influences. Double skin facades need to provide an acceptable daylighting penetration yet offer a thermal defense for the benefit of those people working inside the buildings. The DSF certainly offers for these needs in an elegant and innovative way. This study discusses the benefits of Double Skin Facades for the indoor surroundings in terms of daylight penetration and cooling load reduction. It assesses the probable positive impact that double skin facades use can bring on the indoor surroundings. During the discussion process, various literature sources and studies concerning DSF and indoor surrounding conditions will be collected and analyzed. (Harris, 2004)

Various material used as outer skin in double skin facade system will be analyzed and discussed to ascertain their benefits. In most cases, the outer layer acts as the glass outer shading device and it is not the main weather barrier. It just offers shading to the interior space. Since the external layer is not a key thermal or weather barrier, we can always use laminated glass and lessen the joint sizes. This can provide us with the taut screen effect we are in search of. The frit and coating on the glass, treated wooden blanks, aluminum or concrete shaped organic give the first layer of protection from solar radiation. The glass, wooden blanks or concrete shaped organic fins are fritted, where the second layer offers protection against thermal radiation. (Bragança et al., 2007)

This system can be applied to new designed buildings as well as the old existing ones. Where the existing building must undergo major alternations and carful structural calculations in order to utilize this strategy to maximum benefits. A study conducted in Egypt, in 2008 showed the performance of a single skin facade against the performance of proposed solutions based on the use of double skin facade where a simulation model was created for an office building with serval profile options (clear DSF, tinted DSF, reflective DSF) (Hamza, 2008).

The building facade subject of energy-efficient whether it is innovative, old, basic, or extravagant. A properly sealed facade is a global requirement to conserve energy of building, repeatedly signifying the use and worth of such system structure. Small details like coloration, building materials, acts as an aesthetic element as well as an architectural one. Careful planning is required during design development. This can be very crucial in commercial office buildings double skin facade. (Chan et al., 2009)

1.3 UAE Sustainability Scenario

Improving energy consumption practice is beneficial for every person. Plan to reduce energy consumption starts at an individual level and affects the country and the entire worlds at the end. Energy efficiency benefits are numerous. Some of these benefits can be to save money, improves the economy as whole, contributes to a better environment, and enhances the quality of life in general. (Alliance to Save Energy, 2012)

Attaining reduction by optimizing energy usage, rather than merely cutting back, means that there are no disadvantageous effects on the users. Energy consumption management and reduction of fuel bills, also decreases greenhouse gas (GHG) emissions and shrinks the country's dependence on fossil fuels. Buildings are accountable for the world's electricity consumption by 60 percent with one third of greenhouse gas emissions from energy usage. (Ees.ae, 2015) as can be seen in Figure 1.1

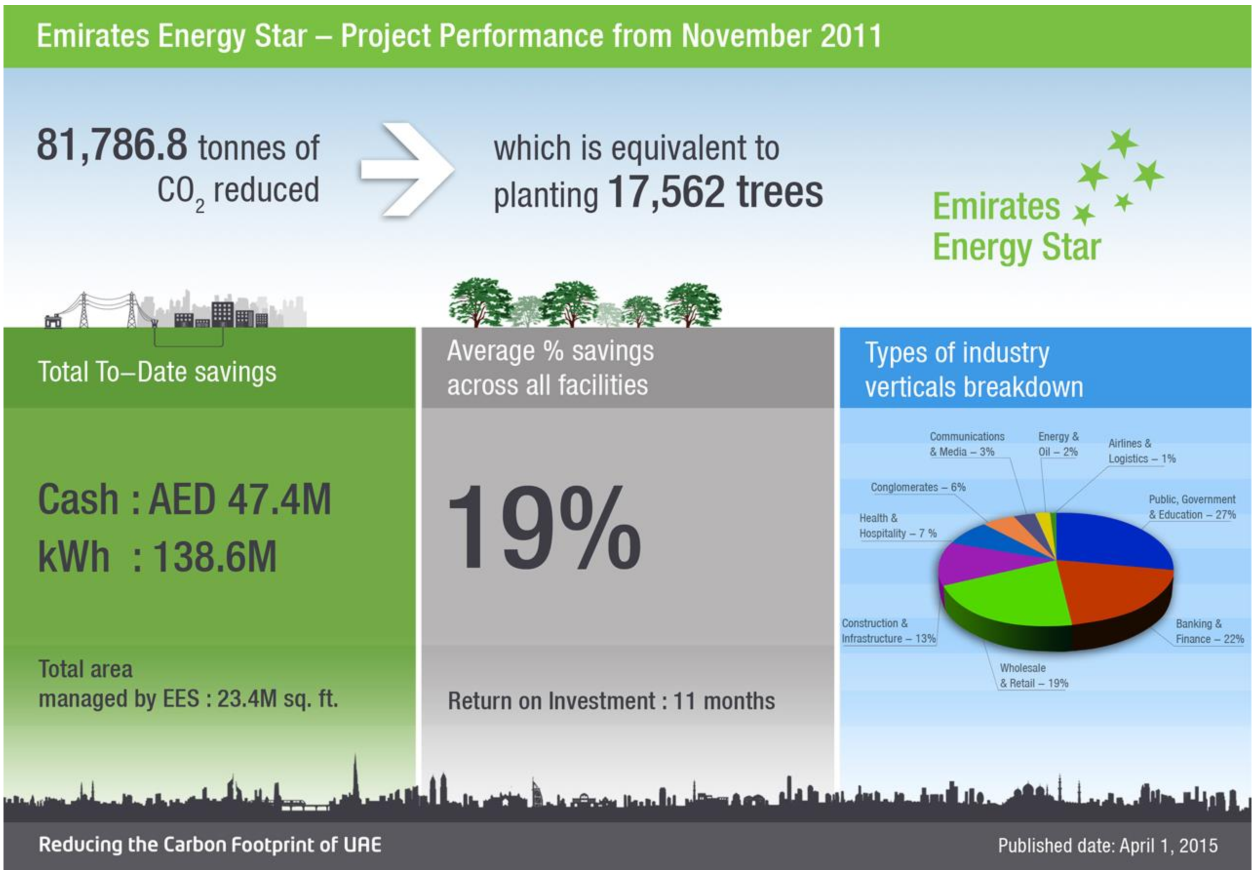

Figure 1.1: Reducing the Carbon Footprint of UAE (Source: EES Project Performance Dashboard, 2015)

Dubai Electricity and Water Authority (DEWA) targets a reduction of 30 % in total energy consumption by the year 2030. The standing point today is 4% compared to results from 2013. In 2010, per capita consumption of electricity was 16,022 kW where today the reading is 15,346 kW. In order to achieve these targets set by the Dubai’s Supreme Council of Energy has charted many programs and initiatives aiming to accomplish energy reduction. Dubai municipality had issued in 2011, a new guide for specifications and regulations related to green building design and construction. Regulations have been made to raise the common standards to address even existing building in retrofitting and district cooling. Dubai alone holds a number of retrofit projects that includes over 30,000 buildings. (Ees.ae, 2015)

In order to achieve better solutions for energy consumption, Etihad ESCO a company launched by DEWA, which is specialized in the consumption of water and electricity reduction. This company main mission “To make Dubai built environment a leading example of energy efficiency for the region and the world”. One of many goals is to increase buildings energy efficacy 20% by 2020 and 30% by 2030. (Etihadesco.ae, 2015)

This study will present an example of a retrofit building that is 20 years old. The aims to achieve a model that can serve as a solution to retrofit existing buildings using a double skin facade system. The commercial office building selected, as this is a vital sector to Dubai economy and growth to show a sample that target reduction in energy consumption through reduction of cooling load and utilize daylighting effect on the building internal envelop. A similar building style and design selected by earlier studies. (Chain et al, 2009)

1.4 Importance of The Study

The study targets to compare merits of adopting various building facade finishes, particularly for office structures and its influence on the building`s energy use. The study attempts to ascertain whether double skin facades play a significant role as far as energy saving in UAE`s office building is concerned. According to Pell et al (2010), BIM tools such as Revit, Studio Project and Green Building adopted in that study enabled a rapid visualization and modelling of dependable energy performance in conceptual stages of construction. As claimed by Schittich et al (2012), the results revealed that double skin facade –at least for office building – was the better solution to reduce thermal radiation and providing quality light during the day.

This investigation aims to improve and incorporate answers to enhance the energy utilization of buildings, yet secure the flexibility to accomplish occupants comfort. These arrangements aim to moderate practical arrangements and afterward stretches negligible issues arise on where by building operators to help reaching reduction targets. Double skin facade serve as an outside shading gadget for year-round temperature regulator. (Selkowitz, 2005).

Energy usage and its reduction, has been always on the governmental agenda and local authority, started pressuring energy service related companies to provide more sustainable and efficient systems in the energy field that are vital parts of all building today, HAVC systems, are being rated and inspected of accuracy and efficacy. Dubai Municipality introduces its Green Buildings regulations and specifications, uses The Chartered Institution of Building Services Engineers (CIBSE) Commissioning Code, Air Distribution Systems, Code A-2006 as the standard for HVAC systems.

This study also uses a computer simulation software (DesignBuilder). This software uses EnergyPlus Engine for calculating a simulation (Cockcroft, 2015). A validation of the software is discussed in the methodology chapter

1.5 Dissertation Aims and Objectives

The research aims to compare benefits and examine the technical aspects of DSF technology, by inspecting the effect of changing materials used and answering the following research questions below:

- What is the impact of using double skin facade as construction style on the energy usage or needs by the building?
- Which outer skin material have the most impact in terms of energy reduction?
- Which cavity depth performs better in for DSF in desert climatic condition and help reduce energy usage?

- Which depth configuration performs better to each suggested scenario and material of DSF in desert climatic condition and help reduce energy usage?

The study aims hopes to conclude with tangible results, where it can clearly identify the followings objectives:

- Show the optimum cavity depth that best performs towards cooling load reduction & maximum daylight penetration.
- Show the optimum outer skin material that best performs towards cooling load reduction & maximum daylight penetration.
- Show the optimum cavity condition that best performs towards cooling load reduction & maximum daylight penetration.

1.6 Dissertation Outline

In order to organize this study, the dissertation will be divide as per the following guide:

Chapter 1: to give an introduction of the topic and area of study. As well as introducing the UAE energy scenario and governmental plans for Energy consumption plans for 2013.

Chapter 2: to have an overview of the literature review done in the same area. Also covers the some projects, which were done in similar climatic conditions to reduce the energy consumption.

Chapter 3: Introduces different methodologies related to the topic. Additionally, it introduces and mitigates the use of a computer simulation to address the related investigation.

Chapter 4: Introduces the case study and case study parameters and related information.

Chapter 5: Presents and discusses the results from the simulation along draft a pattern for future research. It also, sheds an eye on the possibilities of using double skin facade under such harsh climatic conditions.

Chapter 6: Includes the best outcome proposal for the chosen material and explain the study limitation but in the same time open the door for further research in recommended areas.

The next section will review literature on other buildings that have used double skin facade to d determine best practice in this area.

Chapter | 2

Literature Review

2.1 Overview

This section will present and comprehend the negative effects of building on environment. Also, introduce an investigation for the current endeavors towards manageability in outline and development. It is likewise to give a general comprehension of outline methodologies and materials used in building skins. Then again, the principle center of this part is to present worldwide and local supportable strategies with a specific building examples used the skin facade system to comprehend and to highlight the best and most appropriate development in construction area to reduce energy consumption for desert climatic environment and certain perceived conditions.

2.2 Definitions and History of Double Skin Facades

Double-Skin facade is a system consisting of two glass skins placed to provide the intermediate cavity free-flowing air. The cavity ventilations can be mechanically or fan supported or natural. Air origin varies based on the climatic condition, location, the HVAC strategy, whether the building is occupied at the time or not, and the building utilization. At a distance of 20 centimeters up to two meters the glass skin can be single or double glazing units. Solar shading devices are placed inside the cavity for protection and heat extraction reasons during the cooling period.

Double-Skin Facade is associated with various active envelopes, twin facades or second skin facades (Saelens, 2001). It is a facade that is comprised of an inner and outer skin (Gan, 2005).

Most of the time, buildings are made of single skinned facades. Outside a low structure building some type of masonry, and stucco, while high-rise buildings include metals, glass, and other materials, and the exterior veneer is often more varied.

It is now more common to build a double skin facade (two skins to the building). These buildings are built in such a way to allow a person to walk between the two skins or with less than a space of one foot apart.

The assembly of double skin facade was labelled with different characterization and tags to illustrate the assembly. Based on its configuration or function,

Some examples of buildings that make use of a skin facade are 1 Angel Square and 30 St Mary Axe (The Gherkin). Both of these buildings have a great environmental impact for their size, with the double skin face being the key for this. 30 St Mary Axe has triangular windows on the outer skin which skelter up the skyscraper. The windows open based on the building data and the weather, which causes more or less air to flow through the building ventilation.

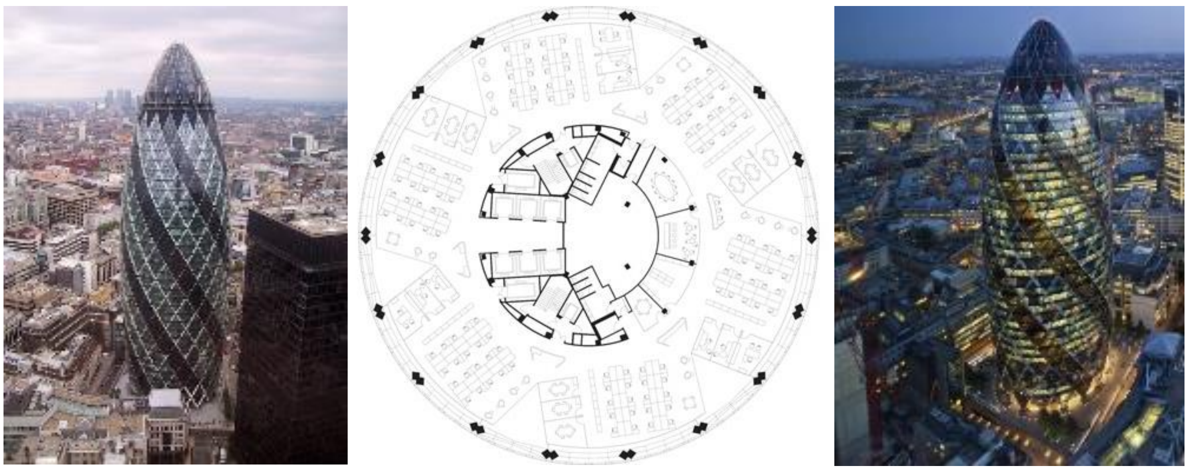

Figure 2.1: 30 St Mary Axe (2004), UK (Source: fosterandpartners, 2015)

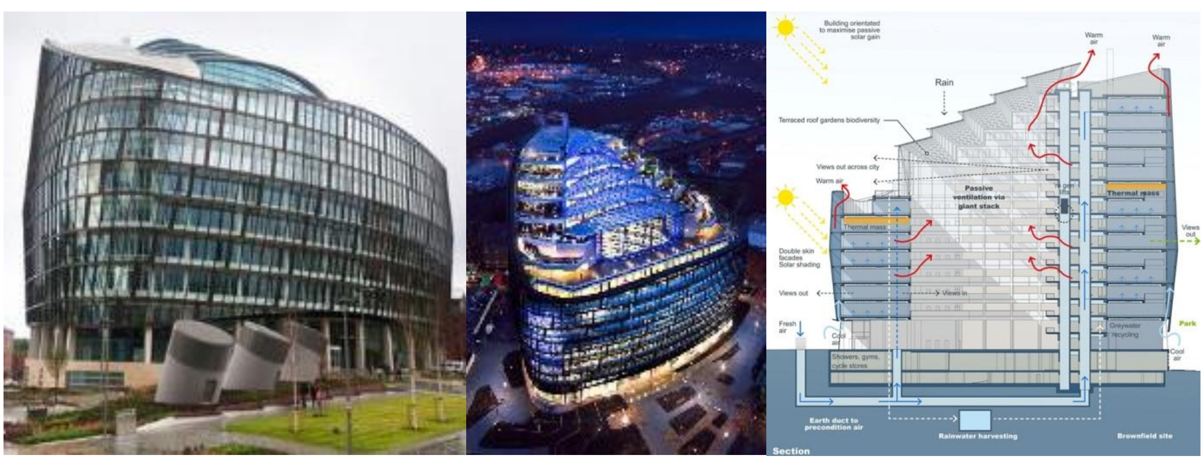

Figure 2.2: 1 Angel Square (2013), UK (Source: Colt Group, 2015)

2.3 Classifications and Typologies

Arons (2000) pointed out the two types of double-skin facade: airflow facade and airflow window. The airflow window is a double - leaf that has an outlet and an inlet spaced less than the vertical spacing between floor and ceiling; while the airflow facade is a double-leaf facade that is continuous for at least one story, with its inlet and facade that has an inlet and outlet spaces.

McCarthy (2004) put double skin facade in five different categories:

- Category A- Sealed inner skin- ventilated; controlled flow intake; mechanically ventilated; and serviced.
- Category B- Openable outer and inner skin- full building cavity; single story cavity.
- Category C- Openable inner skin –controlled flow intake; mechanically ventilated; ventilated and serviced.
- Category D- Sealed cavity-zoned full height cavity; floor by floor
- Category 5 - Acoustic barrier – lightweight extension envelope; massive extensive envelope.

Stec and Paasen (2003) conducted a study that focused on the integration of various typologies of double skin. The study considered explaining the functions of double skin, control techniques and the different types, and optimizing the design of HVAC. The research study stressed that during summer time; the double skin protects from solar radiations and during cold weather, thin cavities is more suitable to produce heat.

Ding et al (2004) emphasized on the efficiency of using solar chimney on a double skin to provide natural ventilation. Its purpose is to strengthen the stack effect, passing through intermediate rooms to natural ventilation between rooms.

An 8 floors building was used as the research experiment. To determine its performance a 1/25 scaled model was used and the CFD analysis. The study found that the increase in ventilation is relevant to the height of the solar chimney. The authors recommended the design to be used for two story high or more.

Gan (2005) tested the implementation of tromble wall, double facade, and solar chimney settings installed at six meters high. The findings were:

- Solar gains are increased when buoyancy is in open cavities
- If ventilation is enhanced, and its rate also increases up to a point within the cavity
- The optimum width for a solar chimney of six meters high is between 0.55 and 0.6 meters of an open cavity.

Solar control can be gained by using plants for shading the building. Papadakis et al (2000) studied the effect of using plants for solar control. The research pointed out that trees and plants influence the transfer of heat into a building facade. Comparisons were made from one location to another shaded with trees, explaining several advantages of using plants or trees to provide shading. It showed that plants have an ability to managing and keeping a temperature lower than their air environment by producing great amount of water and evaporates. Furthermore, conventional sunscreen tends to make higher temperature than the surrounding air. The Rise in temperature drives up thermal radiation which in turn burdens the building's walls.

