Comparison of Different Facades for High-rise Buildings in Hot and Cold Climates in terms of Material Usage

Salih Ben-Nail Abu Sief

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Approval of the Institute of Graduate Studies and Research:

Prof. Dr. Elvan Yilmaz
Director

I certify that this thesis satisfies the requirements as a thesis for the degree of Master of Science in Architecture.

Prof. Dr. Ozgur Dinçyürek
Chair, Department of Architecture

We certify that we have read this thesis and that in our opinion it is fully adequate in scope and quality as a thesis for the degree of Master of Science in Architecture.

Asst. Prof. Dr. Halil Zafer Alibaba
Supervisor

Examining Committee

1. Asst. Prof. Dr. Halil Zafer Alibaba.

2. Asst. Prof. Dr. Ercan Hoskara.

3. Asst. Prof. Dr. Nazife Ozay.

ABSTRACT

Use of “facade” in tall buildings is mainly with materials like glass and aluminum. Other suitable materials are also being used in construction but are not feasible in all climate conditions. Thus, in this study, I am going to present a detailed comparative analysis of glass and aluminum, estimation of their fixing methods, construction and composition of facade materials in architectures’ aspect. In this era, tall buildings constructed with facade materials having renewable energy converter to allow “Green Building” effect. Thus, this study will have great contribution and would be helpful in constructing large buildings as it consists on best utilization of different materials.

In addition, it also comprises description and recommendation that will assist to improve healthy environment with facade material. Facade considered as the first aesthetical feature on a building that differentiates one building from another in terms of strength and flexibility.

Keywords: Construction, Material, Climate, Facade, Building Environment and Green Building.

ÖZ

Yapılara ait cephelerde genel olarak cam ve alüminyum malzemesi kullanılır. İnşaatta kullanılabilecek diğer malzemeler de vardır; ancak bu malzemeler her mevsime uygun değildir. Bu nedenle, bu çalışma dahilinde; cam ve alüminyum, uygulama yöntemleri, cephe kompozisyonu ve inşaasının dahil olduğu ayrıntılı bir karşılaştırmalı analiz sunacağım. Son dönemlerde, cephe malzemesi ile kaplanmış yüksek yapılar "Çevre Dostu Yapı" etkisi yaratmak için geri dönüştürülebilir enerji konvertörleri ile donatılmaktadırlar. Böylelikle, bu çalışma yüksek yapıların inşaasına büyük bir katkıda bulunacaktır. Çünkü her farklı malzemenin kullanımı sırasında ortaya çıkabilecek avantajlar ve dezavantajlar mevcuttur.

Ayrıca, bu çalışma'da cephe malzemelerinin dahil olduğu daha temiz bir çevre için-birçok açıklama ve öneri sunmaktadır. Bir yapıyı esneklik ve sağlamlık açısından diğer yapılardan farklı kılan ilk estetik özelliğin cephe olduğu kabul edilmektedir.

Anahtar Kelimeler: Yapı Malzemesi, İklim, Cephe, Yapılmış Çevre ve Çevre Dostu Yapı.

TO MY FAMILY

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABELS

Chapter 1

INTRODUCTION

1.1 Background

Facade materials are being used in the construction of tall buildings for decades, especially in well most developed countries like Turkey, Kuwait, Bahrain and America, where the climate situation is always on extreme in all seasons. The most useable construction materials by architectures to construct tall buildings include glass, aluminum and steel, which is handier to provide people more desirable, feasible and well developed living standard within these buildings.

The addition of aluminum material provides more protection in the construction of the building facade. Application of glass in glazing facades brought great change and increased the environmental and aesthetic efficiency and also it is quite economical in price as well. A famous architecture Le Corbusier proved this fact by using glass and steel combine in designing of building facades.

The use of Glass material has been adopted since centuries. It was not just used as transparent material, but also as a hard and resistant material in various projects. On the other hand, aluminum is another type of taller building Facade materials that have a unique specification such as durability, strength and recyclability. In addition, aluminum has also been widely applied as building facades in all over the world for 50 years.

History revealed that the use of glass and steel materials for soaring building's facade is not a new innovation. For illustration, Empire state is one of the remarkable and a famous soaring building situated in New York and was completed about 82 years ago. This building is integrated with glass and stainless steel materials that emphasize the art Deco style of the building and acknowledged as the tallest building in the world for almost 40 years (Giord, 2007).

Moreover, in the past and even current several problems has been identified with tall buildings in different climates because of material integration of facades. Furthermore, there are various soaring building materials all around the world which is although not favorable in both hot and cold climates whole year due to their efficiency indexes.

High-rise buildings should be capable to maintain and preserve all climatic conditions most importantly in aspects of structural stability and architectural aesthetic. Wrong and unusual usage of material may simply lead to waste of resources or cause harmful environmental effects such as global warming.

Several researchers have found out that climatic issues have been ignored and neglected while planning to construct a tall building facade in some specific region. For example, single skin facade is implemented on building facade, instead of double skin facades in cold climate region, in this way facade may tend to be less efficient towards weather which is one of the essential functions of material to be complied with.

1.2 Objective of the Study

The aim of this research is to make a comparative study that investigates the strength and efficiency of glass and aluminum in terms of materials usage and effect in large building facades. It also identifies that which is the most efficient material for hot and cold climate regions, as well as the material which has a better fixing method of building facade.

1.3 Significance of the Study

This research will serve as a guide to both architects and architects' industry to get a better solution in cold and hot climate. It will provide a prior knowledge to take a decision on the best quality facade materials with maximum efficiency for building facade construction.

1.4 Research Methodology

In order to collect data for our study, Qualitative research was used as an effective tool and methodology and to accumulate relevant data, we travelled to Ankara, Turkey for on-site observation, photographic documentation, we interviewed with weighted building engineers, did an intensive literature survey and also reviewed scholarly articles online about other countries such as Kuwait, Norway and Alaska to determine the facade construction materials and to compare the efficiency and cost for glass and aluminum facades in different climates. The intensive search of materials through a literature survey helped in the analysis and determination of the material behavior based on different hot and cold climate regions.

1.5 Scope and Limitations

Scope and limitations of our study contain on most well-known constraint Time. Scope based on efficiency of facade construction materials (glass and aluminum) for heighted buildings in hot and cold climate conditions, while limitation of the study is associated with time.

1.6 Problem Statement

The consideration of appropriate building facade materials is a major factor that is often undermined in the building sectors which relatively decreases the functionality and the overall productivity of buildings.

By concluding the significance, it can be considered that the overall comfort level of the intended space can be increased. However, only few countries in the globe have fully adopted the integration of appropriate construction Facade materials such as steel, aluminum and glass in their entire building facade to achieve the effectiveness of the material. Therefore, the efficiency of building materials considers as one of the major factors in the generation of resources and economic growth as well as the comfort of the occupants. Architects and engineers should properly implement these materials for the maximization of adequate efficiency of tall buildings.

1.7 Literature Review

Helen, Wei Pan & Pieter. D (2012) has performed exploratory research to find out elements that should consider while making decision about facade selection for multi-story buildings. Material, performance, quality and appearance of the facade are the aspects that should be taken into account while making decision. It was concluded that in research, Architects have a leading role in the decision making process of facade while the client and the planner make the final decision.

The article written by Jason Meyer & Fawcett (2007), in their article they are stating that Alaska center for Energy and Power (ACEP) and Cold Weather Housing Research Office after several observations has led to conclusion that some conditions are necessary for ground source heat pump(GSHP) usage in cold weather, in order to analyze the performance of ground source heat pump (GSHP) in Alaska a case was studied, it provided comprehensive guide and update knowledge of those customers who live in cold climate regions such as Alaska and interested in installation. It was not a biased research, nor to promote ground source heat pump (GSHP) neither to discourage as a method of space heating. However, this research didn’t present any site-specific or project-specific information that could be useful in proposing designing or sizing a ground source heat pump (GSHP) system.

Wurms, (2007) has put combined efforts to conclude that building temperature should be in range of 18°C to 28°C minimum and maximum respectively and the comfortable temperature range is considered in between 18°C to 28°C. It is difficult to meet all standard requirements of suitable temperature. Clothing is most important and typically used to maintain comfort. Several researches confirmed that if the room temperature is above than 27°C, mental performance will decrease and work rate will also decline. In the light of the above discussed fact, we can say that it’s a bad deal to invest in suitable air-conditioning equipment.