In the review of literature made by Hamza and Underwood (2005) it was mentioned that an exterior leaf of double facade reduces the heat gained through direct solar. Natural buoyancy is induced due to trapped heat in the gap; hence, the inner building skin becomes free from elevated air temperature.

Hamza (2004) also states that if the outer reflective surface on the double skin facade is predicted then the annual cooling load is decreased by 40%. Soberg (2008) mentioned in his study that the design of a double skin facade covered the height of entire building from the 4th floor up. To improve solar protection, solar shading devices can be installed within the cavity. The solar shading is designed to be adjustable; this will help control and maintain the optimal angle. The device's designers sealed the double skin from the exterior environment to increase the system functional longevity. With this idea, the shading device will continue to operate properly and the device and its mechanisms will be protected from external elements that might cause interruptions.

A comparative study was conducted by RMJM (2007) about solar heat gain expected between two facade options: double facade and typical double glazing. He calculated that double facade is more favorable than double glazing in terms of cooling requirements. Double facade generates 5.8 KW of solar heat gain while double glazing generates 6.1 KW.

2.4 Double Skin Facade Examples in UAE:

- **0-14 Tower:**

The “Swiss Cheese”, a 22-floor office block in Business Bay, Dubai is wrapped in a 40-centimetre "exoskeleton" of white concrete with 1,300 holes. It is a very unique design, and that was the original goal. The design was planned as an aesthetic design but the eco-friendly advantages were soon discovered, created by RUR Architecture of New York, compared with some of the glass and steel towers. The designers were surprised by an energy-saving phenomenon caused by the gap between the main building and its concrete skin. The distance was designed to allow room for cleaning the windows, but to the designers’ surprise, the space caused a vacuum, which allowed the cool air to pass through the holes of the concrete wall. The vacuum also forced the hot air to go up and away from the inner tower, which resulted in the cooling costs to be reduced by 30 per cent. (TheNational, 2014)

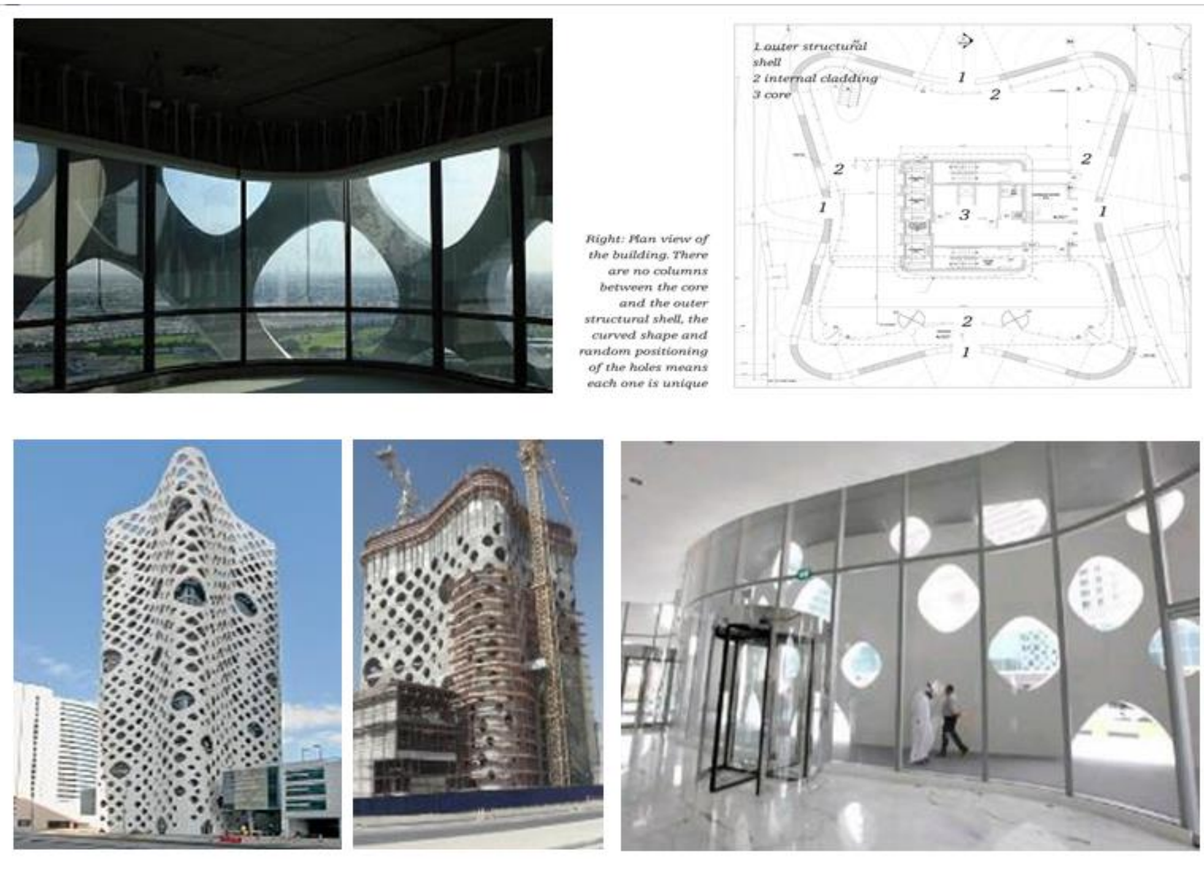

Figure 2.3: 0 – 14 Towers, Dubai (Source: The National, 2015)

- **Capital Gate Tower, Abu Dhabi**

The project’s design includes several innovations, such as the dramatic 18-degree westward lean, that has earned it the title of “world’s furthest leaning man-made tower” from the Guinness book of world records (Guinness World Records, 2010). The building is the first in the world to utilise a pre-cambered core with a built-in lean of 350 millimetres that has been engineered to straighten with the addition of the upper floors. From the start of the concept design, the engineers and architects included many active and passive sustainable systems into Capital Gate, a double skin facade, including metal mesh sun shading, reduced amount of materials, high-performance glazing, low-flow water fixtures, variable speed air conditioning, district cooling, energy monitoring and controls, and heat exchange for ventilation.

The most noticeable feature of Capital Gate is the “splash,” it acts as a shield that by twisting toward the building from the south protects it from as much direct sunlight as possible. The metal mesh reduces the sun’s heat by 30% before it hits the building, which help reduce the cooling load on the protected floors. The mesh also shades the main entrance on the ground floor. The upper half of the tower has a double skin facade to reduce the solar heat gain at the hotel levels.

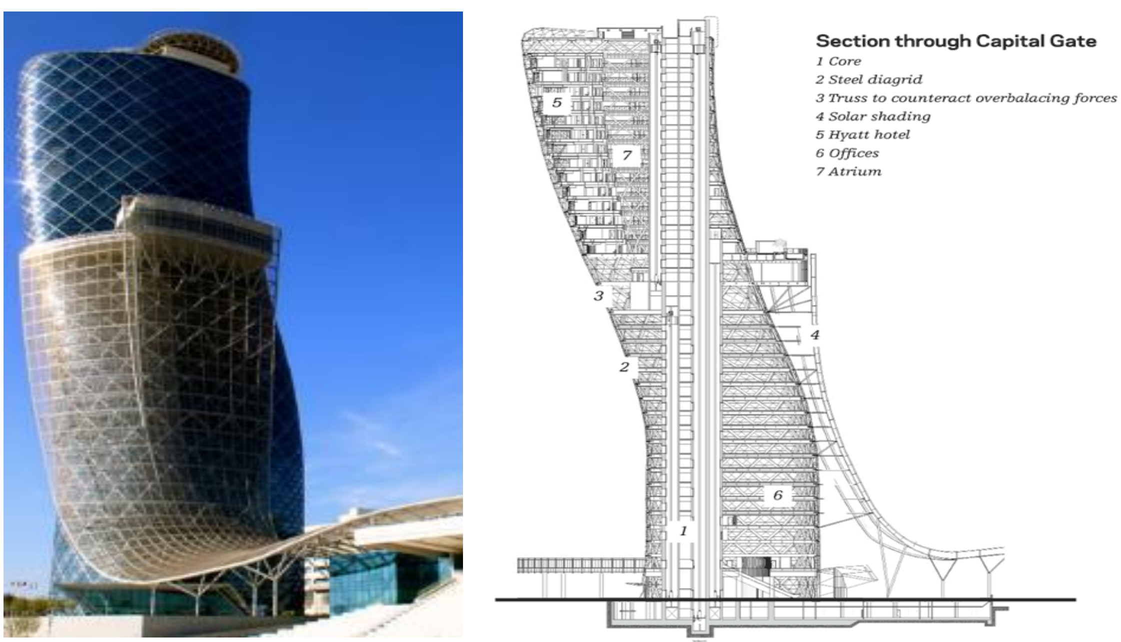

Figure 2.4: Capital Gate Tower, Abu Dhabi (Source: The National, 2015)

This is a modified double facade, which recycles interior air from the guest rooms into the facade cavity. Here it creates an insulating buffer between the hot outside air and the cool inside air. The air is re-used in the room rather than exhausted and replaced with outside air. (Ctbuh.org, 2015)

- **Institute of Diplomatic Studies – KSA**

Figure 2.5: Institute of Diplomatic Studies – KSA (Source: RLB, 2015)

The building has a three dimensional facade pattern. One will be able to sense the lively atmosphere inside the building through the facade. From the stepped oasis inside, there is a clear view of the outside. Although the facade is the most appealing part of the building, it also serves as a shell providing shelter for wind, sun, and climate. This facade design is perfectly adaptable to Riyadh’s conditions. The triangles leaning in and out from the vertical plane creates shade for one another and the angled position of the shading opens the facade towards the north where it will have the optimum daylight without heat gain from direct sun impact. (RLB, 2013)

- **Abu Dhabi’s Al Bahar Towers**

Abu Dhabi’s Al Bahar towers have received accolades and acclaim as pillars of sustainable design, the lead designer of the project says that they barely made one-step towards truly sustainable construction.

The 25-floors building, which serve as the headquarters for Abu Dhabi Investment Council’s (Adic), utilizes an external facade made of 2,000 umbrella-like elements. These elements follow the sun, allowing in light but also closing to block the heat. An array of solar panels on the roof is also utilized to heat water. (Afcarillion.ae, 2015)

Figure 2.6: Al Bahar Towers, Abu Dhabi (Source: The National, 2015)

Although, it’s often to focus on a facade’s U-value (the insulation characteristics of a material), it is really the G-value (the shading coefficient) that is important. In any building, 70 per cent of air conditioning is resulted from direct exposure to solar rays.

The Al Bahar facade mitigates such heat transfer by 50 per cent, reducing carbon dioxide emissions by 1,750 tons a year. The system allows natural light through, reducing the need for artificial lighting. (Cilento, 2012)

2.6 Building Physics

Heat prevention is the main concern in desert climates as far as reducing energy use and offering comfort to occupants is concerned. Most office structures in the UAE utilize horizontal shading as a way of reducing solar gain. For instance, Abu Dhabi which is located at 24.43 kilometers north of equator, has embraced double skin facade technology. This is because the projection necessities are minimal for the south facade shading compared to the necessities for latitudes north. By simply utilizing maintenance platform and grated cleaning that is usually provided in broad air corridor double skin facades, can reduce solar gain and achieve shading protection for without any additional louver shades within the cavity northern locations of the equator. The west and east facades of tall buildings in particular face a greater problem since they cannot be equipped with simpler horizontal systems which are effective in the case of south facing glazing of high sun angles. Thus, if we are considering buildings in hot desert climate or north of equator, double skin facade reduces solar exposure but allow enough daylight into the building. Particularly, this is of concern for iconic tall buildings as they appear to be positioned on more isolated areas which upsurges their solar exposure. Commercial towers in big cities like Dubai appear to be positioned on smaller locations and crowded together thereby offering shading to one other, using an old-fashioned hot climate clustering method. (BEDP ENVIRONM E NT D ESIGN GU I D E, 2009)

Even though double facades of usual buffer, extract-air, and twin face types are still being built in these hot desert climates, unique double facades that uses unique materials, such as aluminum and concrete shaped organic have been developed to focus exclusively on the shading provision as the primary way of solar gain avoidance. This is normally coupled with comparatively high performing glazing within curtain wall skins so as to further limit solar gain and heat transfer into the office building. Most of the facades shading systems that use wooden blanks are inspired by the Islamic Mashrabiya`s tradition: a wooden frame screen which is used as a way of allowing some air circulation but blocking significant solar gain and offering visual privacy. This vernacular founded model for the second layer may be seen as a natural creation to modify the current type of double skin facade system. So long is the custom of Mashrabiya screen and it is tolerable in the hot desert climate since it has clear views of the outside from the obscured screens. This is significant to note when evaluating the benefits of double skin facade systems which use various material to achieve the projected energy reduction target. (ALMERBATI et al., 2014)

According to Hough (2006), double skin facade systems will continue to be adopted for reasons which are hands-on and easily understood. Knaack & Klein (2009) adds that the purely energy reduction benefits of these hands-on reasons can be far more clear than the gains provided by from economic benefits. The benefits in terms of energy reduction may be a bit more tangible since they have visual or physical consequences to the users and occupants of the office buildings.

As numerous buildings are getting constructed in or around noisy urban settings, double skin facade technology has been successful in controlling unwanted noise. An extra layer offered by the twin face, extract-air or buffer systems has always been effective in enhancing the buildings` acoustic performance. Many sustainable structures are turning to natural ventilation as one way of improving the comfort of occupant and lessening the cost of energy in hot climates where temperatures are very extreme. Double skin facade systems can offer natural ventilation via strategies which offset the incapacitated air flow systems thereby reducing the overall solar gain effects that would result from overheated rays into the building. This ability to provide ventilations can also mitigate problem of air pollution – occasioned during the weather events or peak traffic hours – in the office building fitted with less closable dampers. The ventilations will also lessen the influx of urban noise to the inner spaces. (Harris, 2004)

Currently, natural ventilation in many commercial towers is not being used in extremely hot desert climates. There is a full reliance on mechanical cooling created along with its luxury expectations. That aside, the insertion of certain operable windows in commercial towers in developing nations is quite normal when compared to buildings in UAE region. Most of these desert climate regions do have considerable months where natural ventilation is perceived as being beneficial. As such, double facade technology is seen as an effective remedy in the future. Even in Western localities, double facade technology safeguards solar shading devices that would otherwise get exposed to ice, snow, rain, and wind. This permits ultimate flexibility as far as designing and deploying shading systems and operable louvers is concerned.

The ultimate benefit can also be environmental protection as the system can serve to lessen the cleaning requirements, and wear & tear of mechanical components, thus assisting with problem of longevity and durabili8ty. In London, the Helicon Building became one of the initial extract-air systems which its louvers being secured within the cavity. Bell & Rand (2006) notes that desert climate applications have appeared not to place operable louvers within unsealed air corridors because of issues of fine sand and dust accumulation that results in problems of cleaning. Interior blinds remain the preferred choice in assisting with shading and glare regulation and it offer occupant control. The general double skin facade types of twin face, buffer and extract-air which reflect a specific climate target consideration shave developed and could be seen in present desert climate projects situated in UAE region. In some cases this may have occasioned a hybrid tactical approach to the double facade. For others instances it was the simplification of a complex, old-fashioned approach which was expected to handle the opposing concerns of solar gain and cooling. In exceptional desert climates the design plan has emphasized on the benefit of double skin facade approach as far as achieving the desired daylight and avoiding solar gain is concerned. In some desert climate double facade technology has embraced the shading system, which is the outer layer, thereby removing the more common and additional curtain wall layer. Nonetheless, it still executes the ultimate goal of heat avoidance.

2.7 Outer Skin Components

The climate in desert regions like Qatar and United Arab Emirates is uncommon and extreme since it is extremely humid. However, the impression and appearance if one who has not visited the region would be that it is actually arid because of the lack of fresh water bodies and vegetation that usually exist in hot-humid climates. Combined with extraordinary levels of fine sand gravels from the windy conditions in the desert, the high humidity make condensation process an issue (Almusaed, 2011). That is, highly chilled glazing facades that result from extreme air conditioning levels get into contact with outdoor temperatures of 45 degree Celsius with humidity of about 80%. When U-values of glazing units gets upsurges the dew point might be reached around the outer skin surface Figure 2.5 (aluminum, concrete shaped organic, wooden blanks or glass outer skin). This makes the blowing sand to stick to the outer skin facade, thus, limiting the overall light penetration and solar gain regardless of the material used. The thermal performance of each skin facade is adversely affected by these dust and fine sand gravels. Moreover, the maintenance and cleaning cost shoots up due to local climates.

Figure 2.7: Skin Components Sketch ideas (Source: Author, 2015)

Doha Tower, for instance, uses the double skin facade which employs a static screen component as the outer skin of the system. This outer skin of the Tower of Doha has four “butterfly” aluminum components of various scales to induce the symmetrical intricacy of Islamic Mashrabiya but serve as shield from the sun. Across the region, this pattern varies depending on the material orientation and respective desire for solar protection. The variation in opaqueness of the material screen (concrete shaped organic, wooden blanks or aluminum) addresses the disparity in solar avoidance needed from facade orientations.

Because of its round shape, the tower needs some shading on the “north” surface as it receive daylight in the morning and evening hours.

Benefits observed of each skin

I. Outer Skin: Concrete Shaped Organic

Sometimes concrete tends to be covered and is usually dressed up with several materials, to hide away the large bulk and the discrepancies of the concrete finishes, not like glass, which when used is seen clearly. The necessity of creating stream lined elegant buildings does not permit for hiding and cladding the structure, but some designs entails that the concrete structure to be stream lined as well. This visibly executed in the shell concrete structures. The replacement of the steel members in the concrete with the fiberglass as a result of the new technology makes the process possible to cast much stronger and thinner concrete. This particular kind of concrete does not necessarily have to solve the usual problems that are related to the deterioration of the steel reinforcement (Pix 12).

The mold ability feature that the concrete displays make it to be a desired medium to create built-in furniture. As a result of the new casting techniques it has been possible to create comfortable and sleek furniture which are stand alone and movable units, in contrast to bulky units (Pix 9 & 10). Apart from being used in the form of tiles, concrete is mostly used as cladding. The new structural systems have created optimum use of the characteristics of concrete making it possible to enable adding of vibrancy, texture and color though the mounted concrete panels. The adoption of an innovative reinforcement system and a lightweight concrete mix has been a mechanism to counter the great weight that such a facade would impose. The designing of the Soccer City Stadium in Johannesburg by Boogertman, (Pix 13) Urban Edge + Partners has made use of this technology. Another innovative surface finish make use of the photolithographic techniques for the embedding of white and black or two tone images on a concrete facade. The similar technique been adopted by De Meuron and Herzog in the Fachhochschule Eberswalde’s library (Pix 14).