Mario Guarracino, (2005) has analyzed previous researches and argued that as in the situation when different people has different set of demand on their workplace, in that case solutions vary system to system or system should be flexible to meet requirement of different people and the environment.

Yeang, (1996) investigated the same issue and conclude that highly glazed facades are the major sources of energy consumption in hot and dry environment.

Wurms, (2007) reveals that the traditional technique is being used to manage micro-climate in the environment, and this technique involves the use of specific types of glazing. This process actually adjusts the amount of insulation to balance the temperature. Previous researches indicate that use of solar protective glazing and shading devices on windows reduces the amount of saved energy or didn't save at all that could be utilized to maintain the temperature in cold weather, such as use of solar film on windows does not save the energy.

Bilgen, (1994) presented findings as use of films prevent energy to reach inside, it increased the cooling load because this energy could be used in increasing the temperature of a room in winters. Their findings confirmed that shading devices increases the heating load and solar protective devices like exterior shades also work as energy loser in cold climate such as in Florida.

Billow, (2012) devoted himself to his studies and presented his views as air and warmth should pass through interior and exterior facades of building to ensure the comfort of the user.

Facades facilitate in various aspects, if facades doesn't work as certain then the additional facade layer is used for this purpose. Facade should also meet interior requirement. The facade should be able to resist local influences and able to manage them in an energy efficient manner.

Cetiner & Özkan (2005) has studied to analyze climatic data and discover the physiological impact on solar radiation system and air temperature and humidity to develop strategies to manage climate comfort problems. The data gathered for analysis from Beijing, China. The climate of Beijing has cold winters and hot and humid weather in summers. Winter is the longest season of climate. Cetiner & Özkan (2005) presented guidelines as site and design of the building should provide protection against cold winds high solar radiation. Whereas the summer season is shorter, but to cope up with high air temperature and humidity the natural ventilation, thermal mass/night cooling and solar shading system should be used. By using passive strategy 44% of energy can be saved in winters.

Sherwood, (1985) investigated the solution of the condensation issue of heightened building in hot climate.

The high efficiency insulation system for wood-frame residential construction that later become the standard for in several regions of country in last recent years. This system includes rigid foam wall sheathing, foil-backed foam wall sheathing and wall studs. This system provides walls with higher “R” values and lower perm values. The higher “R” value works in colder surface with great condensation potential while lower perm protect against moisture movement.

Burch & Tread (1978) in their study pointed out that in present situation condensation occurs as a thin film on cold surfaces and has minimum effects on the rate of heat transfer because it don’t moist the insulation. However, wet insulation can be observed on walls after prolonged periods of condensation. In some situations, condensation moves toward bottom of the wall cavity, saturate the sole plate also decrease the few inches of insulation. Moisture also reduced the thermal resistance of wood and wood products.

Oesterle, (2011) has analyzed that a significant decrease in pressure is actually the result of shallow cavity that was about less than 40 cm among facade skin, and the medium cavity doesn’t resist to the air flow. In Double skin facade exterior facade applies principal to integral elements in air intake openings in addition to air extract openings.

Chapter 2

THEORATICAL BACKGROUND OF THE STUDY AND ANALYSIS OF FACADE MATERIAL

2.1 Historical Development of Facade

It’s important to describe the history of facade to better analyze its significance and functionality in building. Before digging in deep we will explore the meaning of term “Facade”. The term Facade is a French word derived from the Italian word Faccia meaning face. It is used to describe the exterior sides of a building often, but not limited to the front (http://en.wikipedia.org/wiki/Facadism).

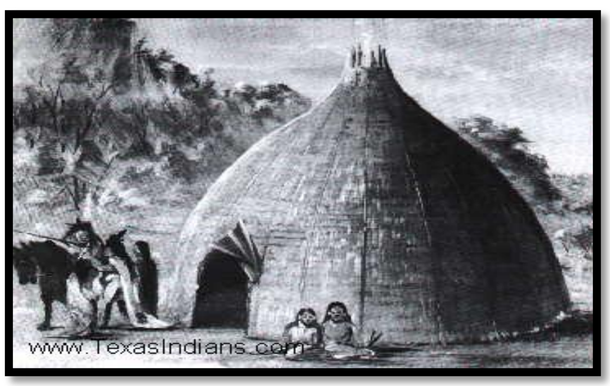

Figure 2.1: History of Facade
(www.digital.library.okstate.edu.com)

In order to find the history of Facade, the history of buildings is necessary to discuss here because it is an integral part of the building. A building cannot exist without Facade.

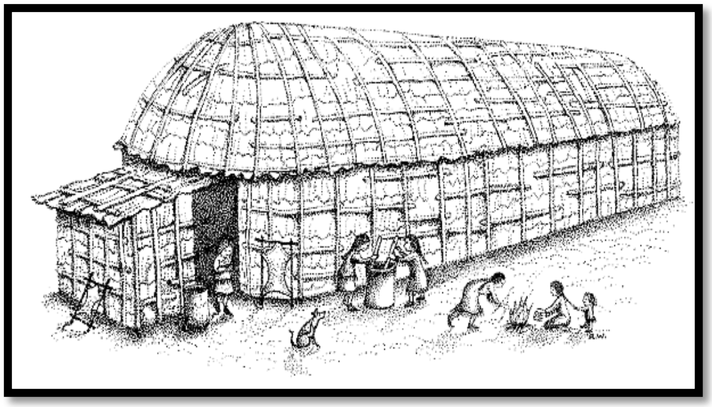

Figure 2.2: The simple facade materials
(www.native-languages.com)

The facades were made up of simple materials and were light and short. With the passage of time facades adopt innovations and composite styles and architecture introduced in building of facades. This modification and development made them able to meet requirements of this era architecture. Because of this journey of innovation and development, it can be observed that heavy facades in high-rise building are in used these days.

Figure 2.3: Building Facade Location
(www.fexaslndians.com)

History also narrates that earlier facades of a building were changed only in their sizes. The above showed picture giving a view to building of Native American Indian, which were built of local material. The Oklahoma society was practicing various construction styles that were not similar to nature but termed as traditional of early history.

2.2 Functions of Facades

Facade has essential role in performance and presentation of any building, its integral part of any building and bearing different responsibilities at a same time. In presentation aspect, facade plays important role such as clients, sponsors or even road passers position the image of building and organization in their mind and perceive their level of professionalism and how much they care their assets. Facade should be strong enough to prevent the forces of nature that act or might influence with change in climate on building such as wind, gravity, seismic loading and extreme temperatures need to be evaluated and resisted. With the responsibility of all functions facade should be smart enough to act in intelligent way such as should possess ability to save energy that can be utilized when needed. Beside architectural aspect there is another leading responsibility of facade in this 21st century, in this era when security has got first priority, facade should able to protect and prevent any uncertain situation of violent attacks or minimize the damages.

According to Billow, it is necessary to further specialized the components and planning processes of facades to increased differentiation in their functionalities. That is why climate engineering and Facade planning has become an essential part of the planning process and influence the performance of the Facade (Billow, 2012)

The major functionality of building facades are as following:

2.2.1 Buffer and Regulating Functions

Buffer zones are created with double glass skins in order to protect from the sun and to avoid direct exposure of the work space to the sun. It also deters the sound and chaos to reach inside the room of German building codes. To control airing in work place it is required to manage substantial amount of inner glass screen. I relate the Living Quarters through the shared outdoor corridors (Billow, 2012).

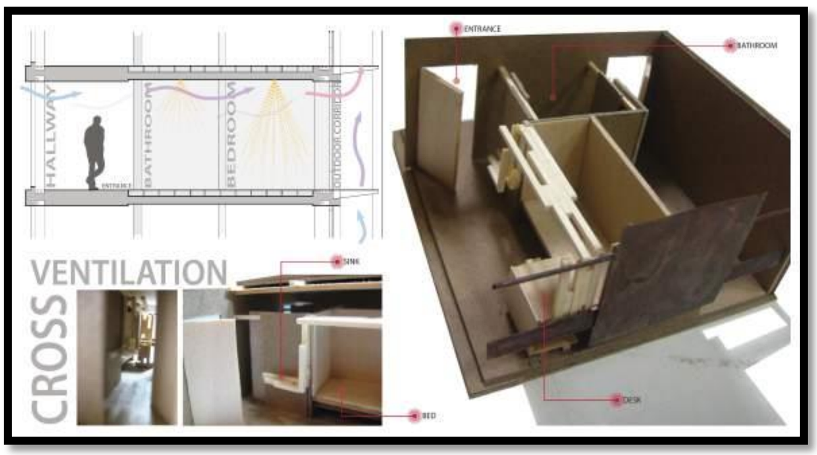

Figure 2.4: Buffer and Regulating Functions
(www.vr3qz.wordpress.com)

2.2.2 Visual Functions

Facade are considered as aesthetic signature of any building, they offer different and important advantages, they are aesthetic as well as responsible for diverse functions, such as main appearance is necessary because it stands out and in term of functionality it works as solar protection. It is linked with climate development.

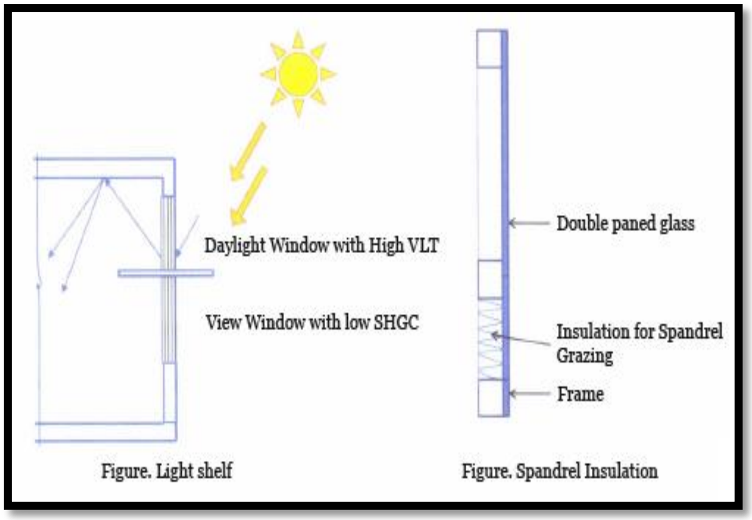

Figure 2.5: Visual Functions
(www.teriin.org/index.phpoption.com)

In Hospital Manuela Gonzalez, Torre de Especial utilized his idea and introduced Exquisite embroidery in building construction. Mexico is considered as highly airy city, where a 2500 meter square crystal facade composed of three dimensional architectural modules with photo catalytic pollution-fighting technology is been used in developing high-rise buildings. This decorative architectural module actually decreases the air pollution in urban areas (Hadden & Lee, 2002).

The above discussed modules are highly decorative modules use "ornament", which act as a synergy between design form and molecular technology. The undulating shapes maximize the surface area of active coating to diffuse light, air turbulence and pollution. These modules contain superfine titanium dioxide a pollution-fighting technology that activate through ambient daylight (Hadden & Lee, 2002).

By organizing location, pollution can be avoided. Modules usually break down and neutralize (nitrogen oxides and volatile organic compound) directly when generated. There is a fundamental grid of mathematics that generates a pattern in irregular form but consist of only two constituents. It forms a periodic interconnection that strongly resemble to sponges or corals. Furthermore the modular system develops a situation of visual aimlessness. Traditionally built structures pro solve require about 370e essential tunes to perform in a better way as invisible criteria to avoid air pollution (David Hadden & Lee, 2002).

2.2.3 Hygienic Function

A comparative study of German Federal Ministry of Research and Technology (1998) proved that in offices employees feel more comfortable in naturally ventilated rooms as compared to air-conditioned spaces. To work in naturally ventilated room increased their productivity at workplace. So features of room plays significant role in hygiene. If room is naturally ventilated contaminations such as dust, gases, CO_2, odors, viruses and bacteria will not stay in room (Chikaher & Hirst, 2007).

Figure 2.6: Facade of the Library and Cultural Building
(www.thecelosiasofbigshovels.com)

2.2.4 Acoustic Functions

Acoustic function involves protection from noise pollution, and sound can be transmitted from outside, inside the building and can also be self-created sound or their reflections.

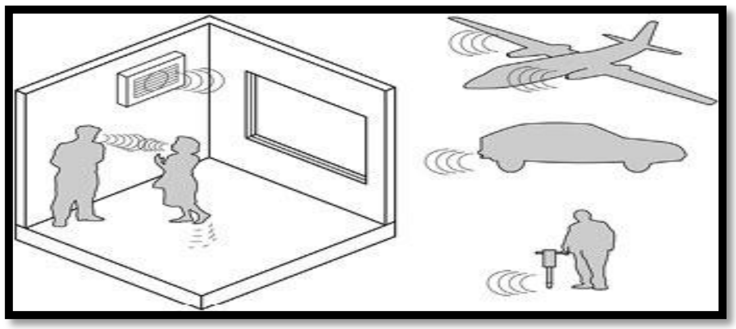

Figure 2.7: Sound Development Inside and Outside Of Building
(http://www.thecelosiasofbigshovels.com)

It is one of the functions of facade that it resists against such noises and let those reaches inside.

Sometimes it becomes difficult to manage all the functions at once. Such as acoustic function requires suspend the entire ceiling but from the aspect of thermal function it reduces thermal storage capacity. Thus, in planning all requirements must be considered at all stages to accommodate them at each level (ASHRAE, 2004).

2.3 Definition of High-Rise Building Facades

Facade of any building defines the architectural appearance of the building, provides the views to the inside and outside of the building, also absorbs push and pull forces from the wind loads, bears its own weight as well as of other components of building.

The building's Facade allows sunlight to penetrate into the building while provided protection from sun at the same time. It also resists against rainwater and also handles humidity. Facade of a building provides insulation against heat, against cold and against noise and also can facilitate energy generation (Northwestern Material Industries, 1999).

As people judge any book with its cover page, similarly outlook of the building develops image of building in people mind. It's the first thing people observe when they enter in to building and the last thing when they exit. As a result, an architect needs to be careful and vigilant in the designing of the building Facade.

2.4 The Characteristics of High-Rise Buildings

Invention of elevators, advanced technology and reliable material made possible development of tall buildings. In early stages the material used for the structural system of high-rise buildings were mostly reinforced concrete and steel. In North American style of first tall was constructed with basic composition of materials such as steel frame and residential.

In this research it is been discovered that how tall buildings are situate long in highly hot and cold climatic environment, by deep analysis and evaluation of material we will be able to identify their sustainable advantages and disadvantages. Architects consider several aspect when chose material for building (Carbary, 2009).

2.5 High -Rise Buildings in Hot Climates

Large structures in terms of design and structural are challenging to geo-technical engineers and architects of buildings. This research will focus on materials used in tall buildings that will facilitate the architects. It also emerges serious and different negative challenges, this study is solution oriented, so solutions will also presented later for both hot and cold climate (Gyula,2003).

General purpose of all buildings is to provide shelter to its occupants from outdoor unfavorable conditions like cold, heat or raining. The building must meet certain requirements for which it is designed such as desirable indoor climatic condition. Concerns arise on sources of energy and environmental issues, these are the factors to with a building has to cope and to manage in favorable manner. A large number of researches have been carried out and indicate that if an architect has understanding of climate characteristics they can chose appropriate material, suitable design for the building. Architects investigate issues that occupants might face in different climates and also identify their requirement in every climate, this research lead those to present solutions and suggestion to avoid issues and develop flaw less design. This practice is called climatic design and in this research it is our primary focus (Gyula, 2003).

It has become common nowadays to design tall in other words tall buildings with facades having large glazing areas. This trend is emerged in many countries around the globe including the Middle East region. The use of large glazing areas offers many architectural, energy and even psychological advantages.

Main purpose of using large glazing is they are light in weight and fast-to-build construction materials which are very suitable for tall buildings. They are also flexible materials allow creative and unique building forms.