II. Outer Skin: Aluminum

Since aluminum can be painted with any color, to bring any optical effect, it is can always be painted with colors that reflect more light or retain more heat depending on the comfort of the occupants. Aluminum also has a considerable strength-to-weight ratio; a unique feature that allows architects to achieve the required energy performance specifications, but still lessen the dead weight on supporting structure of the building. This is a major benefit for roofing and cladding applications. Moreover, due to the material's inherent stiffness and strength, aluminum curtain wall and window frames may be made very narrow, thus optimizing glazed surface and energy reduction for the given outer skin dimensions.

The material also has high reflectivity: a characteristic feature which makes aluminum a highly efficient material as far as daylight management is concerned. Aluminum light channels and solar collectors can be fitted to reduce energy consumption for man-made lighting or even heating in winter. Its shading devices may be used to cut down the use of air conditioning during hot seasons.

Finally, aluminum is an exceptional conductor of heat, thus, it is an effective material for exchanging heat in solar heat collectors or energy proficient ventilation systems.

III. Outer Skin: Treated Wooden Blanks

A clear benefit of using treated wooden blanks in the outer skin is that its insulation is restricted within the material`s depth, so a typical treated wooden wall may be thinner compared to its masonry equivalent, say, by 50mm. The moment a considerable insulation level is attained, the amount of solar gain or heat lost due to air leaking to the surrounding from the building then gets more of a concern. Treated wooden blanks structures appear to perform well in this case since they are impenetrable and thus prevent moist air from reaching the indoor of the building.

Moreover, the difference between other material facades and treated wooden blank walls is on how successfully they retain heat. People who have been in buildings of other outer skin materials will be confirm that the main heating is set on well prior to getting to the winter’s seasons to ensure comfortable indoor stay. This is because, other outer skin materials, such as concrete shaped organic inner leaf of building must first be heated before the room temperature can reach the desired level. Treated wooden blanks do not absorb heat in this manner. Because of this factor, a building enclosed by insulated wooden frame walls can heat up but then cool down almost immediately. Whether this is some desired feature or not will depend partially on the inhabitants` lifestyle and whether the building has to get heated endlessly or just at night time, as is the case in desert climates.

IV. Outer Skin: Glass

Numerous new building designing trends have been globally proposed due to the urge to remain environmentally friendly. Buildings outlook are no longer required to look only presentable and good but are expected do more than just that. Today’s buildings made up of glass skin have thermal protection property, are also capable of controlling the amount of light flowing through them and are capable of electricity production as well.

Thermal Insulation: Systems with double skin facade can afford greater thermal insulation property both in the summer and winter as proposed by many authors due to their outer skin. As described by Lee et al, (2000), during summer time, the warm air enclosed inside the jacket can be harnessed mechanically or naturally when it is ventilated. As the absorbed radiation from the re-radiation process is emitted into the middle jacket, a natural load then impact on the results thereby causing the air to rise, carrying with it immense supplementary heat energy. In order to guarantee proper jacket ventilation, a robust combination of the various forms of the shading devices and panes are cautiously integrated to prevent overheating of the jacket cavity and hence the internal superficial. Due to the jacket cavity opening size, width and height, the jacket cavity geometry is taken as critical, and is therefore crucial for the airflow and ensuing temperatures, that is, if ventilation of the jacket cavity is naturally. Considered again to be a great important parameter that needs to be critically examined is the positioning of the shading devices.

According to Patterson (2011), for energy to decrease and attain thermal comfort in a building, there are parameters that should be put into consideration like noise, humility, temperature and light. Most part of the heat gain or losses in buildings comes from opening like windows. For that reason, it is clear that windows are the core element in the transfer of big amount of heat between an exterior environment and a building. Therefore, a feasible material is applied across more facades so as to maximize energy reduction. The more you apply the material on more facade, the more we achieve the projected energy reduction target. When this is observed, the solar gain coefficient can be roughly 17% which is considered to be a low CO2 committer and also interpreted as a good value (Baker, 2009, pg. 59). In the case study villa the single glazing was replaced by the double glazing with a 16mm void containing Argon instead air (Aksamija, 2013, pg. 49).

The most cost competitive and feasible outer skin material is aluminum. Exceptional strength to weight ratio is one of Aluminum's primary appeals to specifiers. It weighs lighter than steel at 2.7g/cm2 by 66% and far less susceptible to brittle fractures. Certainly when the materials are compared, Aluminum has a greater modulus of elasticity meaning that it weight ratio of 1:2 which is easily achieved. At the same time Aluminum has relatively high co-efficient of linear expansion, at 24X 10-6/'C in its pure form. The temperature induced stresses to be accommodated being enabled by the 65,500N/mm2 for 6063 alloy (materials low modulus of elasticity). In fact these are generally far lower than steel structure in comparison (M of E=21,000N/mm2). Aluminum's load-deflection curve is illustrated graphically without a yield point and it is continuous. In addition, when the two are compared Aluminum sections are generally deeper and thinner than equivalent steel sections to attain the necessary strength and rigidity. Moisture has no effect on Aluminum therefore, it makes Aluminum windows not to stick, rot or warp. The strength, rigidity and intrinsic lightness of aluminum frames improves in door construction by typically using hollow-section extrusions and sight lines reason being that it multi-point locks and other door furniture can be fitted within the frames.

Despite the reality that aluminum can be painted with any color, to bring any optical effect, it can always be painted with colors that reflect more light or retain more heat depending on the comfort of the occupants. Moreover, due to the material's inherent stiffness and strength, aluminum curtain wall and window frames may be made very narrow, thus optimizing glazed surface and energy reduction for the given outer skin dimensions. The material also has high reflectivity: a characteristic feature which makes aluminum a highly efficient material as far as daylight management is concerned. Aluminum light channels and solar collectors can be fitted to reduce energy consumption for man-made lighting or even heating in winter. Its shading devices may be used to cut down the use of air conditioning during hot seasons.

Aluminum has low maintenance cost. Most of aluminum construction products are coated and treated because it assumes a defensive layer of oxide the moment it is open to air (has a natural, built in durability). Oxidization process can be improved in one way by adonization; this improves its ability to withstand attack in aggressive environments. This process natural results in the same way silvery finish to oxidized aluminum, although it can also introduce a range of colors. Reasons being, after anodizing, the surface film remains porous, allowing it to accept coloring agents like electrolytes, pigments, metallic or organic dies. In the same way, attractive bronze, gold, black, grey are commonly achieved. Most specifiers go for electrostatically sprayed polyester powder coating for a wider choice of color. The powder is used to provide resistance to the acidity of rainwater this is common in finishing curtains walling, cladding panels and rainwater goods. In this stage, charged paint particles which have undergone a twelve stage pre-treatment process are blown onto the extrusion and the stove at between 200 and 210'c, for 10 to 12 minutes. All this provides a high quality surface with excellent accurate coloration, film thickness and adhesion.

Aluminum has the compatibility with today's fast track construction techniques and just in time ordering that is one of the principal's reasons for it being able to endure and grow popular. The final outcome is earlier building occupancy and greater profit margins for the ultimate customer. Aluminum window systems, door assemblies and shop fronts present comparable on site merits, which are now being improved by fabricators computer-controlled machining rigs that can miter, countersink, grind and drill to exact tolerance enabling the easiest possible installation of ironmongery and other secondary elements.

2.8 How to Make The Study Beneficial to The UAE

Passive cooling strategies should be used to enhance thermal performance and decrease energy consumption of residential building in UAE in order to make the study comparative across UAE. To maximize the comfort and health of the building users when minimizing energy use, the passive design should be used to respond to local climate and site conditions of the same. This design can be defined as the technologies or design features adopted to decrease the temperature of buildings with no the need for power consumption thus it should take advantage of the local climate. Subsequently, the study should test the effectiveness of applying selected passive cooling strategies to enhance thermal performance and to decrease energy consumption of commercial buildings in hot humid climate conditions such as United Arabs Emirates in general and Dubai in specific. The buildings` performance is gauged by the energy simulation software that is DesignBuilder. Daylight simulation, part of the DesignBuilder software was also used to assess daylight penetration performance. Energy reduction will be attained by minimizing of heat gaining line with applying double skin facade system alongside the use of four different scenarios with 3 cavity depth options. Significant findings were revealed in the study, that the total annual energy consumption of a commercial office building in Dubai might be decreased by 37 % when building uses double skin facade system.

According to Dubai Chamber of Commerce annual report the 4 most mainly common construction materials are: concrete, aluminum, wood and glass. Therefore this study takes these materials as the testing edge for the double skin facade as an outer skin parameter. (Economic Research Department, 2014)

Chapter | 3

Methodology

3.1 Overview

This chapter will present different methodologies that have been used to assess and evaluate the performance and workability of green and sustainable double skin facade buildings. However, every methodology has its own pros and cons and both will be evaluated in order to justify the selected methodology for this research. Extensive research been conducted in evaluating the performance and effectiveness of double skin facade buildings in the western world but limited research in the same field was conducted in the gulf region and particularly United Arab Emirates. Therefore, this chapter will cover some of the papers that studied Gulf region as well as in other regions that have similar conditions in order to understand the influence of double skin facade buildings in hot humid climates and its impacts in the energy consumption via different methodologies. (Shameri et al., 2011)

The selection of the suitable research method is very important to enable the existence of this study. Before starting the study, it is important to have a full understanding of the appropriate research method used to assess the energy consumption reduction through monitoring reduction cooling load and daylight penetration in commercial office building in order to achieve the main goal of this dissertation. In addition to that, a comprehensive understanding of the limitation of the preferred methodology needs evaluating within the research time line. Methodology limitation includes research resources, time, applicability to the research problem and validation of the research method.

Furthermore, it will show different ways of describing the findings in qualitative measures, which allow the researcher to give the reader a mental image of what is observing. In addition, quantitative measures are the one that deals with numerical figures to test and prove a hypothesis and usually presented by figures, charts and tables or mixed methods that will combine some quantitative and qualitative findings either to support the findings of each other or to validate the observations with the founded numbers.

3.2 Comparison Between Methods

3.2.1 Laboratory Approach

In conducting the research using this approach the researcher is required to use the laboratory, set up the experiment and simulate the environmental conditions from outside. The study is performed under controlled conditions.

In the study of Zhou (2007) about a novel model for photovoltaic array performance prediction, he tested and predicted the PV modules in terms of its performance by creating a simple model based on parameters (short-circuit current, open circuit voltage), fill factor and maximum power-output of the PV module. Various solar irradiance intensities and module temperatures are the bases of these parameters. In estimating the actual performance of the PV modules under varying conditions with minimum data input and simple iterations, the researchers attempt to pursue a simulation model with acceptable precision.

Too much time will be utilized when laboratory approach is applied as a method of research to determine the performance of a double-skin Facade. It requires a lot of money and the researcher may experience difficulty if his or her budget is insufficient to conduct such research. The researcher has to find somebody who will sponsor and help in the establishment of the laboratory, materials, and equipment.

Additionally, the results of the study in this approach might not be accurate since not all parameters needed could be measured inside the laboratory.

3.2.2 Modelling / Software Simulation Approach

In this approach, the researcher needs to create a model of the building to use in the study. The created model will serve as a replica or representation of the actual size of the building and its natural features. The researcher should bear in mind that the objective is to get as close as possible to the actual dimensions of the building (Hamza and Underwood, 2007).

Another example of software simulation modeling done to evaluate the performance of double skin facade system on a residential building. A computer simulation model can be easily built and validated allowing multiple selection of materials, profiles, structures especially when dealing with complicated structure. This is the best alternative method other than experimental approach where it is costly in one end and it needs to be built inside a controlled environment in order to obtain valid results. Kim study performed a computer simulation to test the performance of double skin facade. (Kim et al, 2012)

3.2.3 Field Monitoring Approach

This type of approach could be characterized as an effective approach because accurate information can `be obtained and results of the study are reliable and verifiable. In the study of Song (2008), he applied and uses a full scale mock-up model to measure the electrical performance of a thin film. Under prevailing weather conditions Wah (2005) conducted field Measurements to investigate thermal and optical properties and power output of different types of STPV modules in different areas.

However, this approach is not required in the analysis of double-skin Facade using different choices of materials since the study will be established in one area and does not require any monitoring outside the designated place of study.

3.2.4 Historical, or Literature Review Approach

In historical, or literature-review approach the researcher is required to gather relevant information from various material resources such as books, journals, theses, dissertations, Internet, and other sources which will provide data or information that present the effectiveness of the study. They must be a wide-reader to analyze the results of various studies or articles that will serve as his references. Unfortunately, as this study depends on papers that had investigated the same topic and under same climatic conditions, such information is very limited for the gulf region and UAE.

In this approach, the review of literature is advantageous to substantiate the initial argument and validate the importance of this investigation. Similar parameters could be reported through literature reviews and case studies. (Hamza and Underwood, 2005). With their own criteria and variables, specific to the research could be referred to. Hence, literature and historical data are not only the basis of the research. However, reviewing literature could add to a wider framework of knowledge in the formulation of questions. It will only provide information as valuable as historical data if the research question is approached through literature review.

3.3 Research Method Applicable to The Question

Various methods used in the analysis of Double-Skin Facade through thermal gain and daylighting effect using different material choices. As already mentioned some of these are:

a) Laboratory approach;

b) Modeling Approach;

c) Field Monitoring;

d) Historical or literature review approach.

Among these types, the most appropriate and applicable to use is the modeling approach using computer simulations. As mentioned below in details

Modeling approach using simulation method was chosen by the researcher because no large amount of investment is needed and it can be used at individual research level. Equipment resources and materials are less; compared to other methods like laboratory approach that requires laboratory facilities or equipment and a large space for experimentation.

Using Simulation Method, a short span of time could be spent, but study is completed. Small area and less capital or investment is needed. The method classified as an empirical approach because it involves gathering of information through observation of the resulted data. The researcher simulates scenarios and must provide evidences based on knowledge. One great advantage using this approach, compared to the three other types of research methods incorporated such as experimental, laboratory, and field monitoring.

In testing and validating using simulation method, of a hypothesis, data analysis is the Quantitative Analytical Methodology to determine the performance of double-skin Facade for cooling load reduction and daylighting effect using different choices of materials under desert climatic conditions. The data to be collected shall be organized, analyzed, and interpreted to come up to an optimum design and common trends found.

To conduct this research, a simulation method shall be used. It will investigate the performance of innovative low-energy buildings in terms of accuracy and availability of building energy analysis tools and engineering models. This research covers building energy simulation tools (DesignBuilder), emerging modular type tools, and will use concepts on innovative low-energy design. In building energy simulation software, the tasks will include development of analytical comparative and empirical methods for evaluating, diagnosing, and correcting faults.

Initial approach can influence the design stage; hence, it is important to determine the classification of Double-Skin Facade. The design and the technical parameters that can influence the function and the performance of the system and the physical properties of the cavity will be defined.

Architectural design will include:

- Plan and layout of office floor
- Building with double facade
- Advance Exterior Facade as a whole with a special architectural feature to allow directed penetration of day lighting.

In maintaining a good indoor climate, a thermal comfort such as use of solar control and preventing office from overheating will be done. For winter and summer seasons, acceptable internal surface temperature will be a part of the tasks. Using the Double-Skin Facade cavity, natural ventilation shall use instead of mechanical.

Methods appropriate for the research on performance of solar gain and day lighting effect are modeling, simulations using computer and field monitoring. Integration of various methods could provide accurate and reliable results but less investment required. As the study uses many parameters and conditions the best practice and effective way to obtain results is the use of computer modelling software where it is easy to manage multiple profiles and cross-reference them together. (Chan et al., 2009)

3.4 Research Methodology

A modeling approach deemed most appropriate in this study because of speed, cost, and flexibility to control parameters.

To establish a common ground, from which the energy benefits of applied skins observed, a base-case model made. The prototype will be a standard 7-storey office building of 20m x 30m open space plan. For the proposed solutions model it will contain a *double-skin* around its perimeter, where it will also have special conditions to the cavity gap as not only the horizontal spacing is a perimeter but also the vertical gap condition also would maintain special conditions. Optimizing the thermal comfort through testing effects on cooling load reduction and daily lighting penetration.

3.5 Selection of Software and Training

DesignBuilder Simulation Software is software that allows designing and operating comfortable buildings that uses significantly less energy and incorporates low-carbon and renewable technologies. The software enables designers to experiment with different design options, find out the best passive solutions, create comparisons between various low-carbon technologies, and reach conclusions on energy use, light levels, occupant comfort airflow, BREEAM, LEED, Part L, EPC ratings, and much more. In addition, it is more suitable for the use of architects where it provide a user-friendly interface. In addition, DesignBuilder uses EnergyPlus Engine in the modelling of cooling load and energy consumption. EnergyPlus is considered an accurate module for the software. While IES needs a mechanical engineering expertise to design and read results through a complicated process, which will needs extra time and expert to best advice about. (Sousa, 2012)

The reason for using The Simulation Method to conduct this research is its flexibility as it offers varying parameters and time requirements. The methodology divided into the following steps:

- Establishing the Climatic Model for UAE
- Establishing a base case for conventional building morphology and building operational profile for commercial buildings in UAE

- Establishing the multiple option of DSF configurations to be tested and modeling of the same:
  - Testing DSF systems effects – material of outer skin
  - Testing DSF systems effects– material of outer skin with air-gap (most common used gaps to be tested)
  - Testing DSF systems effects – effects of material choices on outer skin with air-gap – naturally or mechanically ventilated loads.
  - Testing DSF systems effects – effects of material choices on outer skin with air-gap – natural lighting.
- Establishing the various parameters and range of values for the same to be tested on the different configurations of facades

Instruments and Software – The simulation would require the following software's:

- DesignBuilder – For Cooling load and natural lighting simulations.

3.6 Software Validation

Introduction to the software at use in this case study. DesignBuilder is a building simulation computer software, which allows users and specially architects and designers in general to construct simulation modeling of their buildings, as well as run many different environmental analyses. DesignBuilder has a friendly user interface and can import files directly from multiple other computer software's, as well as building the models from scratch inside the software. Many components in DesignBuilder of modeling such as parametric, materials, ventilation schedules, occupancies, windows shadings, etc. in theory, each of these elements can be easily modified and changed. The software also contains large extensive Pre-loaded libraries. DesignBuilder offers a wide range of detailed formats of results that can show reasonably precise data and easily exported to a chosen MS. Office program. (Cockcroft, 2015)

In order to confirm the validity of the software results a study was conducted by Baharvand et al., (2013) to cross check results obtained from DesignBuilder software against readings taken from experimental test that was done where two main parameters of temperature and air velocity were checked. This study resulted in a conclusion that

DesignBuilder performed to acceptable measures as data collected had some minor errors. However, the final software results were well in agreement with data collected from the experimental test case. See Figure 4.1.