From the architectural point of view, Glass is the most suitable construction building material for tall and modern looking buildings. They connect the inside to outside environment and provide ‘‘life’’ to the building. Occupants from inside can take spectacular exterior views. They also have direct connection to the outside weather conditions and time of day. It provides significant psychological advantages to the occupants that can increase their productivity (Gyula, 2003).

In Hot and humid countries like Malaysia usually require air conditioning but for residential buildings they depend on thermal comfort by minimizing the use of air conditions. The prospect for not using air conditioning in rural area is relatively high when good designs are adopted (Brookes, 1996).

2.6 Material Selection for High-Rise Building Design

It’s most important decision to select material for tall building. This decision involves broad vision and consideration of several aspects of material and influencers that will effect on building. Engineers evaluate the performance of material in both hot and cold climate. They analyze requirement of functions. Structured technology plays vital role in construction of tall building (Goncalves, 2007).

2.7 Selection of Facade Material for High-Rise Building in Hot Climate

This section is the most important part of this research as it covered the process of selecting right material for developing building in hot climate. If architect don’t choose the right material the whole construction will be fail. Thus, mentioned below are few points that should be considered during selecting material.

2.7.1 Glass Facade Material for Hot Climate

Glass is good material for the construction of tall building facade, it gives view of outside. Rays of sun strike on the glass but can't reach inside directly. In this way it provides protection against excessive sunlight. Use of Dynamic Facades provides direct protection against the solar radiation. The external parts of the building are the best sources to intercept heat or cold before it's been introduced to the buildings (Haldimann, Luible, & Overend, 2008).

2.7.2 Glass Facade types (PVB, EVA) Material for Hot Climates

Poly Vinyl Butyral (PVB) and Ethyl Vinyl Acetate (EVA) are most common types of Glass facades. Laminated glass is made up of two or more layers of glass with one or more "interlayer's" of polymeric material bonded between the glass layers. Laminated glass offers several advantages. Such as safety and security is most popular than shattering on impact. Laminated glass forms an interlayer to reduce the safety risk in case of shattering of glass pieces. The inner bed also gives a way to apply several other technologies and benefits, such as colouring, sound dampening, resistance to fire, ultraviolet filtering, and other technologies that can be built in or with the inter layer (Narelle, 2005).

2.7.3 Aluminum Facade Material for Hot Climate

Aluminum cladding involves thin coating of aluminum on the exterior side of Facade. Cladding in general is the application of one type of substance or material over a different material that creates effective protective layer on the underlying material. The use of aluminum creates high quality cladding especially with architectural products like windows and doors.

The process of aluminum cladding is known as "Extrusion". In this process aluminum acts as a skin over another metal. This process requires fusion of two metals by using high-pressure equipment, or use of sort of die to create the adhesion. In both processes, extreme and constant temperatures of heat are necessary to create the necessary bond between them.

A number of building materials are clad with aluminum. For example in some cased wood windows are clad with aluminum to give strength to window sashes. The outer skin protects wood from weather damages and extends its life. Use of aluminum in cladding make cleaning task easier (http://www.singularbuilding.com/facades-engineering).

2.7.4 Double Skin Glass Facade Material in Hot Climate

Double skin glass facades are composed of two glass skins and a large cavity in between. The middle cavity functions basically act as a thermal buffer zone that reduces heat losses and provides passive heat gains from solar energy, it also provide an opening to outside for ventilation. It ensures natural form of ventilation and night-time cooling of the building resultant reduction in energy consumption that needed for running air conditioning system.

The further advantages of the double skin glass facades are the application of effective solar shading in the cavity and the easy ventilation, which causes the air to circulate and convective heat to lose resulting passive ventilation and convection reduces the temperature of the air in the cavity (Alibaba, & Ozdeniz, 2011).

2.8 Selection of Facade Material for High-Rise Building in Cold Climate

Literature review, research and analysis of statistic affirm physiological impact of solar radiation system, air temperature and humidity. It identifies design strategies for each climate to ensure comfort and mitigate problems for such type of study Beijing, China is finest place because there winters are very cold and summer always be full of humidity.

In Beijing, winter is the longest season so building are designed accordingly, the material used in construction protects against cold winds and maximize the solar radiation. While summer season is short there but high temperature and humidity requires cooling which can be provided by natural ventilation, thermal mass/night cooling and solar shading. By using passive strategy 44% of energy is being saved in Beijing (Cetiner & Özkan, 2005).

Micro-climate can be modified through detailed site analysis, site planning and landscape design. By reducing the heating and cooling loads of adjacent buildings relieve can be provided to outdoor spaces throughout the year. In Beijing Courtyards are being used traditionally for neighborhood and building design that act in responsive manner in any climate (http://www.buildingscience.com, 2011, Controlling Cold-Weather Condensation).

2.8.1 Aluminum Facade Material for Cold Climate

Nowadays ability to be self-sufficient for energy has become one of the key criteria to evaluate the sustainable character of buildings. Certification schemes are being developed in many countries to evaluate the energy performance.

Figure 2.8: Contribution-to-Energy-Performance
(www.Energy-Performancebigshovels.com)

It has become complex issue to keep in balance the amount of thermal energy, and there is no any harmonized methodology to assess thermal performance. There are some constituents that influence the thermal process such as building functionality and design, climate zone, season and orientation.

In most of the Intelligent Facades, aluminum system is incorporated that decreased energy consumption in buildings by up to 50%. Interaction with exterior environment is key feature of such type of buildings and because of this feature energy demand for heating. Cooling, ventilation and lighting have largely reduced. It can be implemented by numerous techniques and processes include photovoltaic, optimized glazing systems, intelligent ventilation mechanisms and appropriate light and shade management. Design of glaze and windows has contribution in optimization of building’s thermal energy balance (Watson, 2000).

In cold climates, heat losses should be minimized, while solar gains should be maximized. In order to attain such targets large insulated double or triple glazed surfaces with high solar gains will be used in the highly exposed areas. Maximizing the transparent areas of windows through the use of slender frames can also help to optimize the solar gain. Aluminum profiles can increase the transparent areas of windows by up to 20% as compared to other materials.

The use of insulated aluminum shutter in cold season minimizes heat losses at night. On the other hand in hot seasons, it is required to minimize solar gain in order to optimize the occupants' thermal comfort or to reduce the air conditioning needs (Watson, 2000).

As a result, in warm regions, colored glazing with low solar gains should adopt shading devices, such as solar blades. However, intelligent designs combined with responsive building behavior can reverse negative contribution. Better energy balance can be achieved by using heating, insulation shading and ventilation according to the weather and the season.

2.8.1.1 Advantages of Aluminum Material for Cold Climate

1. Aluminum combined with an appropriate alloy ensures steel durability.
2. It can be easily utilized in all machining processes, such as rolling, embossing, forging and die-casting.
3. Aluminum structures have considerable insulation properties which secure from air and light activity.
4. Structures designed from aluminum are light, which facilitates assembly and transportation.

5. Aluminum has a natural anti-corrosion layer which efficiently protects.

2.8.2 Glass Facade Material for Cold Climate

There are two common types of Glass facade that particularly used in cold climate, mentioned below is discussion about these types:

2.8.2.1 Heat-insulating glass

Windows and insulations are beneficial for reserving heat. Glazing systems has insulation feature that resist against cold. Glass is an insulating material that gives maximum result at even low temperature.

Energy transfers into and out of the building through transparent component of facade that is glass. A surface perpendicular to the sun can receive a substantial amount of energy that can be utilized by building for heating and lighting purpose (Mario Gonçalves, 1989).

2.8.2.2 Reflection glass

Reflective and tinted glazing's can be effective in warm climates but its use is questionable in cold temperate climates where cooling is often only required during the warm season, sufficient energy reserve can largely reduce internal heat loads (Gratia & Herde, 2007).

2.9 Condensation Problem

Condensation is a natural process by which gas or vapor turn into liquid. Condensation occurs because of a very complex relationship between moisture content of the air, the temperature of both the air and the building. It cannot be controlled if other sources of damp have not been addressed.

2.9.1 Condensation Problem of Tall Building in Hot Climate

A condensation problem in warm, humid climates is different from cold-winter climates. During warm and humid climate water vapor moves onto the walls from outside to inside of building and may condense on colder surfaces. Moisture condenses at temperatures that favor growth of decay organisms. However, indoor humidity can be controlled by effective ventilation that offers an effective way to prevent condensation in walls during the winter. Architects believe that this issue has only one solution that is application of effective vapor retarder (Mei & Woolrich, 1963).

2.9.2 Condensation Problem of High-Rise Building in Cold Climate

In a building condensation can be of two types, a condensation that is visible on surface and another that form condensation on the fabric of building and known as interstitial condensation. The second kind formed in cold weather because water vapors are able to move outward through diffusion from. In cold climate, there is high risk of condensation in area of interior face of the facade.

Condensation within a building can form as visible surface condensation or can form on surfaces within the building fabrics are known as an interstitial condensation.

In cold weather, interstitial condensation is caused because when water vapor inside a building is able to move outward through diffusion from permeable fabric of building. Condensation occurs on smooth surface such as metal sheet, even fibrous or glass wool insulation. A cold condensed surface absorbs heat of vaporization and raises its temperature slightly. Therefore condensation occurs rapidly on a metal frame, and less rapidly on an insulation material. But both can condense a considerable amount of water. Interstitial condensation considered as more damaging to the building than surface condensation. Interstitial condensation can go neglected if building fabric is not designed with function to dry moisture within building. It can trapped and compromise the durability of the building and the safety of the occupants (Yeang, 1996).

2.10 Double Skin Facade Strategies

Strategies need to be developed to achieve long term objectives, so this section consists on the discussion about strategies of double skin facades in developing high-rise buildings:

2.10.1 Double Skin Facade Strategies of Cooling by Focusing on Cavities for Cold Climate.

Movement of air inside the cavity enables the glazed surface and shading element to reduce the thermal load of room and cool it down. It occurs as result of natural convection which raises the air flow. From architectural aspect if any cavity and air input/output sections are limited, ventilation fans can be used to ensure proper circulation of air flow in cavity.

The dynamic behavior of the system which adapts to the external thermal load must also be taken into consideration. For the comfort of building's users, double skin technology reduced the temperature of the innermost glass surface, and glass can be cooled by itself by flow of air circulating in the ventilated cavity (Calgarian, 2007).

2.10.2 Double Skin Facade Strategies of Heating by Focusing on Cavity for Hot Climate

Air velocity and the type of flow inside the cavity depend on two major factors, the depth of the cavity and natural ventilation. Air exchange between environment and cavity depends on the wind pressure on building surface, the stack effect and discharge coefficient of opening (Compagno, 2002).

In an experiments research investigate that the air flow is an extensive description of the function, the air flow of the cavity is correlated with constructional parameters. When the cavity between the facade skins is relatively shallow (less than 40 cm) significant pressure losses are likely to occur. Otherwise, the intermediate space offers no major resistance to the air flow. Exterior facade openings claims that in a Double Skin Facade the principles applying to inbuilt the elements in air –intake openings, also apply to air extract openings (Oesterle, 2001).

2.11 The Utilized Curtain Wall

A glass and aluminum curtain walls are designed and installed as a panel system- and referred as unitized curtain wall system. The unitized curtain walls have the same components as a stick built curtain wall system.

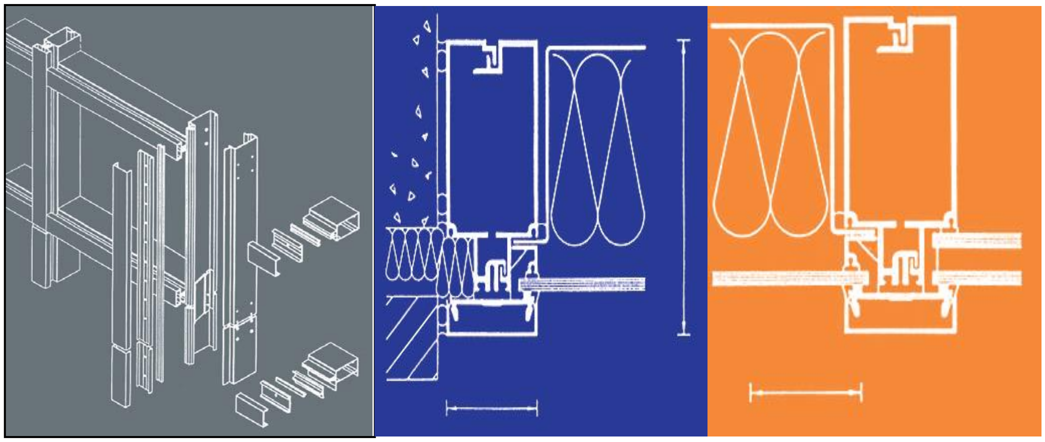

Figure 2.9: Typical Components of Stick Built Curtain Wall System
(www.cwct.co.uk/construction/installation.com)

It consists of aluminum mullions, IGU and spandrel panel that is mounted in a prefabricated aluminum frame. Most of the system components are assembled in a plant under controlled working conditions instead of assembling glass and aluminum curtain wall in the fields. It promotes quality assembly and allows for fabrication a rapid closure of the building **(**Calgarian, 2007).

2.11.1 Curtain Wall Aluminum for Both Cold and Hot Climate

The curtain wall is the most air tight and weather resistant cladding. It acts as an exterior wall system among all options. It provides the architect or designer the facility of curtain wall technology to design a structure with air leakage control, rain penetration control, heat loss (or gain) control and condensation control. Consideration is given to testing of a new curtain wall system design.

Figure 2.10: Facade Curtain Wall Posses
(http://www.steelconstruction.info/Facades_and_interfaces)

The curtain wall is characterized as colored vision and spandrel glass areas that we usually known as a grid of aluminum caps and metal or stone spandrel covers. It can also combined with other types of cladding systems such as precast, brick or stone to create attractive and durable building facades (Brenden, 2006).

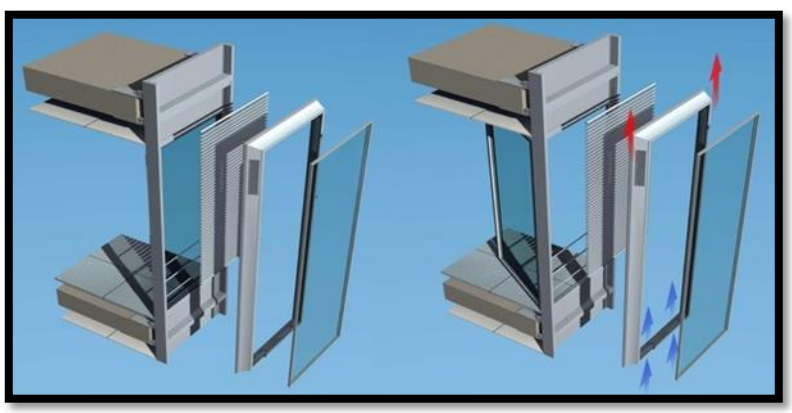

Figure 2.11: The Process of Double Skin Facade Installation
(www.cwct.co.uk/construction/installation.com)

Curtain wall comprises of a complete cladding and exterior wall system with the exception of the indoor finishes. They are generally assembled from aluminum frames, vision glass and spandrel glass (or metal or stone) panels to enclose a building from grade to its roof. It is available in three system types to include the stick built system, the unitized (or panel) system and the structural glazing system (cap less vertical joints). The glass and aluminum curtain wall is designed to resist any wind and earthquake loads as well as to limit air leakage, control vapor diffusion, prevent rain penetration, prevent surface and any cavity condensation. It also limits excessive heat loss or heat gain, and protects against noise and fire (Chew, 2006).

2.11.2 Aluminum Glass on Curtain Wall Systems

When a sealed glazing unit is installed into a curtain wall frame opening, it usually places at the quarter span locations on two setting blocks the EPDM and the other is silicone or neoprene. These support blocks for the IGUs may impede the drainage of rain or melt water. Manufacturers punch a third drain hole in the center of the pressure plate to drain incidental moisture that may have entered into the glazing cavity along the sill between the setting blocks (Matteis, Brando & Mazzolani, 2012).