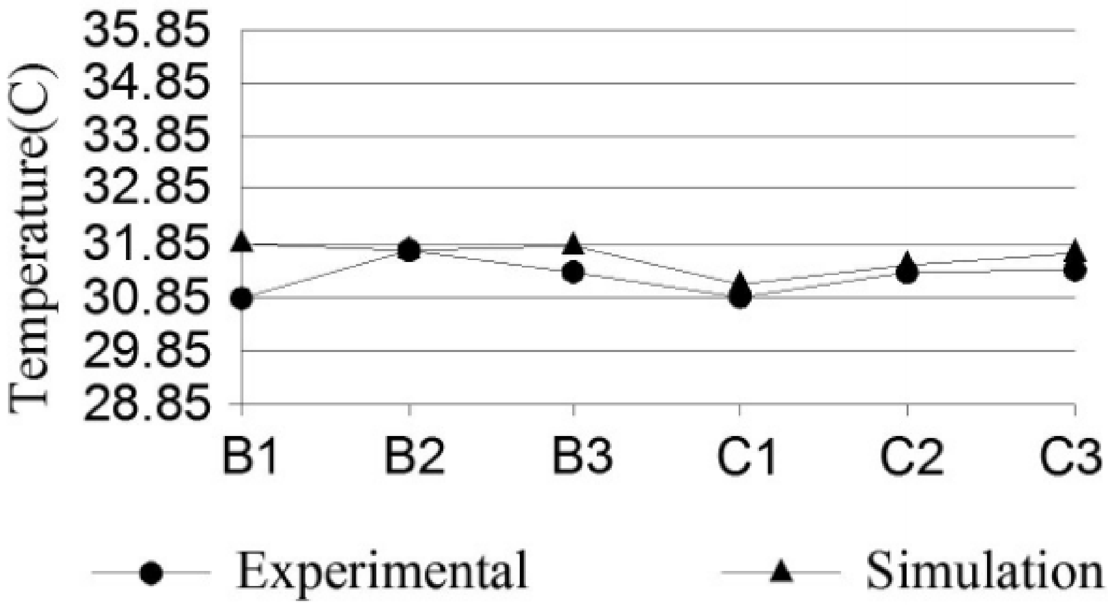

Figure 4.1: Experimental and simulation temperature results (Source: Baharvand et al., 2013)

Such research based on comparing the current and used Construction Materials, along with examining the effect of orientation and climatic regions during that considering the office timing will be from 8:00 a.m. to 6:00 p.m., for five working days in a week. Many factors will be study such as Human comfort i.e. temperature fluctuations, humidity levels, heat gain reduction also the effect of different Facade Systems, DFS partitioned by story (No-partition, low partitioned, high partitioned), multi-story type DFS outer skin different effects , and finally the shaft box type DFS systems natural ventilation. (Harris, 2004)

3.7 Limitation of The Study

Unfortunately, due to the time limitation this study allocated to take. The research would not simulate more floors or multiple conditions inside the cavity also the materials are limited to the common materials used in the construction field rather than testing alternative new materials. In addition, the cavity depth is divided into three intervals 0.5, 1.0, and 1.5 only. While double skin facades buildings may reach up to 2.5 meters cavity depth.

Chapter | 4

Simulation Models

4.1 Overview

Based on the information discussed earlier in the literature review and provided data gathered by other researchers, a computer simulation analysis will be needed to fully check and measure the effect of the follow there conditions:

- The effect of the introduced gap between the internal skin and the external skin at the double skin facade.
- The effect of the gap condition (open, centrally closed, multiple closed)
- The effect of changing the external skin (Concrete, aluminum, treated wooden blanks, glass).

The analysis aims to check these above-mentioned conditions in relation to cooling load and daylight penetration. In order to satisfy the research question, performance analysis of solar gain and day lighting effect using different choices of materials of double-skin Facade under desert climatic conditions, a commercial office building selected and located in Dubai. This will help test these conditions under desert climatic parameters.

A case study through computer simulation software will be introduced in this chapter. Many aspects will affect the results of such simulation such as; climatic condition, building site location, building type as it has an effect of building usage in terms of cooling load and the need of natural lighting and finally main operation hours.

4.2 Case Study Description

The intention of the study is to study the proposed research under a desert climate. The city of Dubai in the United Arab Emirates Figure 4.2 is the location of the baseline case building, a commercial office building with commercial glazing tested through computer simulation to find out the effect of each of the proposed conditions. Al Rawabi Building is a commercial occupancy office building located in Deira, Figure 4.3 - 4.5.

Al Rawabi Building is a 20-year-old building with 7 typical floors and a ground floor. The typical construction at that time was concrete walls and commercial double glazed windows with aluminum frames. For this study, the 3rd floor will be mark test of the simulation. An old typical floor plan Figure 4.6 showing that a typical floor is sized to be 30 mtr * 30 mtr. In addition to office spaces, a central area for storage, facility rooms, stairs and elevators (20% of the floor area).

Location Data:

- Latitude: 25°15'49.17" N
- Longitude: 55°19'43.88" E
- Altitude: ~ 6.00 m
- Time Zone: + 4:00 Hours (GMT)

Site Data:

- Ground reflectance: 0.20
- Terrain type: City - Buildings
- Wind exposure: Normal (Heating load by CIBSE)

Figure 4.2: Dubai, United Arab Emirates (Source: Google Map, 2015)

Figure 4.3: Al Rawabi Building, Case Base building location at Dubai city (Source: Google Map, 2015)

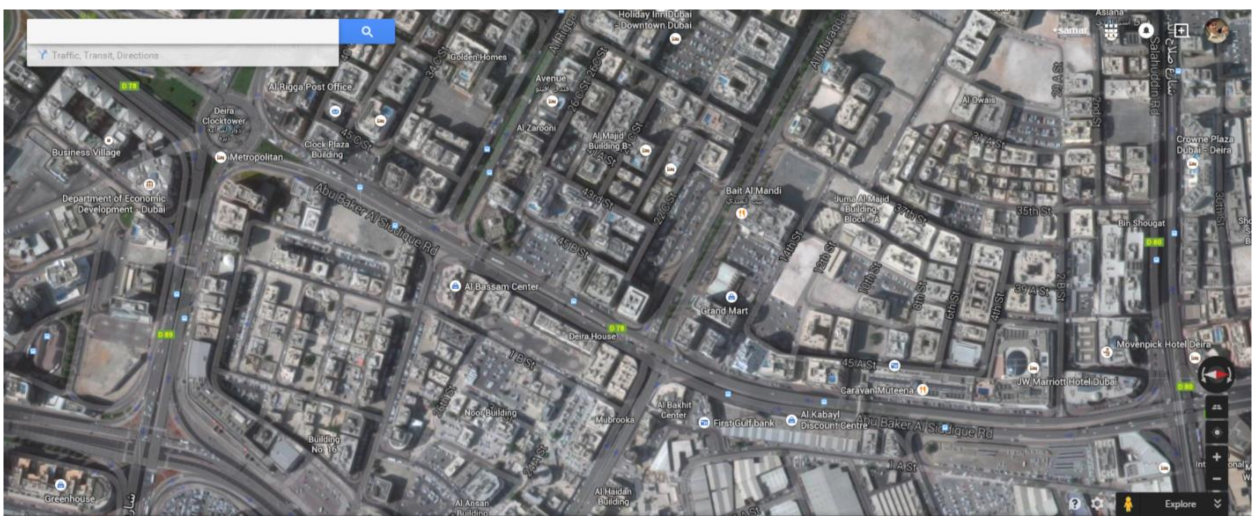

Figure 4.4: Al Rawabi Building, city location (Source: Google Map, 2015)

Figure 4.5: Al Rawabi Building (Source: Google Map, 2015)

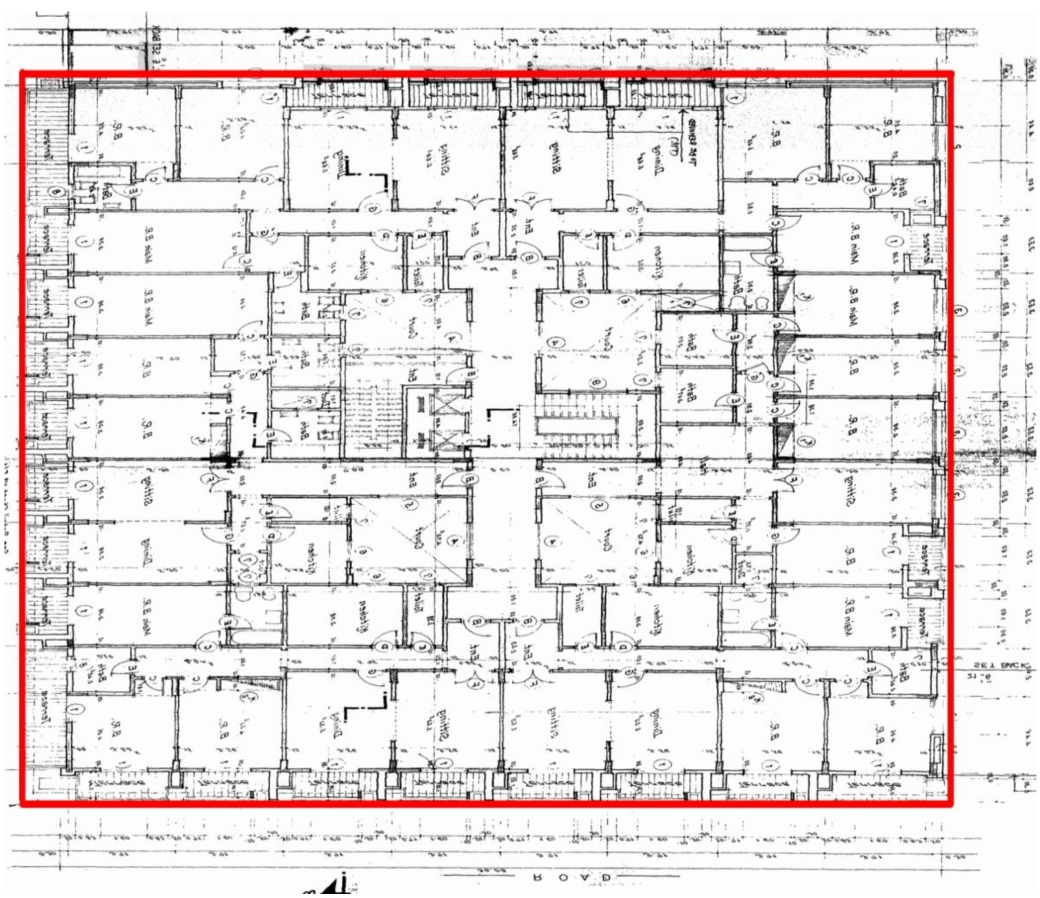

Figure 4.6: Al Rawabi Building, Existing typical floor plan (Source: Archive, Dubai Municipality, 1995)

The DesignBuilder software will simulate the effect on cooling load and Daylight penetration to the building, measuring each of the parameters given earlier.

Although, the main idea is to test the performance of the building and specially cooling load, where its reduction will mean reduction in energy consumption, which leads to reduction in operational cost. Daylighting is a major factor in this equation, and for this research, as it needs to be maintained to help building occupants perform their tasks during main operation hours (7:00 a.m. – 5:00 p.m.). It is necessary to maintain the minimum illumination level allowing building users to perform the office related task, this will result in reduction of artificial lighting usage. Dubai Municipality Regulations used to compare the results in this simulation to acceptable standard. (DM, 2011)

4.4 Base Model Data Input - Modelling

With reference to, all of the mentioned above, Figure 4.7 represent the case study model created in Designbuilder software.

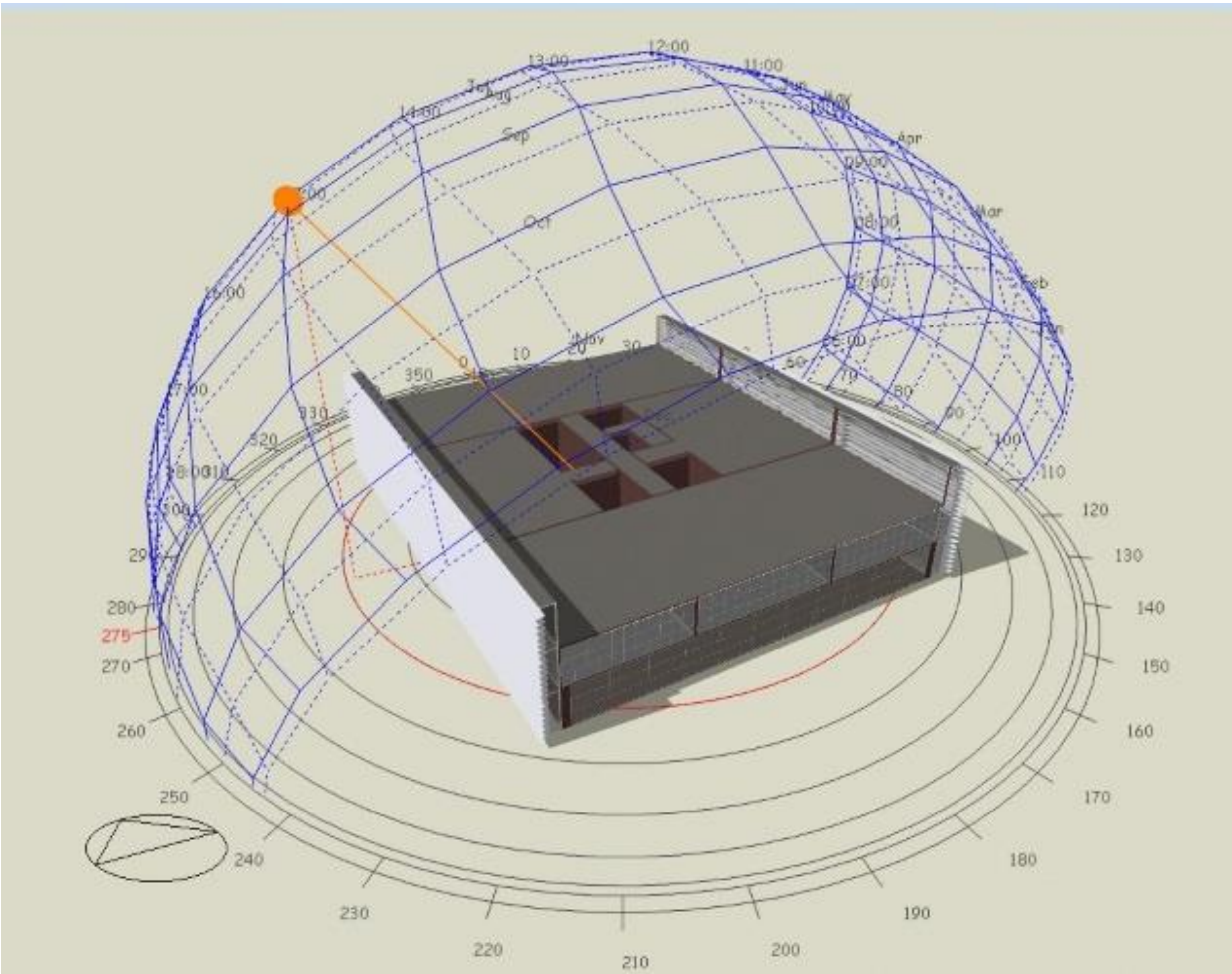

Figure 4.7: 3D Shoot of the DesignBuilder model (Source: Author, 2015)

As presented earlier in the literature review and many attempts by fellow researchers such as Shameri et al., 2011. Table 4.1 showing the Annual Climate and Weather of Dubai, that the peak time is the target for the suggested simulation is July with a temperature reach of 49 °C.

As the temperature increases, the cooling load also increases resulting in an effect on the total energy consumption of any building. Therefore, picking on the highest month in terms of temperature; July and hottest day of the year, 22 July, each of these parameters will be tested for its effect on performance in cooling load as well as the daylight penetration to the building. (Dubai Meteorological Office, 2015)

Table 4.1: Annual Climate and Weather of Dubai (Source: Dubai Meteorological Office, 2015)

Climate data for Dubai													
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C (°F)	31.6 (88.9)	37.5 (99.5)	41.3 (106.3)	43.5 (110.3)	47.0 (116.6)	46.7 (116.1)	49.0 (120.2)	48.7 (119.7)	45.1 (113.2)	42.0 (107.6)	41.0 (105.8)	35.5 (95.9)	49 (120.2)
Average high °C (°F)	24.0 (75.2)	25.4 (77.7)	28.2 (82.8)	32.9 (91.2)	37.6 (99.7)	39.5 (103.1)	40.8 (105.4)	41.3 (106.3)	38.9 (102)	35.4 (95.7)	30.5 (86.9)	26.2 (79.2)	33.4 (92.1)
Average low °C (°F)	14.3 (57.7)	15.4 (59.7)	17.6 (63.7)	20.8 (69.4)	24.6 (76.3)	27.2 (81)	29.9 (85.8)	30.2 (86.4)	27.5 (81.5)	23.9 (75)	19.9 (67.8)	16.3 (61.3)	22.3 (72.1)
Record low °C (°F)	6.1 (43)	6.9 (44.4)	9.0 (48.2)	13.4 (56.1)	15.1 (59.2)	18.2 (64.8)	20.4 (68.7)	23.1 (73.6)	16.5 (61.7)	15.0 (59)	11.8 (53.2)	8.2 (46.8)	6.1 (43)
Average precipitation mm (inches)	18.8 (0.74)	25.0 (0.984)	22.1 (0.87)	7.2 (0.283)	0.4 (0.016)	0.0 (0)	0.8 (0.031)	0.0 (0)	0.0 (0)	1.1 (0.043)	2.7 (0.106)	16.2 (0.638)	94.3 (3.711)
Avg. precipitation days	5.4	4.7	5.8	2.6	0.3	0.0	0.5	0.5	0.1	0.2	1.3	3.8	25.2
Average relative humidity (%)	65	65	63	55	53	58	56	57	60	60	61	64	59.8
Mean monthly sunshine hours	254.2	229.6	254.2	294.0	344.1	342.0	322.4	316.2	309.0	303.8	285.0	254.2	3,508.7

In accordance with the above, and understating the occupancy level and usage of the building is highly crucial. Commercial office building generally operates from 7:00 a.m. – 6:00 p.m. The daylight distribution show in Figure 4.8 that Dubai in particular and The United Arab Emirates in general, has a daylight distribution between 6:00 a.m. –5:30 p.m. In summer, these hours increase to start at 4:50 a.m. and end at 6:30 p.m. (Dubai Meteorological Office, 2015)

In order to perform a typical office tasks, such as reading, writing, operating a computer and many but not limited office tasks, an individual user needs 300 and 500 lux. (The lighting handbook, 2011).

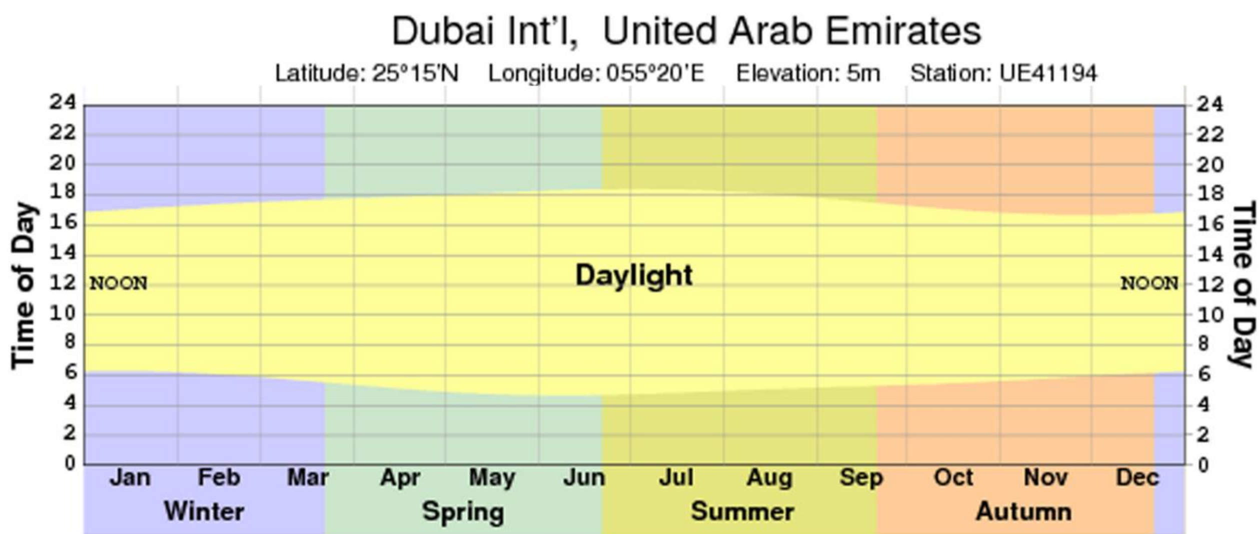

Figure 4.8: Annual Average Daylight Distribution of Dubai per hour according to each month (Source: Dubai Meteorological Office, 2015)

4.6 Simulation Profiles Scenarios and Materials Matrix

Suggested simulated profiles Table 4.2, skin spacing, different conditions of skin gap, and the materials suggested for each external skin (concrete, aluminum…etc.).

Table 4.2: Simulation Profiles and materials matrix (Source: Author, 2015)

Estimated Cooling Load Data (KW)							
Baseline Case	Cavity Depth Sapcing	Cavity Depth Condition	Internal Skin	Concrete Outer Skin	Aluminum Outer Skin	Treated Wooden Outer Skin	Glass Outer Skin
597.05 KW	0.5 Meter	Open shaft	Single Glaze Glass with Aluminum Frame Windows	408.75	456.77	455.77	429.91
		Closed at 3rd floor		391.34	442.73	441.73	391.34
		Closed at each floor		392.34	440.09	439.09	392.34
	1.0 Meter	Open shaft		371.39	468.66	467.66	393.34
		Closed at 3rd floor		443.63	444.63	443.63	506.10
		Closed at each floor		438.67	439.67	440.67	494.51
	1.5 Meter	Open shaft		481.04	483.04	482.04	537.30
		Closed at 3rd floor		429.85	431.85	430.85	501.81
		Closed at each floor		438.75	440.75	439.75	484.15

Results collected per floor area and in the same time per individual office to measure the effect also on facade orientation. Measurements for cooling load will be in KW and daylight penetration in LUX. Moreover, results from the computer simulation compared against the baseline case and acceptable Dubai Municipality regulations.

As per the Figure 4.9 – 4.12, showing the samples of each material profile for the computer simulation, also the material properties given at the computer simulation.

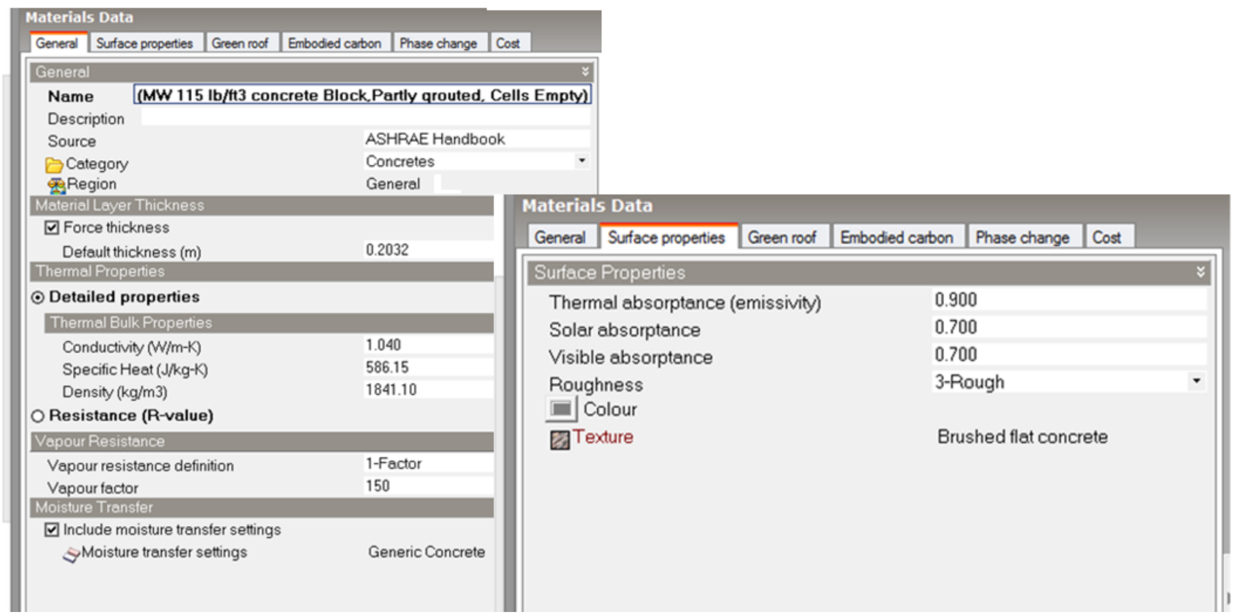

Figure 4.9: Concrete Skin properties (Source: DesignBuilder, 2015)

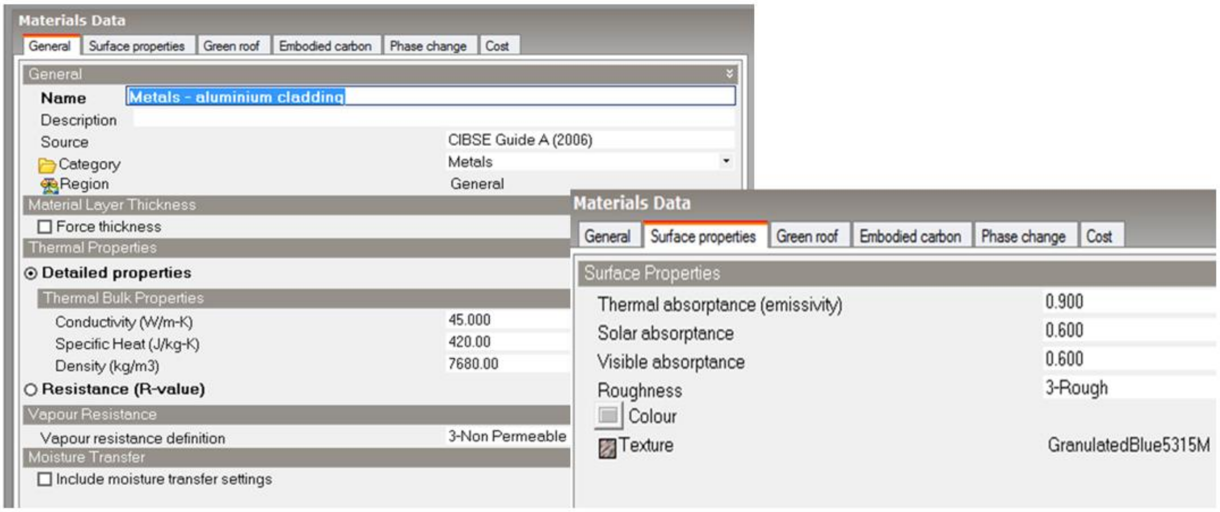

Figure 4.10: Aluminum Skin properties (Source: DesignBuilder, 2015)

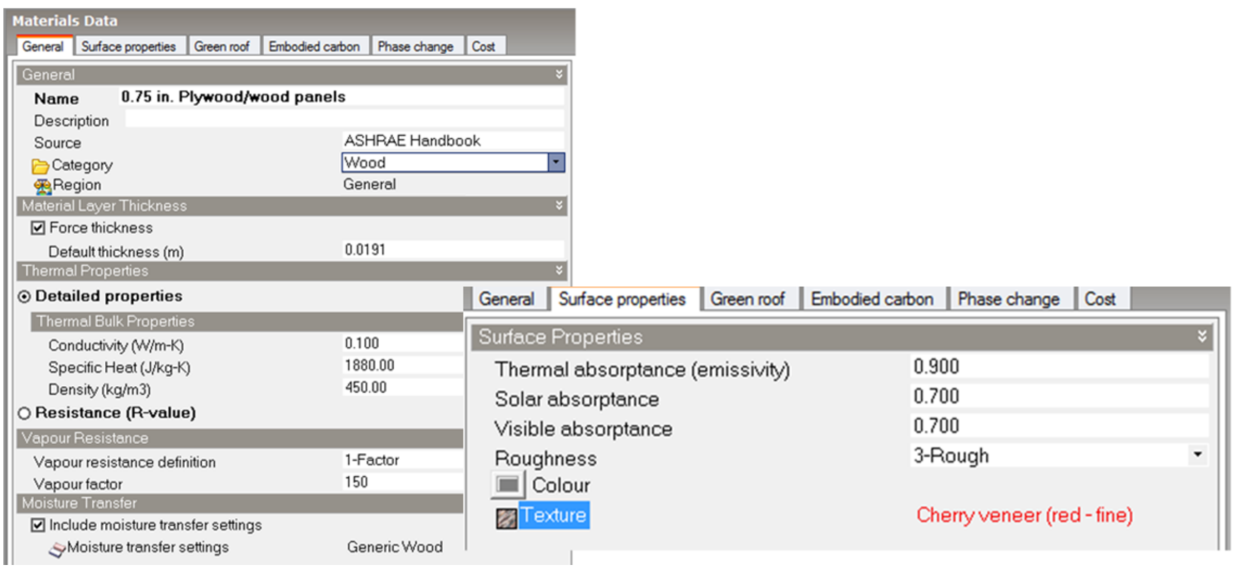

Figure 4.11: Treated Wooded Skin properties (Source: DesignBuilder, 2015)

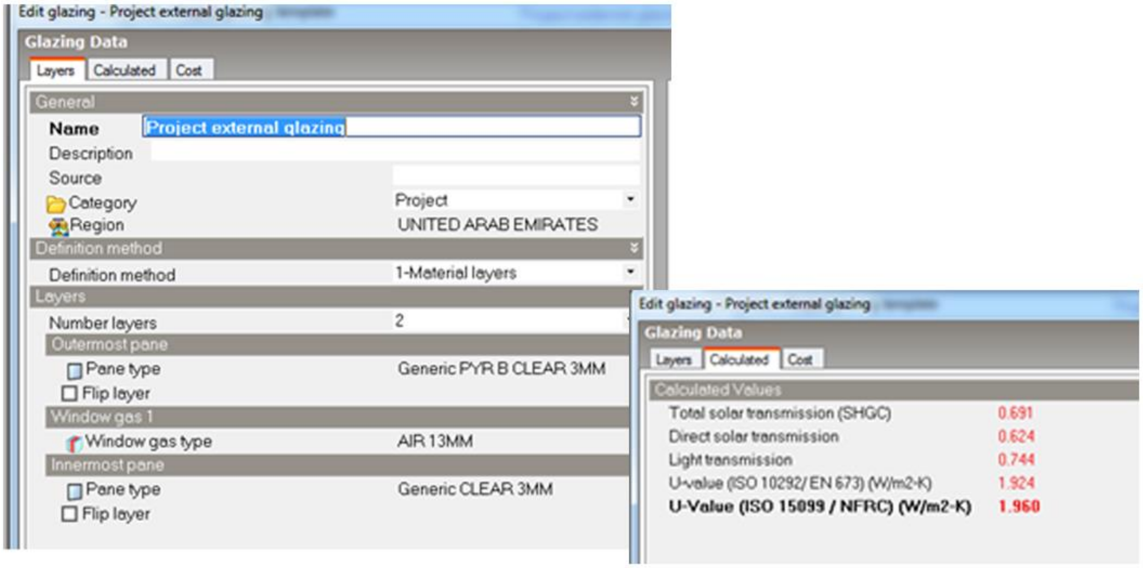

Figure 4.12: External Glass Skin properties (Source: DesignBuilder, 2015)

The baseline case has commercial glazing Figure 4.13 & Table 4.4, as per the regulation of Dubai Municipality for commercial buildings in 1995 and as per the observation of provided floor plans and documentation of the building owner:

Figure 4.13: Baseline & Internal Building Glass Skin properties (Source: DesignBuilder, 2015)

Table 4.3: Baseline & Building Material Description properties (Source: DM Building Regulation Documents, 1995)

Baseline & Building Material Description:	
External Wall	12 mm mortar (skin surface)
	200 mm concrete blocks
Roof	65 mm screed
	5 mm bitumen
	200 mm concrete reinforced slab
Window to wall ratio	80%
Glazing	As per ASHREA 9.1 (Single Glazed with Aluminum frames)

The baseline project case was rendered and simulated with the oldest available data, in the DesignBuilder in order to simulate the needed results for the sake of comparison and performance data check.

The simulation profiles selected and created to examine and test each of the given scenarios. This study will use the double skin facade module of building construction and architecture to create assumption about the performance of the cooling load and daylight penetration. Both of these elements have a direct effect of the total energy consumption the building.

The following four selected profiles for the simulation are:

- Concrete Skin
- Aluminum Skin
- Treated Wooded Skin
- External Glass Skin

Each checked against the baseline case building, where additional parameters were also in place to get a comprehensive report on overall performance. Each of these skins used as per the standard production and given details discuss earlier. The gap between the internal single glazed skin and the external profile scenarios are 0.5 meter, 1.0 meter and 1.5 meter. The chosen cavity depths depended to find 3 points of intervals where some of the conducted research such as Shameri et al, (2013), performed an analytical study on 12 double skin facade buildings that ranged between 0.8 -2.5 meters. However, the most common one was 1.00 meter cavity depth. The research take consideration to measurements below and above by 0.5 meter interval to cover the majority of the study conducted. Moreover, the condition of these gaps also tweaked to common practice double skin facade architecture and way of construction. These conditions are; open shaft gap, closed at the center gap (3rd floor in this case) and closed at each floor. This study indicates the third floor as the level of the simulation base according to Radhi et al, 2013; in DSF higher floors gain more heat. The models recommend the average reductions obtained by choosing the building middle floor, which is in current study, the third floor. The double skin facade use in natural ventilated system provided stack effect taking place to ventilate the gap. Results compared to find the best practice at the best performance for Dubai region and climate.

It is important as considering the above profiles to pay attention to building occupants usage (DiLaura, 2011) in Table 4.5, it shows the general requirement for occupants tasks at an office building. In red color highlighted most of the required tasks managed by office occupants and users. Illumination level is significant for any recommendation for a given profile at a test, the mentioned LUX levels must be preserved in order to reduce dependency on artificial light, therefore contributing to the reduction of total energy consumption. As per LEED V4. IEQ 8.1, LUX Levels must range between 108 LUX – 5400 LUX, for multiple tasks, suggested to maintain an average of 300 LUX throughout the designed area. Also 75% of daylight sustained in regulatory spaces that is occupied or used. (LEED V4, 2014)

Table 4.4: Recommended lighting levels. (The lighting handbook, 2011, Illuminating Engineering Society of North America.).

Activity	Illumination *(lux, lumen/m²)*
Public areas with dark surroundings	20 - 50
Simple orientation for short visits	50 - 100
Working areas where visual tasks are only occasionally performed	100 - 150
Warehouses, Homes, Theaters, Archives	150
Easy Office Work, Classes	250
Normal Office Work, PC Work, Study Library, Groceries, Show Rooms, Laboratories	500
Supermarkets, Mechanical Workshops, Office Landscapes	750
Normal Drawing Work, Detailed Mechanical Workshops, Operation Theatres	1,000
Detailed Drawing Work, Very Detailed Mechanical Works	1500 - 2000
Performance of visual tasks of low contrast and very small size for prolonged periods of time	2000 - 5000
Performance of very prolonged and exacting visual tasks	5000 - 10000
Performance of very special visual tasks of extremely low contrast and small size	10000 - 20000

4.7 Simulation Profiles Process

The 900 sq. /m building floor simulated in DesignBuilider is the 3rd floor as it is estimated as the average of any given result of this study is the test area for all mentioned profiles and parameters. There for the simulation process as it would be comprehensive but manageable through the software. In Table 4.2, 36 simulation will be processed through DesignBuilder as proposed profiles for double skin facade system in addition to the baseline case simulation for the estimated cooling consumption (KW). The same shall be applied for the daylight penetration illumination distribution (LUX & DF).

The results will be processed and evaluated through MS. Word & Excel programs. Each profile tested will be presented and compared individually to the baseline case building results. A final summary of the results and configurations will be discussed in full to reach the best recommendation of such practice of double skin facade, in desert climatic region for office building.

Chapter | 5

Results and Discussion

5.1 Overview

This chapter will include results of this research and its discussion, as well as the reduction and saving achieved by each simulation profile and parameter in overall cooling load that is equal to energy consumption, through different building configurations using multiple simulations to study their thermal performance and daylighting effects. A comprehensive analysis for all related direct results in direct results are necessary to appreciate the potential of energy saving by each of these building skins and their effects on the envelope's inner skin thermal and daylighting performance.

The results obtained aim to reach certain targets in cooling load reductions targeted total energy consumptions. Cooling load reduction means direct reduction to electricity consumption and potential methods to conserve energy under desert climatic conditions in general and Dubai in particular. Additionally, retaining daylighting within acceptable and adequate level using the best profile strategies is a major aspect to achieve the research objectives mentioned earlier. For example, providing enough extent for lighting, and plan for open spaces that allow for light transfer, double skin facade profiles will allow such strategies with little heat gain, and reduction of glare. Integrating daylighting into the depth of the provided floor into will help great reduction to use of artificial lighting during the building main operational hours and especially during the conventional occupants and users general timing of building usage.

Moreover, details of this chapter will present a summary of the possible scenarios, solutions and other combined data proposed by the author. The discussion will directly mark the building cooling performance and daylighting penetration concluded by their performance as materials for an external double skin facade under desert climatic conditions.