It is important to make sure that drain holes in the pressure plates are not higher than bottom of the drainage cavity, it can be unobstructed by debris or too much sealant. The glazing cavity that equalizes the pressure must be air sealed from inside. Air sealing is provided by a gasket or a wet seal between the glass and aluminum surface. Further enhancement can be achieved by making compartments in glazing cavity. Compartments can be created by neck of the vertical and horizontal mullions and the corner block (Matteis, Brando, & Mazzolani, 2012).

In Canada, the spandrel cavity of most of the curtain wall system is acting as pressure equalized system. The metal pans perform the task of the air barrier and maintain the wind pressure. Spandrel cavities are usually located at the top and bottom and dry the insulator.

However, research (2) has proved that the size of the drains and vents in the pressure plates should be 6 mm x 30 mm long and 8 mm in diameter, while the holes in the snap caps are adequate for the volume of the glazing cavity, but inadequate for the dynamic (wind gusts) pressure equalization of the spandrel cavity area (www.abcb.gov.au. education-events- publications Training).

The volume of the spandrel cavity is hundred times larger than the glazing cavity, and it is flexible that's why requires larger vent openings to allow pressure equalization with similar effectiveness. It proves that the pressure plate, snap cap drain and vent openings of spandrel cavity should be larger than the drain and vent openings of glazing cavity (Calgarian, 2007).

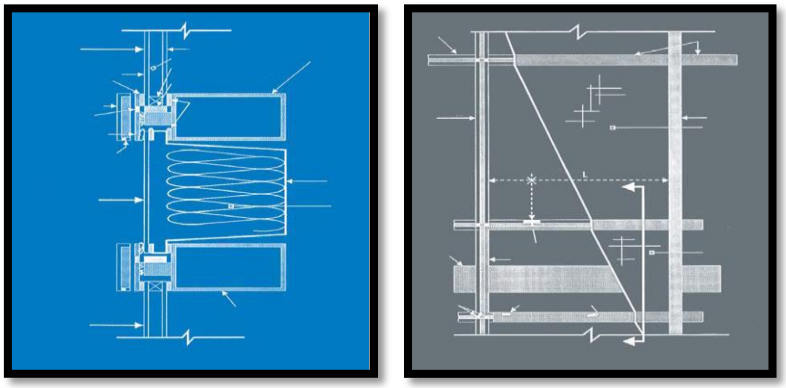

Figure 2.12: Drainage Path within a Typical Curtain Wall
(www.cmhc-schl.gc.ca/curtian wall system.com)

2.12 The Structural Glazing System

Structural glazing curtain wall systems can be observed in several cities of Canada and US. It consists of two or four sided cap less glazing application. In Canada two sided applications are being used with the vertical joints of the cap less International Geographical Union (IGU).

A structural glazing curtain wall system uses the same aluminum mullion components as the stick built curtain wall used, except that the mullion nose (neck) of the verticals that is omitted to create a cap less vertical joint system. The vertical joints between the International Geographical Union (IGU) are sealed and for flush exterior appearance the outside is covered with silicone sealant (Chew, 2006).

The horizontal mullions are constructed with standard pressure plates and caps. In order to hold the International Geographical Union (IGU) against the aluminum of the vertical mullion, the inner light of the International Geographical Union (IGU)should be apart from the aluminum mullion with a gasket or spacer tape, while structural silicone sealant applied between glass and aluminum. When the shop drawings are submitted to a silicone manufacturers, they often warranty an application for twenty years if it is determined than compatibility of all the material will be tested. Silicone sealant is also vaporing permeable (Chew, 2006).

In high humid indoor regions, where the structural silicone are exposed to high humidity during winter, the silicone may require a cap bead of moisture resistant sealant (butyl) to minimize the diffusion of humidity into the structural silicone glazed joints.(Chew, 2006).

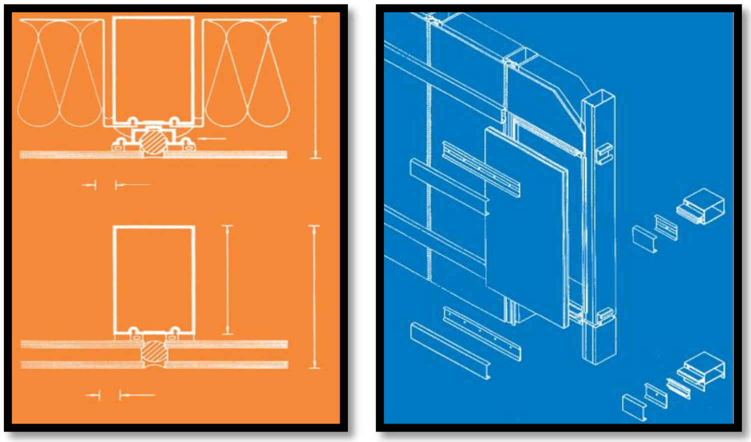

Figure 2.13: Typical Structural Silicone Glazing System
(www.syracuseglass.com)

2.13 Air Leakage Control

To adopt a satisfactory cladding system for cladding, some criteria are essential to meet. This requirement includes air leakage control (the air barrier function), vapor diffusion control (the vapor barrier function – not the same as the air barrier function), heat loss/gain control (insulation and thermal breaks), and rain and melt water penetration control (the rain screen principle). In addition, the curtain wall must accommodate various differential movements. The most critical performance requirement is air leakage control (Divsalar, 2010).

The leakage of air through a curtain wall system in winter may result to excessive ice building in aluminum caps, at parapets or soffits. The ice can grow to develop a safety hazard to persons and property below. Air leakage also causes condensation in glazing cavities to the detriment of the International Geographical Union (IGU) and it can corrode back pans rapidly. Excessive condensation in the glazing cavity can expose an IGU to prolong edge immersion in water.

While sealed unit edges will be able to resist against wetting and drying cycles, immersion in water even for a couple of months, but it can destroy (IGU) in few years (www.Arch3230systemsmc.wordpress.com).

If curtain wall is not tight and sealed properly rain can penetrate inside. When wind and rain intrude into a facade, rain water pushes inside to glazing cavity from outside seal if there is difference among wind pressure and outside glazing cavity pressure.

The rain may accumulate in a cavity ant it won't be noticed until it overflows and appears on the floor of the building, window head or ceiling. Generally we can say that the aluminum curtain wall is airtight. In a typical stick built curtain wall section, the air barrier plane is continuous and structurally supported. The air barrier plane includes the IGU glass, the seal between the glass and the aluminum mullion, the aluminum of the mullion, the seal between the aluminum mullion shoulder and the back pan, the metal liner of the back pan and the seal between the bottom of the metal pan and the shoulder of the mullion below which connects the glass of the sealed unit below. In plan, the same tracing of the air barrier plane will be applied (Divsalar, 2010).

The leakage of air at the glass aluminum joint can be minimized with wet or dry seal. In a unitized system, the mullions are split that include an additional air barrier joint between the half mullions. These joints are usually hidden and inaccessible once assembled (Divsalar, 2010).

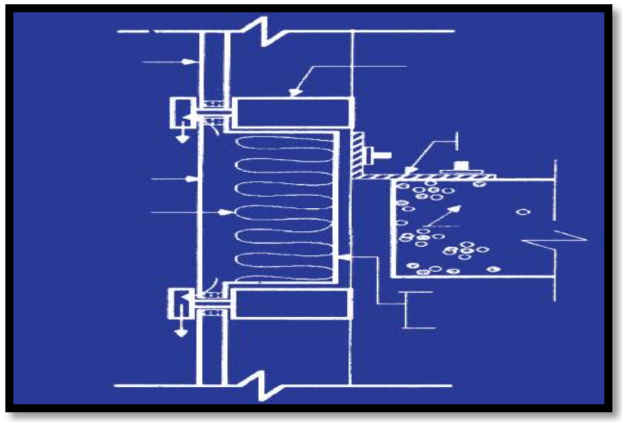

Figure 2.14: Air Vapor Barrier Location
(www.buildingscience.com)

2.14 Rain Penetration Control

Similar to wall system, the curtain wall system also must prevent the penetration of rain or melt water into the building. Glass, aluminum, fibrous insulation and sealants are the components that don’t have ability to absorb or release even smallest amount of rain water, while some types of insulators can absorb the moisture, but it is very little amount of moisture that enters from back pan area. The most of the materials used in curtain wall are corrosion resistant, so water cannot damage the system materials, but seals of IGU may damage if it get wet for long time (Ballast, 2007).

To enhance the rain penetration control of a glass and aluminum curtain wall system, the rain screen principle is applied. The rain screen principle incorporates various features to control:

• Direct entry of rain or melt water.

• Capillary action,

• Surface and cavity drainage.

• Pressure equalization of the glazing cavities.

The stick built system resist to penetrate direct entry of rain and melt water by outside seal or gasket at the glass to cap joints. However minor amount of rain or melt water can reach inside through the head, jamb, sill gasket or seal of vision glass that can be channelized on sideways and downwards through jamb cavity to sill glazing cavity (Ballast, 2007).

In stick built system, resistance to the direct entry of rain and melt water penetration is provided by the outside seal or gasket at the glass to cap joints. However, should any minor amount of rain or melt water penetrate through the head, jamb or sill gasket or seal of the vision glass, that is channeled sideways and downwards through the jamb cavity to the sill glazing cavity below. The rainwater can be diverted horizontally by the corner to the drain holes in to pressure plates and the curtain wall snap caps to drain outside (Kurniawan, 2006).

2.15 Design of Infill Walls

The facades are designed to also act as a rain screen by creating a cavity behind the facade material that provides wider joints around the perimeter of the cladding panels. Therefore wind pressure equalizes between the cavity and external air so wind driven rain is not enter into cavity thus risk of water ingress through joints is minimized. (www.steelconstruction.info/Facades_and_interfaces: Steel Construction).

To fill the walls of facade glazed curtain walling system is widely used. In highly glazed curtain walling systems triple glazing is often used that allows a gap between two of the glazed sheets that can be incorporated with shading devices. Generally windows are sealed in modern offices so control of ventilation by other means is important. Triple glazing system also offers high level of acoustic attenuation in city center buildings (Giord, 2007).

Modern curtain walling often consists of unitized systems that provide all the building physics and structural functions and also forms the external and internal faces of the facade. The size of the unitized panels is dictated by the floor to floor height and a sensible width for transportation and installation and should be compatible with the planning dimensions of the Facade normally a multiple of 300mm (Giord, 2007).

Figure 2.15: Fully Glazed Curtain Walling System Used in a Multi-Story Steel (www.steelconstruction. Facades_interfaces.com)

2.16 Glazing Support Systems

Modern glazing support systems are consist of attachments of 2 or 4 separate glass panels using stainless steel brackets that known as spiders because of their multiple legs. The attachments to the glass panels are generally made by stainless steel brackets with neoprene gaskets through the glass as shown below. These attachments permit tabulation due to thermal and structural movements so glass has local stress in existing office building columns (Corgnati, Perino & Serra, 2007).

Figure 2.16: Glazing Support System
(www.cmog.org.com)

Glazing support structures has several kinds. The external and internal tubular columns of this system may be inclined. Horizontal tubular or lattice members cross between widely spaced columns (Corgnati, Perino & Serra, 2007).

Chapter 3

ANALYSIS OF CASE STUDIES IN HOT AND COLD CLIMATE

3.1 Methods of the Study

In order to collect the data for our study, “case study” has been chosen as the research tool, as it contains on several data collection methods such as questionnaire, interview and survey as well.

3.1.1 Data Collection Methods

To perform an appropriate and unbiased research it’s essential to acquire real and relevant data for analysis and extract interpretation. In order to present a refined research in this thesis we have collected real facts by deep analysis, and keen review of related literature, taking interviews to the public and the most important and interestingly by observing tall buildings around the world in different climate conditions. This research is carried wide collection and analysis of facts in which observation during a survey of Turkey, an intensive study of tall building, analysis of various material used in facade, particularly in Kuwait, Norway and Alaska playing vital role in leading us to conclude. Functions and requirement of facades are evaluated in both cold and hot climates, Literature study helped to analyze specification, nature, energy efficiency and performance of materials used in facade in different climates.

3.1.2 Observation and Interviews

Observation is one of the tools of data collection. Fundamentally, the observation of the sample population enables to achieve a valid and flexible conclusion. Because of the reason this research provides a major portion to observation and one-to-one interviews in the data collection phase.

During survey of Ankara the construction and installation method, building orientation, site location and commonly used architecture in region have been observed for three buildings. This review directed me to analyze:

- TOKI Building used steel material in the middle of facade.
- Three orange colored tall buildings in Ankara employed aluminum and steel material in double skin facade of balconies.
- The building named “Next level Building” has fully glazed main facade of slope design.

3.2 Case Studies

In this research different buildings were selected for study, and this study will differentiate them in term of their material usage in facade and location.

3.2.1 Case Study 1 (Ankara, Turkey)

Ankara has climate relatively hot in summer and considerably cold in winter that is why we focused on Ankara for this study. In preceding years, concrete is mainly used for construction of facade in the capital of Turkey. However development in material science and introduction of lighter, harder and durable materials decreased the usage of concrete in facade construction largely. These days steel, aluminum and glass have dominated the fields of constructions and became the main material of building the facades. Steel is usually used as trusses behind the glass or aluminum and even around the edges and corners. Both glass and aluminum, in some cases either one, become in front and makes the beautiful view of the building.

Figure 3.1: The Next level Toki Tower type of Glass with Aluminum Supporting (Taken by an Author 2013).

In Ankara, generally the transparent glass and the colored glass are frequently used as compared to reflective glass, each type has its own pros and cons. Currently the double layered glass (between 6-8mm) is also widely adopted for use. On the other hand, in Ankara there are several types of aluminum that are used in facades, commonly the Aluminum sandwich and the ordinary aluminum, that are considered as thinner of all kinds.

During my survey in Ankara I visited two different locations. The first location was a construction site of Orange Tree (Portakalm Çiçeği), it was a tall building on the Farabi Street in Çankaya district, which considered as the highest building in Ankara having thirty three floors and the heights is more than hundred meters (without the antenna).The ground and initial floors are used for offices and the top floors are residential. During my visit I had a beneficial meeting to engineer of building Mr. Irfan Can Kilia. He provides us advantageous information and explained the method and materials used in Facade. The glass and aluminum for construction of facade has been used.

The western and southern sides of the building are both covered with double glazing glass while the other sides are covered with ordinary glass of different thickness. The aluminum sandwich and ordinary aluminum are also used along with glass in the Facade of the building. The use of the aluminum can clearly be seen around the edges and corners of the building since it's strong and doesn't require much attention in terms of cleaning and maintenance.

The second location for research was the "Next level of tall buildings" located in Söğütözü, at the intersection of the Eskişehir and Konya motorways. This project includes two separate tall buildings, The Next Level 1 and TOKI 2. The first tower is the commercial tower that is taller with its twenty two floors and a 100m height. The whole building is covered with glass, and three types of glass are used. The building is designed in a way that it looks like covered with layers of glass, and to achieve this look silicon structural glazing technique is used in each layer of glass.

The northern and southern sides of the tower are wider and two types of glass were used to cover them. Primarily, the double skinned glass was placed at the middle of each side and on the top of them on sides mirror glass was fixed. On the other sides, the transparent glass was used. In contrast, previous building was completely covered with glass. However the material used in both buildings was in accordance with the climate of Ankara. The aluminum and glass have higher resistance against diffusion and erosion and don't break easily with the constant change of weather throughout the year. Moreover, they don't require as much maintenance or renovation.

Figure 3.2: Steel Facades in the Middle Building
(Taken by an author 2013)

The second tower TOKI 2 had a different shape and unique design, this residential tower consists of twenty floors and 85 meters tall. This building has a unique zigzag structure. Usage of glass in this building is less as compared to commercial tower, and only one side that is exposed to the sun is covered with double skinned glass. The rest of the sides have zigzag structure that provides additional space for balconies.

Around the edges of the balconies, a short layer of Aluminum was fixed. Only transparent glass is used in building that gives it magnificent view. In brief, the residential tower didn't require the extensive use of glass in order to provide enough space for the balconies. The glass is only used on the side exposed to Sun to reflect the hot sunlight in summer. That helps to reduce the expenses significantly for this building.