In the conclusion, all possible laid scenarios presented to comprehend the impact of each element of the study, on building envelope separately and compared to studies managed using double skin facade on the four mentioned earlier profiles. A complete assessment followed similar to the one shown in Table – 4.2 but for entire floor performance as discussed in chapter 4. The conclusion of each scenario will linked back to base case, as it is a mandate to recognize the potential savings options in cooling load and total energy consumption as a result.

5.2 Baseline Case

Computer simulation of the baseline case with regular single glaze commercial glass system (1995) for inner building skin with the third floor shows a clear mark with a cooling load of 597.05 (KW) . Targeting healthier and more comfortable occupants and users where conventional use of office blinds properly manage glare effect as a regular solution and minimize solar heat gain. While, daylighting provides the best practice of lighting in commercial office buildings, research objective aim to reduce energy use for both artificial lighting and cooling load. Enhanced daylight penetration through increases vision glazing means better practice and moves the building design a closer step to green building regulation requirements (DM, 2011) & (Meco Best Practice Specification Guide 2014: V.1.0 5)

The results from the baseline simulation Table 4.2 shows a total cooling load of 597.05 (KW) for related energy consumption. Double skin facade system expecting to reduce the produced results from the baseline to reach 30% reduction in cooling load and resulting with contribution to total building reduction in energy consumption. As per Radhi et al (2013), cooling load contribute to almost 60 - 75 % of total energy consumption of a given building in UAE.

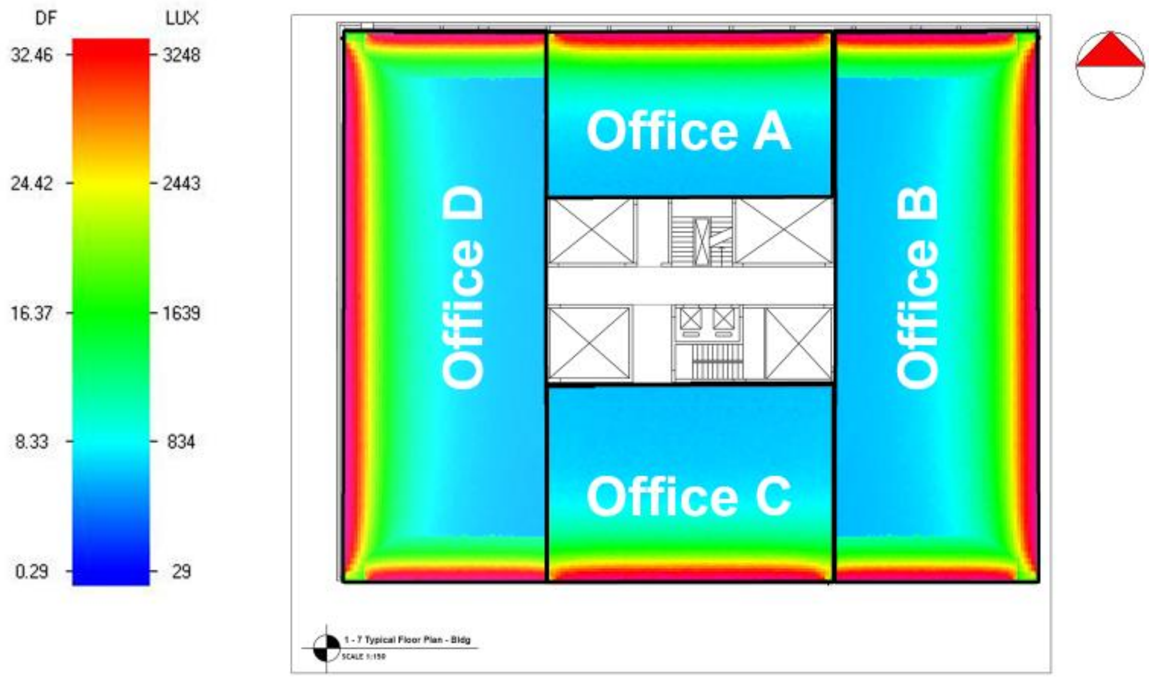

Figure 5.1: Baseline summary of illumination and Daylight Factor distribution. (Source: Author, 2015)

The daylight penetration in Figure 5.1 produced by DesignBuilder simulation modeling, shows that 60% of the floor receive adequate daylighting to perform office related tasks almost between 500 – 2000 LUX (Table 4.5). However, the issue arises to the remaining 25% of the floor as it receives over 2000 LUX, which means that these areas will suffer from glare issues or at least receive excessive daylighting that don't add to any benefit to the required LUX levels to perform office related tasks. On the contrary, it may cause the office environment to be uncomfortable to perform the need tasks. (ECSE, 2015)

It is vital to maintain adequate daylighting distribution while using a double skin facade as a passive design strategy to reduce cooling load.

5.3 Scenario Profile 1: Concrete Skin

This profile similar in material concept been used in Dubai through a building design and execution of the Cheese Tower formally known as 0-14 tower in Business Bay Development area (2014). A double skin facade of concrete using organic forms of circles with 0-degree angles, skin thinness is 400 mm as it molded on site. The suggested and tested profile at Scenario Profile 1 have the similar material but with a skin thickness of

200 mm to match the common practice in Dubai as per the Dubai Building Specification and Regulation Guide. (DM, 2011)

As expected, Figure 5.2, the concrete suggested profile reached cooling load reduction to 371.39 (KW) at 1.0 meter cavity depth with an open shaft condition. Reaching over 37% reduction in cooling load suggests almost 23% on reduction on the total energy consumption of the building. More data to consider at the given scenario at each of the cavity depths, where the minimum achieved reduction could reach to 19% for cooling load.

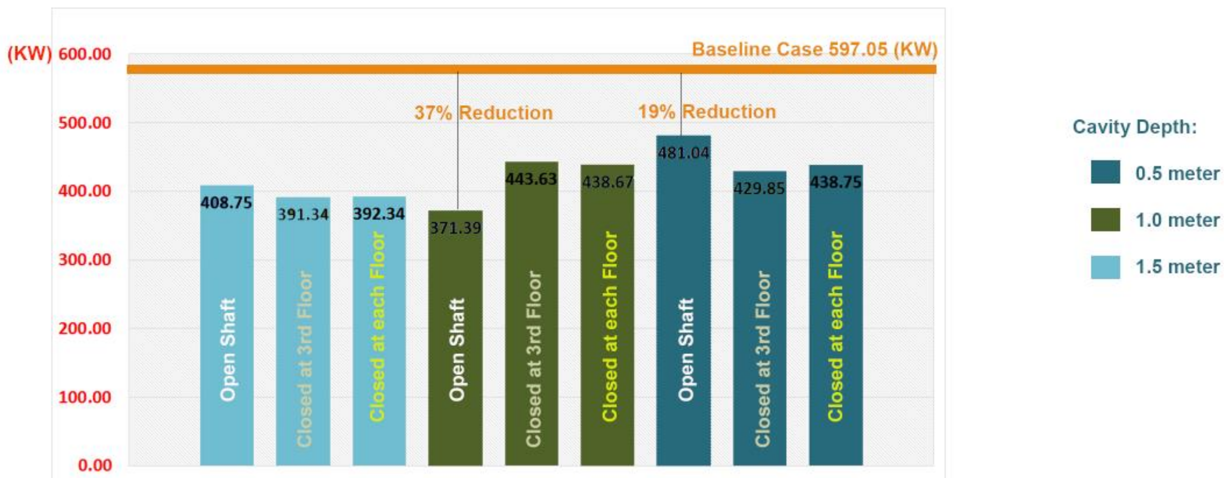

Figure 5.2: Profile 1 – concrete 2nd skin: cooling load KW distribution over suggested cavity depth. (Source: Author, 2015)

Daylighting can be a major issue profile; therefore, a closer look for the daylight distribution needed. Compromising on daylighting will not be beneficial if the occupants switched to artificial light. The energy consumption reduction gained can be lost due to the use of artificial lighting during office operation hours, even with the best practice in lighting design, and this can be a major issue, which needs the attention of any architect or facade designer.

In order to fully examine the daylighting aspect of the suggested concrete profile. A daylight simulation created in DesignBuilder, to show the effect of cavity depth for each of the depth mentioned conditions earlier. In general, Figure 5.3 shows an effective distribution of daylighting across the entire floor area with a coverage of up to 60%. Where

LUX levels distributed through the multiple conditions and options between 200 LUX and up to 2000 LUX. As explained in Table 4.5, this measure to need LUX to perform the office related tasks. However in the scenario had a strange result where the cavity depth is 1.5 meter, it can be noticed a greater illumination levels that the rest of the scenarios in the open shaft condition but a major degrees compared to the condition where the cavity depth condition to be closed at each floor. This means, the users and office occupants will need to switch to artificial lighting systems during the operational hours. As this may lead to increase in the general energy consumption, this may not justify such switch even if for achieving a reduction in cooling load.

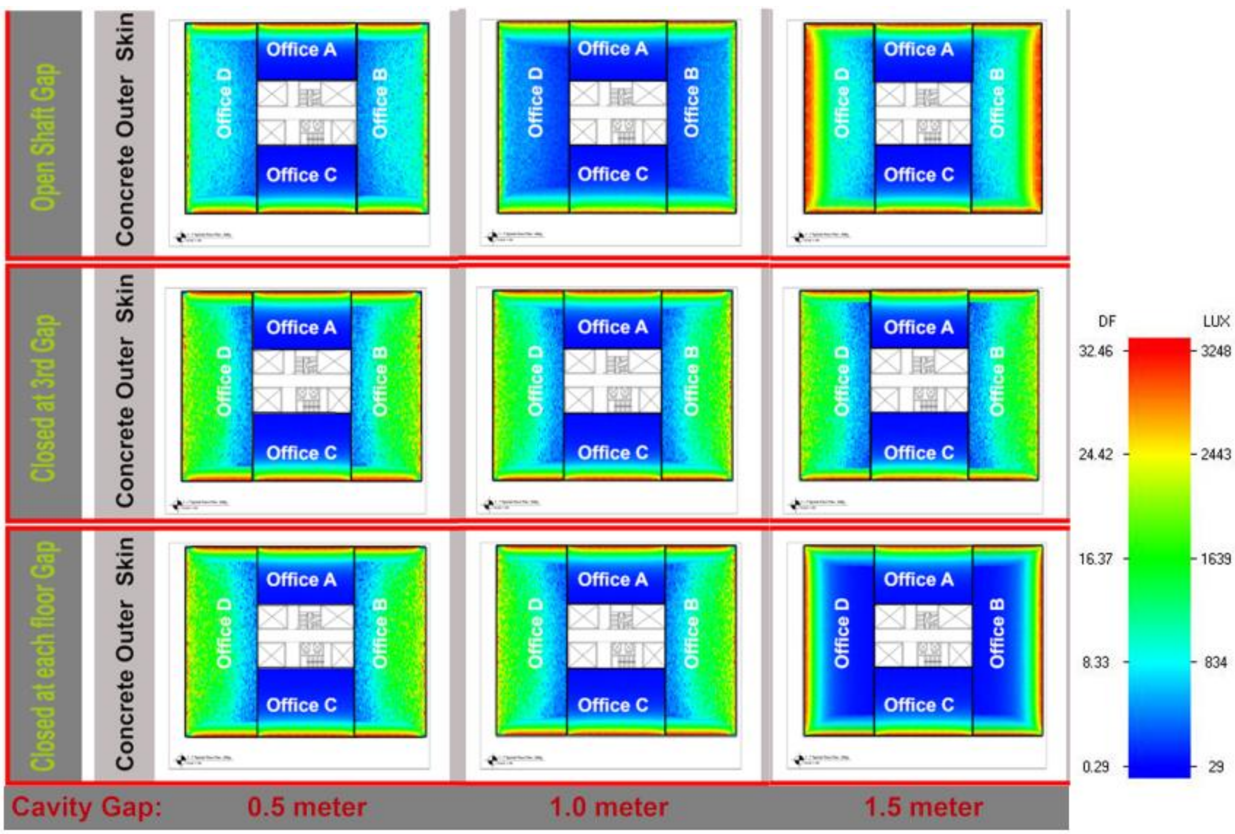

Figure 5.3: Profile 1 – concrete 2nd skin: daylighting distribution at floor area over suggested cavity depth. (Source: Author, 2015)

5.4 Scenario Profile 2: Aluminum Skin

As shown, Figure 5.4, the Aluminum Skin as acting profile 2 reached with its cooling load reduction to 431.85 (KW) at 1.5 meter cavity depth with a closed at the 3rd floor condition. Reaching only

28%, reduction in cooling load mean nearly 16 – 20 % on reduction on the total energy consumption of the building.

Aluminum, known thermal insulated material manages to reduce the thermal gain as the cavity depth increases with minimum separation for the cavity i.e. closed at the third floor condition at cavity depth of 0.5, 1.00 and 1.5 meters. This is a main condition to allow this profile to be a successful one. Moreover, the given scenario at each of the cavity depths mentioned earlier, where the minimum achieved reduction could reach to 19% for cooling load as well.

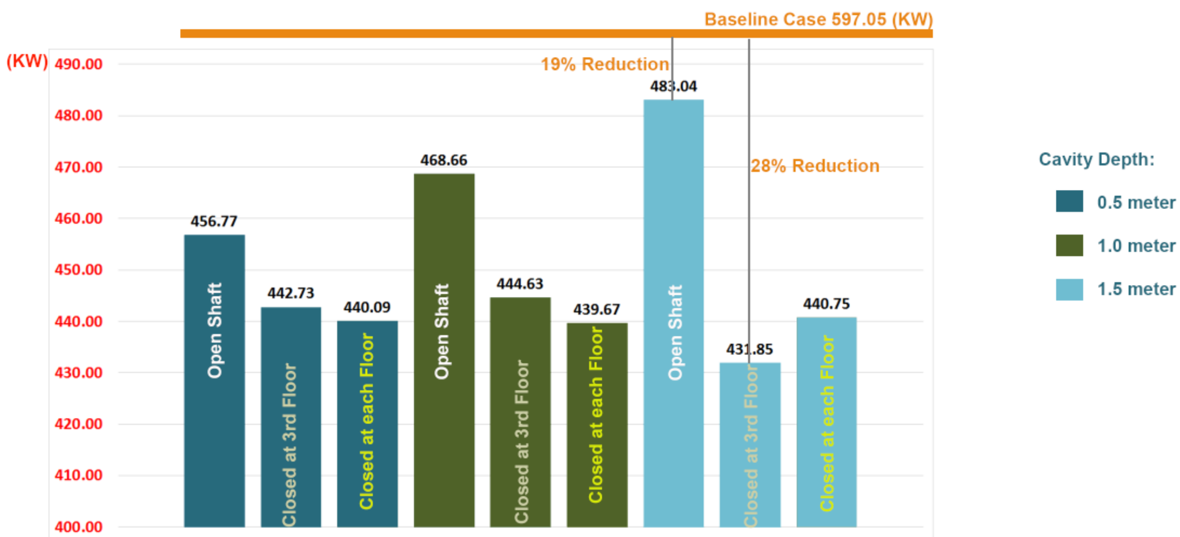

Figure 5.4: Profile 2 – Aluminum 2nd skin: cooling load KW distribution over suggested cavity depth. (Source: Author, 2015)

Daylighting can be a tricky option here for this profile; aluminum if not placed at the correct angle will result in reflect both heat and day light away from building envelope and resulting in darker areas that are not suitable for office tasks.

Daylight distribution compared with the simulated results cooling load and energy consumption reduction gained which further examined in Figure 5.5. A daylight simulation created in DesignBuilder, to show the effect of cavity depth for each of the depth mentioned earlier. In a broad-spectrum, Figure 5.5 shows an inadequate distribution of daylighting where skin profile placed closer to the building's first skin across the whole floor area with a coverage at best reaching 40%.

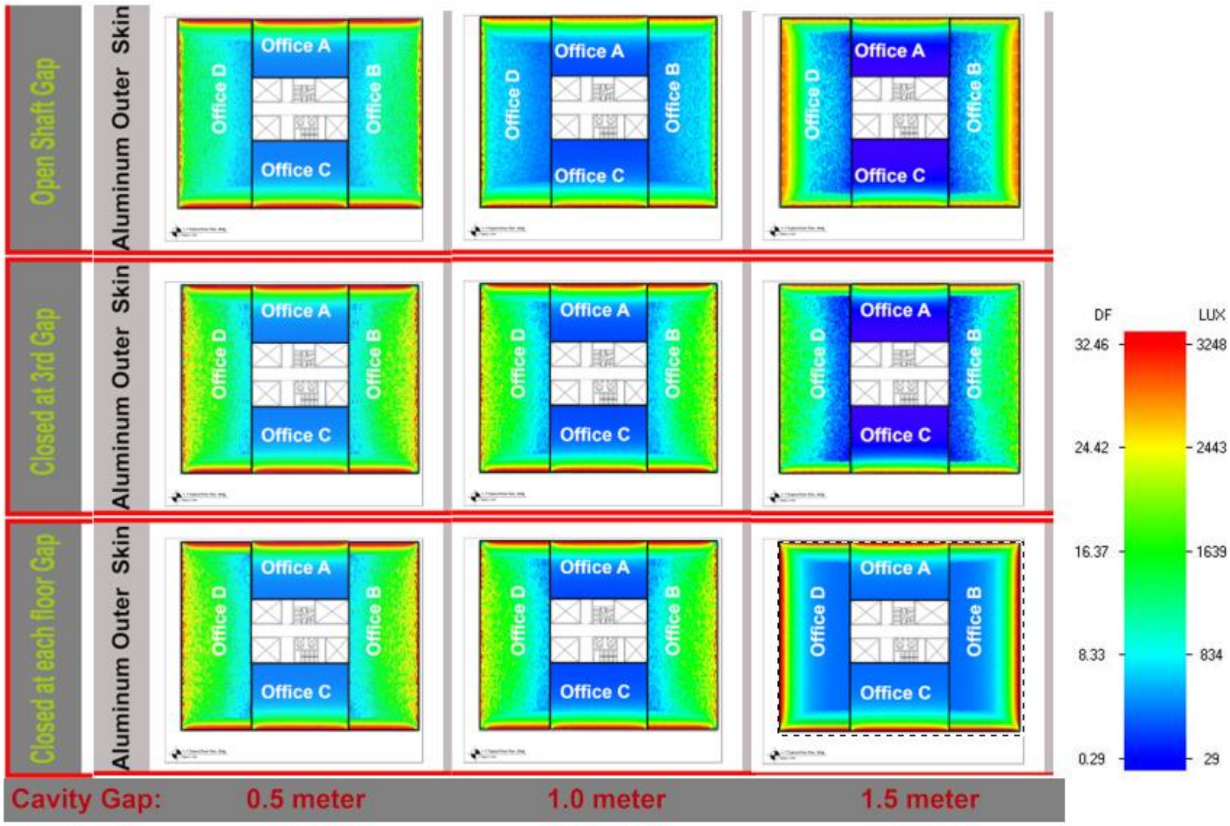

Figure 5.5: Profile 2 – aluminum 2nd skin: daylighting distribution at floor area over suggested cavity depth (Source: Author, 2015)

However, in the scenario where the cavity depth is 1.5 meter, it noticed that there is a huge drop in illumination levels compared to the rest of the scenarios. Even for the condition of open shaft resulted with an uncomfortable LUX levels near the glazing, which means the building internal envelop suffers glare as well. In addition, LUX level measure to 3000 LUX at the condition where the cavity depth condition to be closed at each floor. This means, the users and office occupants will need to switch to install indoor blinds to reduce such glare effect during the operational hours. In general, energy consumption may not be the main issue here, but lighting and visual comfort needs some additional observation and further analysis.

5.5 Scenario Profile 3: Treated Wooded Skin

Treated wooden banks acting in forms, is another widely used material, the warmth color of its color helps to blend with the surrounding architecture context. The material itself performs the required shading with minimal surface reflection, which minimizes glare. This material skin performed similarly to Profile 2 in terms of the estimated cooling load as shown in Figure 5.6 with minor differences.

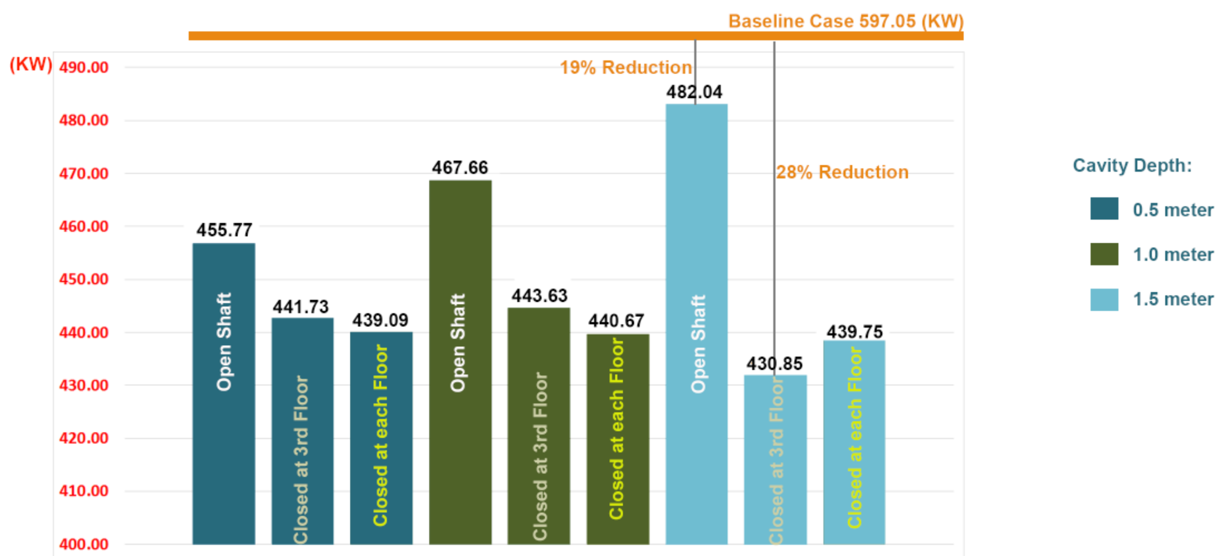

Figure 5.6: Profile 3 – Treated Wooden Banks 3rd skin: cooling load KW distribution over suggested cavity depth.

(Source: Author, 2015)

Daylighting penetration actually had a better distribution in here, with almost no glare for this profile; daylight simulation created in DesignBuilder examined further in Figure 5.7, clearly, shows an a inadequate distribution of daylighting where skin profile's where placed closer to the building's first skin across the whole floor area with a coverage at best reaching 40%.

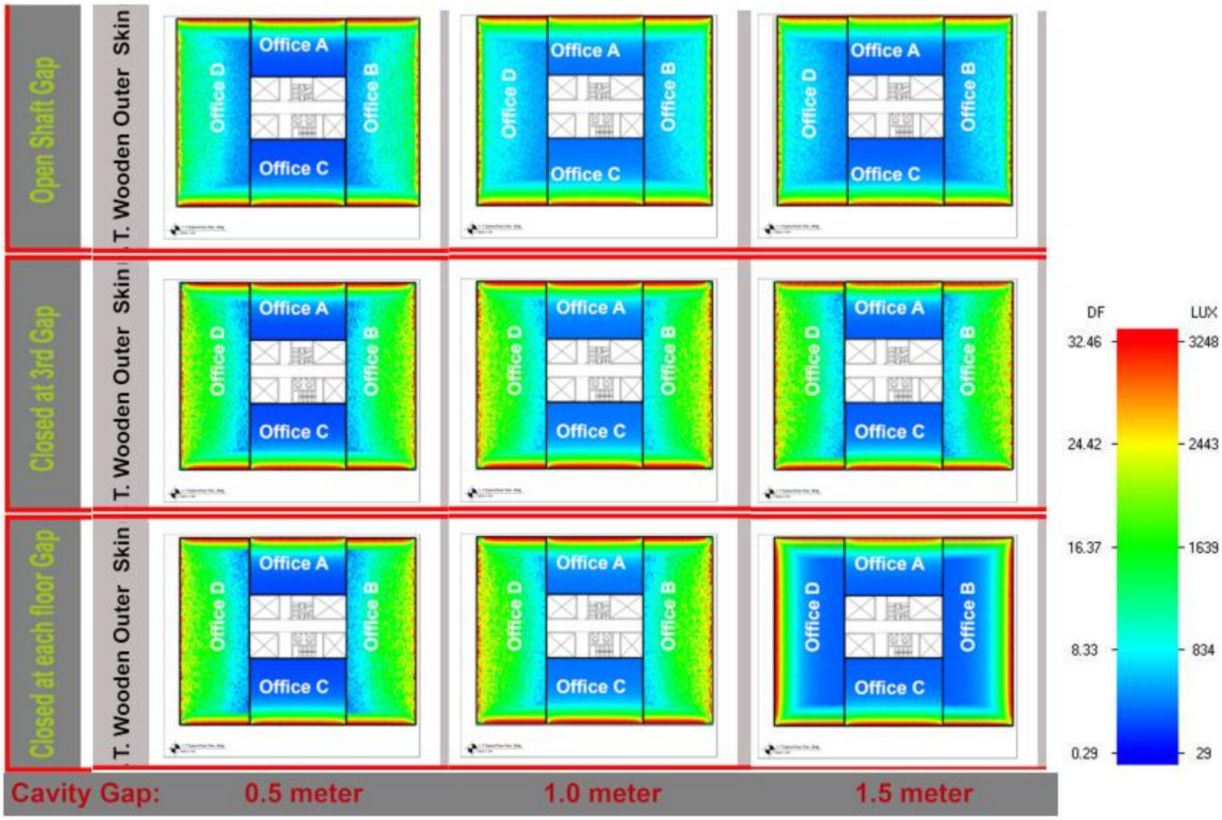

Figure 5.7: Profile 3 – Treated Wooden Banks 3rd skin: daylighting distribution at floor area over suggested cavity depth (Source: Author, 2015)

However, the scenario where the cavity depth is 1.5 meter have the most, an enormous drop in illumination levels occurs in 75 % of the office is occupied area than in the rest of the scenarios, even of the one with the open shaft condition to have an uncomfortable LUX levels near the glazing, but also shows high glare level.

The LUX level measures 3000 LUX at the condition where the cavity depth is closed at each floor. In addition, daylighting decrease after 5 meter towards the core of the building from the widows where LUX levels drops to be less than 500 LUX. As stated earlier 500 LUX is the recommend requirement for the occupants and users to perform office tasks. This means, the users and office occupants will need to install indoor blinds to reduce the glare effect during operational hours near the windows and use artificial lighting for almost 75% of the floor area.

5.6 Scenario Profile 4: External Glass Skin

External glass skin is one of the most commonly used skins and sometimes a building is even defined by it Jeff et al (2010). An external glass skin is more like a layer of protection placed in front of the inner envelope building glass. As a transparent matter with double glazing properties it will transmit the daylight allowing it to penetrate as far as possible inside the building envelope. Cooling load simulation shows that this skin material performed similarly to Profile 1 in terms of the estimated cooling load as shown in Figure 5.8 but it performs with a minor reduction factor of 10% at the cavity depth of 1.5 meter when the shaft is open. A better performance found at the cavity depth of 1.0 meter with only 21 KW difference higher than concrete.

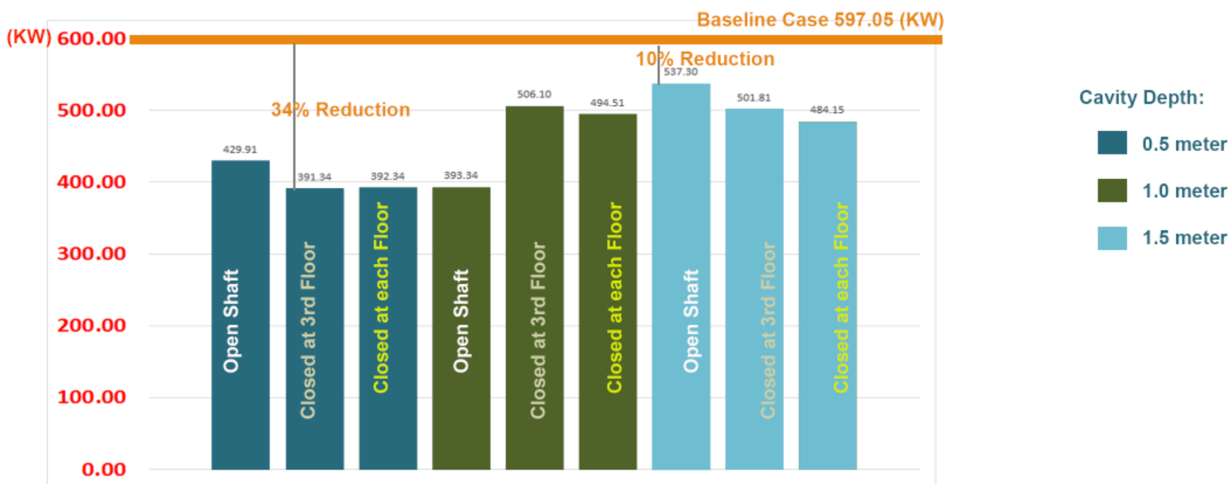

Figure 5.8: Profile 4 – External Glass Skin 4th skin: cooling load KW distribution over suggested cavity depth.
(Source: Author, 2015)

Daylight penetration is at a greater distribution, than any of the pervious placed scenarios, but glare is an issue with such a material with high reflection value. Daylight simulation created in DesignBuilder inspected further in Figure 5.9 clearly illustrates an adequate distribution of daylighting across the whole floor area with a coverage at best reaching 70% with 500 + LUX illumination level. Binds would need to be installed to reduce glare factor and control the LUX levels near glazing.

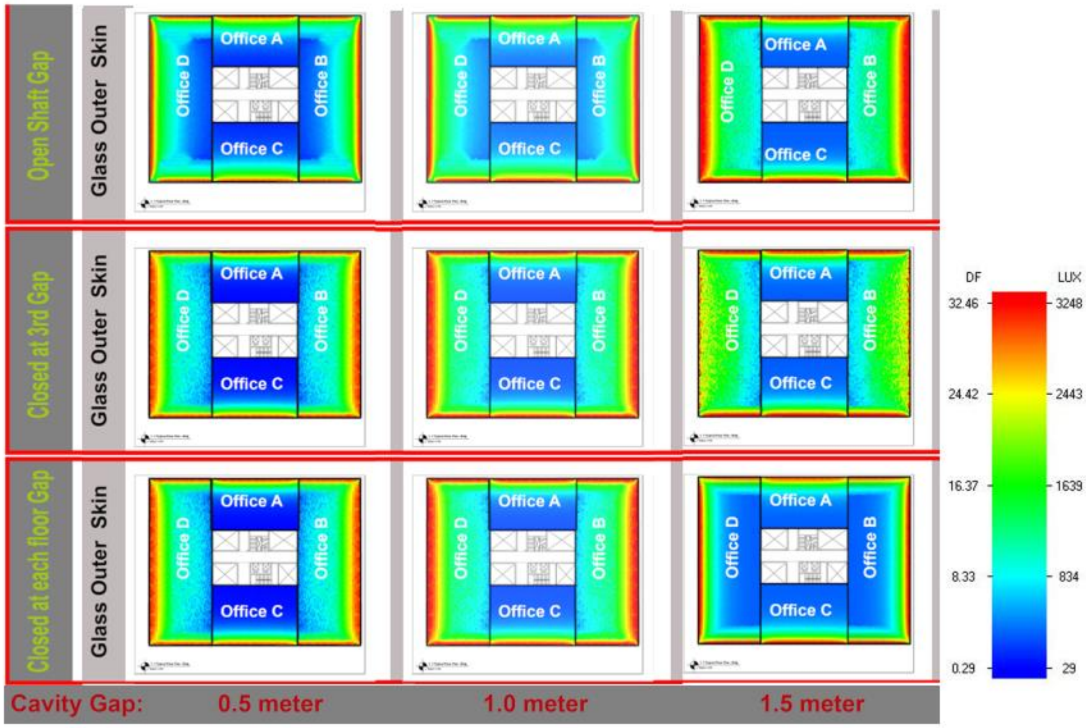

Figure 5.9: Profile 4 – External Glass Skin 4th skin: daylighting distribution at floor area over suggested cavity depth.
(Source: Author, 2015)

5.7 Scenario Profile Comparison

As this section progresses, each scenario and its relation and correlation show the intersection between the materials of the outer skin with different suggest cavity depth and their conditions. Many patterns watched for and checked but for the most important achievement is finding the best practice of the system to obtain maximum cooling load reduction and daylight penetration.

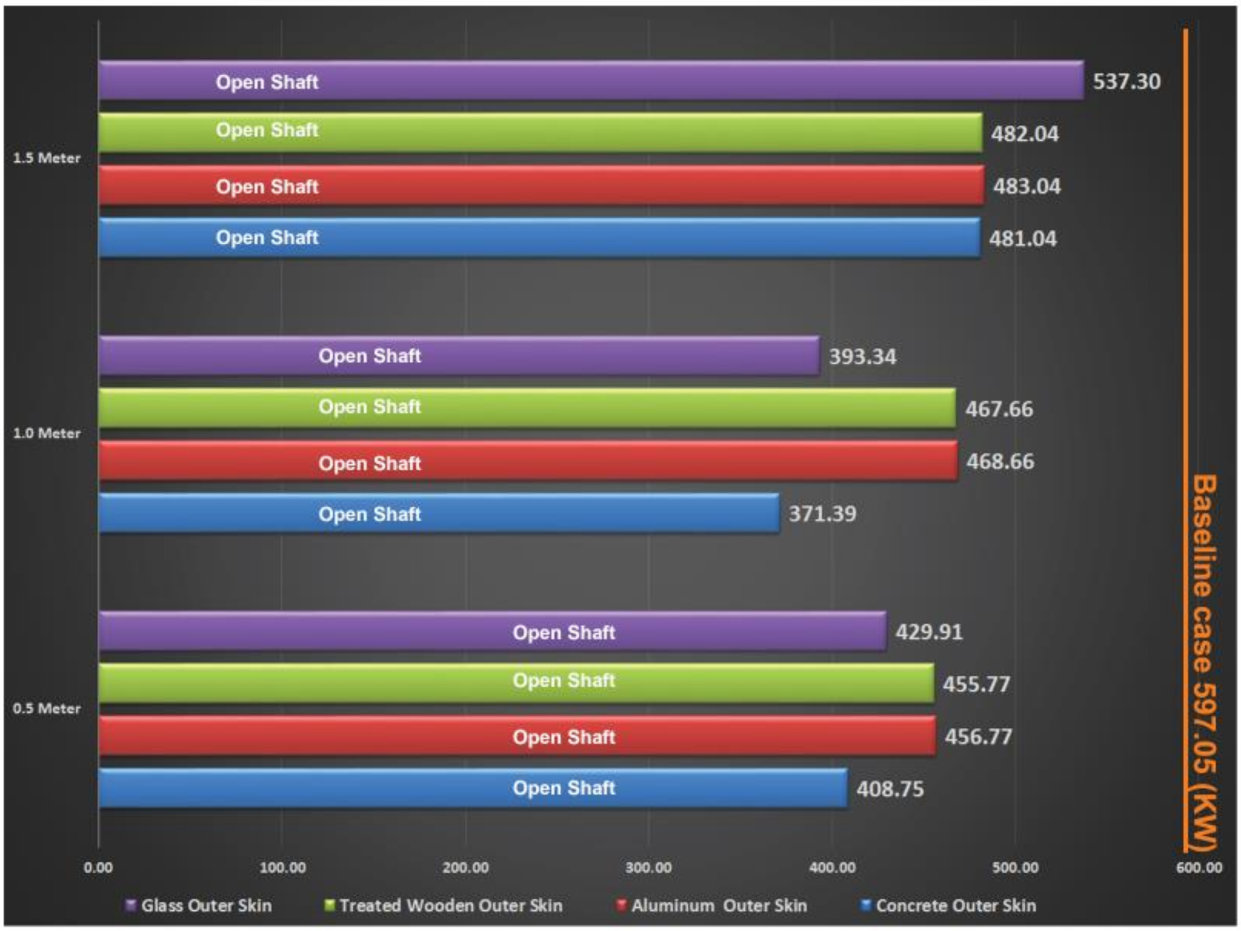

Figure 5.10: The Four Profile Comparison on Open Shaft Cavity: cooling load KW distribution over suggested cavity depth. (Source: Author, 2015)

Double skin facade in Figure 5.10 for a glass outer skin performance at the cavity depth of 1.5 meter with an open shaft option preforms with 10%. On the other hand, concrete outer skin performs at its best on the recommend cavity depth of useful cavity depth of

1.0 meter 37% reduction. It seems that a pattern for similar performance for aluminum, treated wood and concrete on 1.5 & 0.5 meter cavity depth. Additionally, glass and concrete performs similarly with some minor differences. The same pattern noticed for Treated wooden and aluminum skins, aluminum is a widely used material production in the UAE construction industry; it is lightweight plus reflects heat away and diffuses light if surface was at a certain standards. Even as a shading system is also a common practice to reduce building thermal gain on the external building curtain wall glazing where treated wooden banks used as decorative building element. The baseline case has a cooling load of 597.05 (KW), which is resembled 60 -75 % as mentioned in chapter 2 of the total energy consumption of a building. Comparing the above scenario taking into consideration a condition of having an open shaft depth cavity. Considering the internal skin as single glaze building enveloped with an outer skin of glass or treated wood or aluminum or concrete where all show variable of reductions as each performs differently whether it is the 0.5 meters cavity depth, 1 meter, or 1.5 meters. (Jeff et al, 2010).