Figure 3.3: Glass Facade with Steel Supporting
(Taken by an Author 2013)

3.2.2 Case Study 2 (Alaska, USA)

In Alaska, four recently built buildings used Aluminum composite material for cladding purpose. Buildings have to resist climate conditions such as snow, ice, and wind. And for this purpose ACM (asbestos-containing material) for aesthetic reason was used, that presents clean and modern image of institutional buildings.

Figure 3.4: Aluminum Cover on the Wall
(www.cmog.com)

Museum of the North Aesthetics played an important role in the field of architect. Joan Soranno's selection ACM (asbestos-containing material) of the exterior contributed new addition to the University of Alaska's Museum of the North that houses Alaskan art, geological, and cultural artifacts. The architects got a specific challenge of creating a landmark building that lure visitors back to the museum and this has dropped attendance precipitously in recent years.

3.2.3 Case Study 3 (Oslo, Norway)

The "Hovfaret 4" is a new commercial building in Oslo, Constructed and owned by the EDB (Economic Development Board) Fellesdata Company. The main attractive features of the building are glass Facades and a partially glazed roof. While a neutral glass used to allow maximum light into the building. Security is the most important requirement of building because the building will house the computer control center for most of the Automated Teller Machines (ATMs) in Norway, and so security is paramount.

The solution that was finally selected was a combination of solar control glass and safety glass. For this project, the architect tried to renovate an exciting building with characters, with aimed to design rounded glass shape of the 'towers'. The widespread use of glass has a large contribution to the overall atmosphere of the Building.

The glass Facades and glass roof allow to pass extensive amounts of light, gives an interior feel of vast open spaces. This building offers a great sense of security in addition to a light and spacious office environment to its occupant. The solar control feature of the glass keeps balance the climatic condition of the building.

3.2.4 Case Study 4 (Kuwait, Kuwait)

It has been observed that Gulf Cooperation Council (GCC) countries procure Aluminum Composite Panel heavily from Local or international market according to their required quantity. These materials are being used for decorative exterior and interior walls and ceilings of any building, that provide safety from corrosion, fire, sound, and heavy rains.

Figure 3.5: Gulf Cooperation Council Countries Procure Aluminum Composite (www.xinghealuminum.com)

When we talk about Gulf Cooperation Council countries hot climate and sand storms comes in mind. Because Gulf Cooperation Council countries has very hot climate and sand storms are usual thing in that region. So they highly need to use an especial kind of material that can overcome heat and can resist against sand storms. Nano coated Aluminum Composite Panels are the solution of such issues, these panels found to be perfect in such regions, they comprise self-cleaning agents that resists against particles stick on the panel, this feature makes it able to resist against sand. Normally sand particles after hitting the building surface gets stick to it and make building dirty and unattractive, but if Nano technology is applied in aluminum composite panels than it resists against particles to stick on the walls and makes it clean for longer period of time.

3.3 Results and Discussions

The overall effort and collection of data was collected to get accurate conclusion. The observations and detail study make possible to examine practical issues. During the survey of Turkey, Data collected by observation will be presented, analyzed, and interpreted under here in form of tables. Onsite surveys play important role to reveal the facade characteristics, made us able to understand building orientation, dimension of space and allow us to gather evidences by taking photographs of interior and exterior site of building.

Since compliance gave relaxation to local yield to redistribute the stress, the buildings, civil engineering structures and quantity surveyor are not considering local stress concentration. Aluminum has its distinguished qualities among metals, aluminum does not rust but it oxidizes.

3.3.1 Comparing Construction Materials for Each Case Study

During this survey we came to know that aluminum and glass is widely used in facade construction, therefore aluminum and glass profile is presented here following to evaluate and compare their feasibility, strength and reuse ability in given climatic effects.

3.3.1.1 Analysis of Different Facade Material's Performance and thier Management in Different Country Climates

To analyze performance of facade material in different climates according to different region, the conducted data has been shown below in Table 1and Table 2 according to regions and management respectively to understand the results clearly:

Table 1: Material versus Country Climate Analysis

Regions	Glass	Aluminum
Ankara, Turkey(Cold)	Very good	Very good
Alaska, USA(Cold)	Good	Very good
Kuwait, Kuwait(Hot)	Good	Very good
Oslo, Norway(Cold)	Very good	Good

Table 2: Material versus Management Analysis

Facade Material	Performance		Management
	Hot Climate	Cold Climate	
Glass	Very good	Very good	High Maintenance Needed
Aluminum	Good	Good	Low Maintenance Needed

After an overall evaluation of the different types of materials performance based on the systematic analysis of each material from different perspective that are tolerance, anchorage function of material and environmental influence.

Table 3: Material versus it's Tolerance, Unitization and Environmental Impact Analysis

Attributes	Aluminum	Glass
Hot	Good	Very Good
Cold	Good	Very Good
Tolerance	Good	Good
Unitized	Yes	Yes
Environmental Influence	Yes	Yes

Every designer has different perspective for the selection of facade materials. In matrix 3 the analytical range of evaluation process is given and its evaluated and different attributes are defined in “Yes” or “No”. In these matrixes “Yes” indicates high suitability while No indicates Low suitability of particular attribute of defined material.

Here the unitized factor is involved because it helps in high buildings and reduces complications. Glass material is used in various building forms and in different stores for several reasons such as it used as structural member to stand in different climates. Structural glazing system considered as well-expressed design from aesthetic perspective of architecture.

On site surveys, observation and deep studies led us to conclude that designs have been chosen after number of evaluations from several aspects, their reliability and feasibility is determined in all possible circumstances infect uncertainties also took in considerations.

Chapter 4

CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

As per decided methodology, on site surveys, interviews and deep study of facade material made us capable to present our point of view and to come up with possible solution. The result of our research affirmed that it is essential to choose appropriate material for facade by keeping climate of specified region in mind. It has proven that Facade has significant role in tall Buildings and facade built with adaptive material that influence the building lifespan and if it doesn't designed well it may also effect building negatively such as cause overheating of building envelop. Buildings constructed with adaptive material as per region climate have better performance and high life span as compared to buildings built without these considerations.

Buildings constructed with inappropriate and unmatched faced material require a reliable alternative solution as per their climate condition. Thus, many buildings are facing this issue in almost the entire world. Environment and tradition is key influencer that impacts the design of tall buildings. Research verified that the Glass is good material and act as prerequisite to achieve modern structure and aesthetics. Glass is well-known, easily available and considered as most efficient material for tall building facade.

The advanced technologies and product such as heat-absorbing glass and reflective coatings on glass are facilitating to overcome high cooling and overheating problem in tall buildings, these are easily available in market.

In hot climates reflective and tinted glazing can be effective. However, their usage is still questionable in cold climates, because cooling is usually needed in hot climate, and natural lighting is one of the reasons of equipment efficiency and contributes to a gradual reduction in internal heat loads. Various types of glass have been produced to adapt and fit the right prospect in hot climates. Toned Float Glass is an ideal way to decrease the extremes in hot regions.

During assessment of Glass for the construction of Facade in all climates it's extracted that Glass is really good option to satisfy the requirement of building in modern era. The requirement not just satisfy with attractive structure, it also involve radiance look to position an outstanding image of building in peoples. Glass facades are widely using now days because they provides a well-ventilated system ,considered as very good insulator and it also tested and proved a feasible material for facade in diverse climates.

This study also reveal that double skin facades also offering number of advantages, it helps to improve acoustic insulation of facade, provides solar protection, allows natural ventilation, increases thermal comfort as well as saves energy. This list of advantages can be achieved by applying a second glass skin.

The whole research, observation and studies show that Double Skin facade is highly recommended for tall buildings. high rise buildings has to face external noise and high pressure wind load, in this scenario a well-designed double skin facade provides natural ventilation to indoor spaces and help to mitigate noise and wind load issues.

4.2 Recommendation for Future Studies

In this research, we aimed to evaluate the glass as construction material of tall building. We investigate several attributes of glass such as its tolerance ability, profiling, safety and feasibility in different climates. This research suggests that future researchers must have a wide world to explore glass material. They should have a great prospect to search research and do experimental analysis of glass. Incorporation of glass with other element can also open a path of new research and study. Future researchers may also investigate application of glass of facade in tall buildings and can present new ideas. The analysis of glass type’s profiles can bring another option to expand the area of research and studies.

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