In earlier studies such as Shameri et al., 2011, it been noticed to that 1.0 meter showed the best reduction in consumption rate. It is also clear that this study also shows that buildings with a second skin can perform better with a 1.0 meter cavity at the given condition of an open shaft cavity. Concrete performs better than glass with a 20kw difference. The reason behind this is that concrete properties as a material absorbs light where glass has a reflective property that may add to the thermal gain of the building envelop, resulting in minor increase in cooling load requirement.

It was surprising that treated wood and aluminum functioned similarly. This explained by the fact that the aluminum reflected part of the heat gain of the exterior environment back into the internal envelope resulting in the increase in the cooling load requirement as for the treated wood. The properties for the material could radiate absorbed heat back to the internal envelope, which could lead to the seen increase. It concluded certain materials should be avoided if the target is to gain the maximum cooling load reduction. Also the measurement of the cavity plays a major role in trapping and releasing the heat between the two skins for instance 1.5 meters trapped the heat for the glass external skin with as little as 10% reduction compared with other materials at different cavity depths. This shows that each material can perform better with a stack effect if its own properties taken into consideration as well as the conditions added to the equation such as the status of the cavity.

Figure 5.11: The Four Profile Comparison on Open Shaft Cavity: cooling load KW distribution over suggested cavity depth. (Source: Author, 2015)

When the outer skin materials have a condition of a closed shaft at the 3rd floor Figure 5.11 (almost mid-way through the building vertical height), the performance of 1.0 and 1.5 cavity depths have a similar pattern. Each of the materials: Treated wooden banks, concrete or even the aluminum have i.e. at cavity depth of 1.00 meter reduction reading are (■443.63, ■443.63, ■444.63) and 1.5 meter cavity depth reduction reading are: (■430.85, ■429.85, ■431.85). On the other end, glass with only 501.81 (KW) for the 1.5 meter cavity depth and increase to 506.10 (KW) at the 1.0 meter cavity depth. Nevertheless, when it comes to 0.5 meter of cavity depth; glass and concrete function similarly to each other and the same goes for the aluminum and treated wooden banks. This option was to test a certain measurement to release a partial pressure of the heat, which transferred from the cavity back into the envelope of the building whether it is a reflection of a material or if a thermal heat mass trapped because of the depth of the cavity. As the simulation ran it was noticed that by closing the mid of the cavity it did not add to the reduction of the cooling load any benefits. On the contrary, in certain cases, the reduction from the baseline case was less in most scenario. Looking at the 1.0 meter, scenario treated wood, aluminum and concrete skins performed similarly with minor differences where glass performed relatively poorly in the comparison. The results explained by the fact that reducing the cavity height of the area actually reduced the ability for the heat to be ventilated out of the cavity.

1.5 meters was not much in difference with the results, actually the pattern was very similar. The stack effect theory helped the 0.5 meters cavity depth to perform much and almost the same as the open shaft cavity results for the 1 meter depth with both glass and concrete having the same exact cooling load reduction and aluminum and treated wood skin having similar reductions.

Figure 5.12: The Four Profile Comparison on Open Shaft Cavity: cooling load KW distribution over suggested cavity depth. (Source: Author, 2015)

Looking at the scenarios when the outer skin materials have a condition of a closed shaft at each floor (Figure 5.12), with better reduction rates results in general. The performance of 1.0 and 1.5 cavity depths have a similar pattern. Each of three materials Treated wooden banks, concrete, or even the aluminum have very close assessment for reduction. On the other end, glass aches badly with only 484.15 (KW) for the 1.5 meter cavity depth and increase to 494.51 (KW) at the 1.0 meter cavity depth. Nevertheless, when it comes to 0.5 meter of cavity depth; glass and concrete function similarly to each other and the same goes for the aluminum and treated wooden banks. With this option, the intention was to help the skins and condition to be closing at each floor, as it acts as a self-shading. The intention to help a reduction in the cooling load, and benefits some of the light penetration properties with certain materials. By closing each floor, results show better simulation results although it was initially it also looked similar to the one that was closed at the third floor but been noticed that the glass skins for this one performed better especially at the 1.5 and 1 meter depth of cavity. This could be because of the separators performed as an additional barrier for heat with the glass skin where with the others it did not matter much. Some of the reflection properties in the aluminum added to the heat of the envelope, which increased the cooling load minimally almost 1 (KW) difference only.

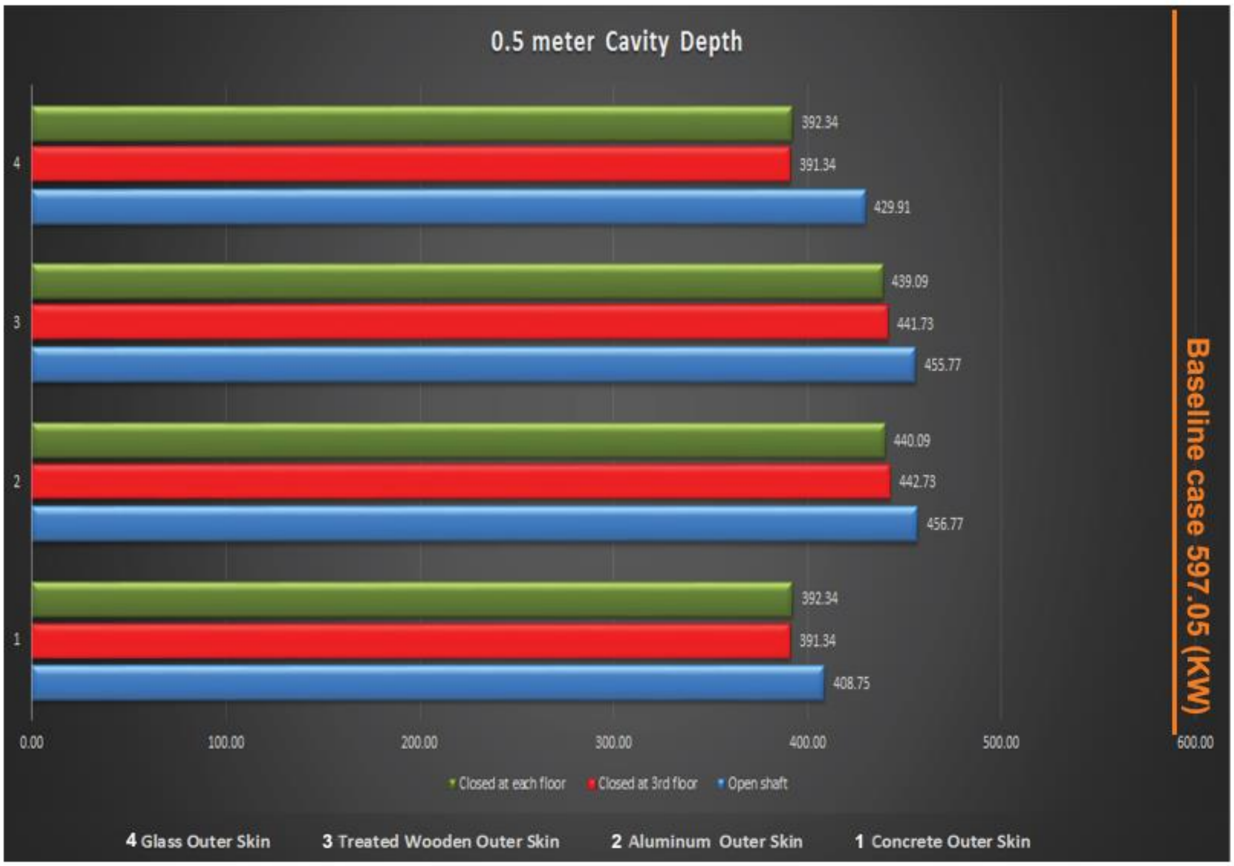

Figure 5.13: The Four Profile Comparison on Open Shaft Cavity: cooling load KW distribution over 0.5 meter cavity depth. (Source: Author, 2015)

Looking at 0.5 meter cavity depth from a perspective towards reducing cooling load, it is clear that glass as an outer skin and concrete outer skin, function similarly with minor differences with both conditions having a closed cavity at the 3rd level for the maximum reduction possible. Great amount of information extracted and inclined simply by looking into Figure 5.13.

In all cases, open shaft condition for all the materials do not contribute better to the reduction in cooling load. However, in certain scenarios, either the land limitation or the neighboring buildings and surroundings do not allow for higher cavity depth 0.5 meters.

A suggested design for any of the materials specially if concrete or glass are taken into consideration as they both perform closely on the condition when cavity is closed at the third floor or closed at each of the floors. Daylight penetration on the other end, may have a different impact, especially when it comes to concrete, as the reduction also happens in the lux levels. This reduction will cause the users to switch to artificial lighting that may lead to an increase in the total energy consumption, keeping this in mind will put the glass outer skin in the top choices and daylight penetration will be achieved with better lighting distribution with this option of profile.

Figure 5.14: The Four Profile Comparison on Open Shaft Cavity: cooling load KW distribution over 1.0 meter cavity depth. (Source: Author, 2015)

In earlier introduced study suggested that 1.0 meter of cavity depth Shameri et al, (2013), is the most feasible depth used within a desert climatic condition. Figure 5.14 clearly shows a variation in patterns as well as the materials reduction rates.

Concrete as an external skin with a reduction performance to 371.39 (KW), seem to be the big winner here. Understanding that such a material composite is not sustainable, comes in line to front glass as an external skin with an open shaft condition for both is the better option with 393.34 (KW) for a cooling load reduction at 1.0 meter cavity depth. This is the ideal cavity depth by this study for the double skin facade system with both glass and concrete performs as the greatest reduction achieved with this study in an open shaft condition looking at the other materials although they have also achieved a reduction in the cooling load. It is best to determine the right option of material for the outer skin by measuring the effect of the daylight penetration and distribution as well as the aesthetic value for each building design.

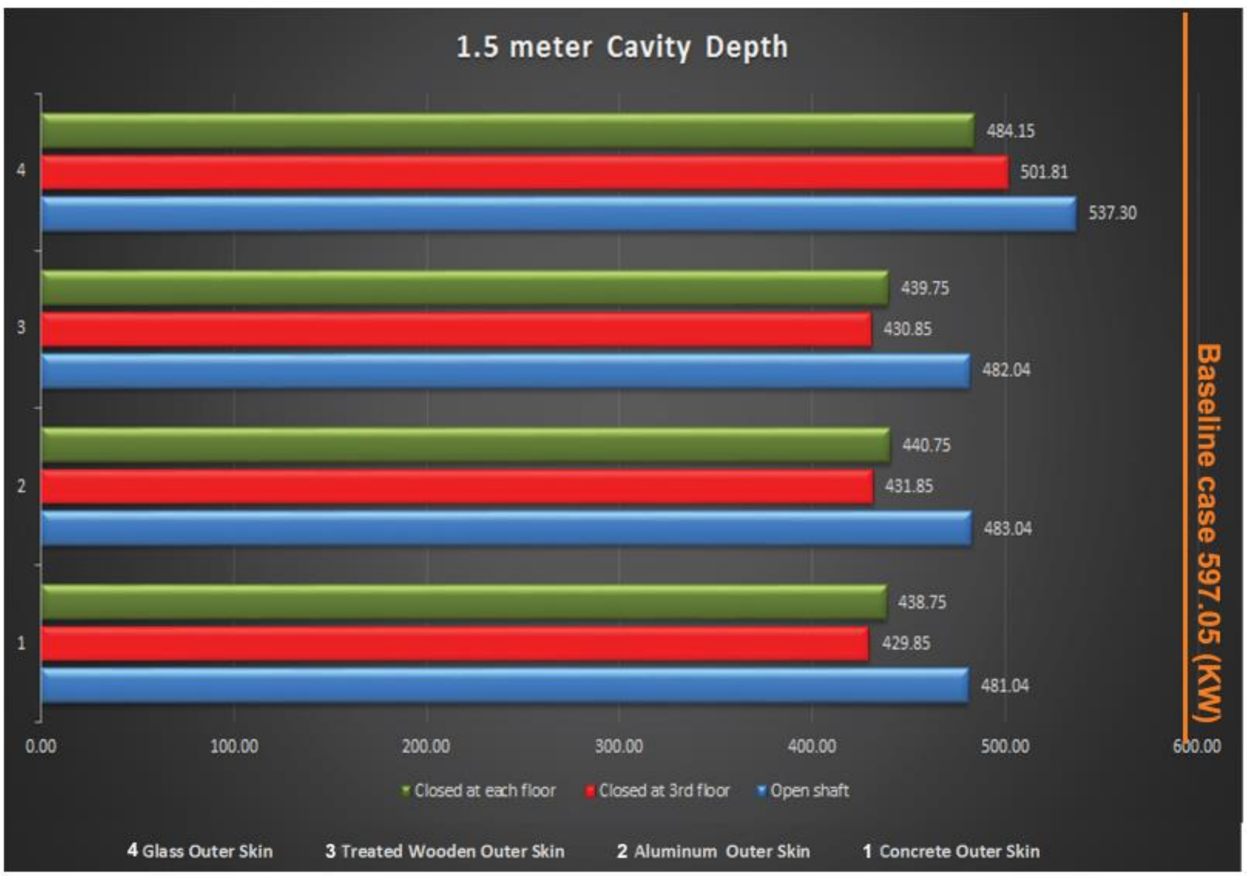

Figure 5.15: The Four Profile Comparison on the 3 Cavity Conditions: cooling load KW distribution over 1.5 meter cavity depth. (Source: Author, 2015)

Another commonly used cavity depth, 1.5 meter consider it being an expensive one and structurally difficulty to be handled at certain scenarios. The treated wooden banks is considered to be the most efficient in terms of reduction of the cooling load with 430.85

(KW) per floor area but with condition to be closed mid-way through the skin cavity. Aluminum functions similarly with some minor difference. However, as a material it is very fixable in terms of shape and color. At the cavity depth of 1.5, Figure 5.15 offers a great deal of additional information that can help understand the behavior of each material and conditions. Such cavity depth recommended, when the space between two skins utilized for additional options such as a walkway. When the cavity condition is to be closed at each floor, as this will take away the circulation from the internal part of the building envelope and where it can be utilized by having a double skin facade with a glass skin Jeff et al (2010). This not only helps a better penetration but also adds aesthetic value, and better yet, the daylight penetration.

In order to reach a recommendation about these suggested profiles. The top option can be concrete not only for reduction in cooling load but also compared to its performance in daylighting at 1.0 meter cavity depth as per Figure 5.3. It however, has poor daylight penetration and occupants and users will need to switch to artificial lighting during operational hours. However, glass as an external skin with a reduction of 393.34 (KW), have almost 34 % of reduction in cooling load better yet, compared to daylight penetration it has the greatest values. Although glare is a major issue at the depth of 1.0 meter as per Figure 5.9, this issue solved by adding blinds or internal louvers to decrease the effect of glare.

In the following chapter, the sum up of the findings will be elaborated further.

Chapter | 6

Conclusion

6.1 Overview

This chapter presents a summary of study of the findings on how different ways of double skin facades can be beneficial for cooling reduction, its occupants, and users. This includes important aspects such as good indoor air quality. In which having balanced temperature throughout the year and access to sufficient amount of daylight with great reduction in glare for most cases, where double skin facades are not only beneficial in reduction of cooling load but also when compared to conventional glass facades they perform very well in the desert climatic conditions.

6.2 Conclusion

The need for buildings with better energy consumption have a direct relationship with their external skin style and material know to be used by the construction industry. When it comes to the rights of future generation, a building owner should consider reducing the energy consumption to help protect our environment. Additionally, the study presented a performance analysis of reduction in cooling load and daylighting penetration with certain results that considers certain materials as per some recommended methods. Moreover, the four scenarios of materials for the double-skin facade under hot climate weather conditions were tested through simulation software ‘DesignBuilder’. Resulted simulation presented; the potential for positive and negative effects of this kindly building construction style and its implementation, when double skin facades taking place in a commercial office building, as a default common practice of construction. Furthermore, throughout ‘DesignBuilder’ each scenario simulated and discussed in the literature review, gave clear idea on what kind of reduction would consequences. In summary, the discussion of the benefits of Double Skin Facades in relation to its effect on the indoor surroundings has assessed the probable positive influence when it comes to daylighting penetration. Having a balanced temperature on yearly basis and access to sufficient amount of daylight considered an important aspect for building today and the construction industry thus making double skin facades a vital option for building owners and future operators.

The simulation results for Double Skin Facades in relation to its effect and compared to conventional glass facades, preforming under multiple conditions and scenarios. DFS systems usage gives the hope to attain solutions that solves several problems such as the following but not limited to it:

- Reduction of energy consumption (usage of cooling load).
- Assurance that daylighting penetration is still achievable.

Several combination between Double Skin Facades smart building systems, can completely tweak the results of the best skin used, skin type, orientation and skin materials.

Recommendation of tested and suggested profiles concludes the comparison throughout several graphical inputs to show concrete external skin that had a massive reduction in cooling load. Furthermore, adding to the comparison, the performance in daylighting at 1.0-meter cavity depth, where the occupants and users will not need to switch to artificial lighting during operational hours (8:00 am – 6:00 pm),; becomes the optimum results achieved by this study. Although, the external skin with had reach to a reduction of 34% in cooling load during the simulation , also showed great values in daylight penetration performance. Unfortunately, the simulation results also show glare, which is a major issue for commercial office building. However, this issue should be solved easily by adding internal louvers to decrease the effect of glare.

The study compare benefits and examine the technical aspects of DSF technology, by inspecting the effect of changing materials used and answering the following research questions mentioned in the introduction above:

- The study shows that by using DSF as construction style it will have an effect on the energy consumption of the building.
- The study shows concrete as an external skin had most impact in terms of energy reduction.
- The study shows 1.0-meter cavity depth performs better in for DSF in desert climatic condition and help reduce energy usage.

- The study shows that by using a midway separator to divide the cavity as configuration performs better in most of the suggested scenarios and helped reducing the energy usage.

6.3. Recommendations for future research

This paper is a discussion of retrofit design solutions of four skin materials and glass envelope where a single glaze façade was built 20 years back. Available materials could be tested to check the best practice and feasibility. In addition, the results from the computer software 'DesignBuilder' obtained the information of the third floor; which can be addressed if further look taken at the seventh floor and on the ground floor.

When it comes to concrete, it seemed to be an option that is open for arguments. If it were replaced by sustainable concrete or by translucent concrete it would allow a better daylighting penetration. As for the cavity depth, it's divided into three intervals 0.5, 1.0, and 1.5. While double skin facades buildings may reach up to 2.5 meters cavity depth. Concluding, this study is a presentation of performance analysis, where it demonstrates the reduction in cooling load and daylighting penetration with convinced results that considers materials and recommendations of methods given.

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