

**DAYLIGHTING AND THERMAL PERFORMANCE STUDY
FOR CLIMATE RESPONSIVE DESIGN :
THE C.E.O (SHOWCASE) BUILDING, PENANG**

By

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(P-RM 0087/05)**

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MASTER OF SCIENCE IN BUILDING TECHNOLOGY

SCHOOL OF HOUSING, BUILDING AND PLANNING
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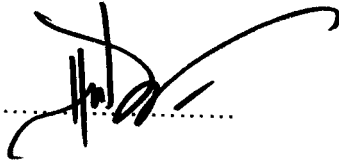
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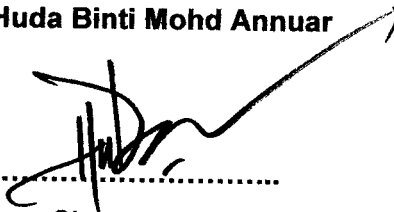
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ACKNOWLEDGEMENT

IN THE NAME OF ALLAH THE MOST GRACIOUS THE MOST MERCIFUL

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DAYLIGHTING AND THERMAL PERFORMANCE STUDY FOR CLIMATE RESPONSIVE DESIGN : THE C.E.O (SHOWCASE) BUILDING, PENANG

ABSTRACT

*C*limate Responsive Design as a whole is an integral part of the environmental framework that is being developed to reduce environment impacts and provide comfort for human well-being. The research aims to study the climate responsive design at the office building especially on the application of *daylighting design and thermal performance* via the shading devices and building envelope's function for the benefit of user's comfort in their internal environment.

The selected case study is the *Showcase units of C.E.O Building* which is located at the roof top garden at Level 8 of Krystal Point Corporate Park, Penang. This building introduces a new concept of 'SoHo' or Small Office Home Office which combines the spaces for home and working under one roof, and therefore the thermal comfort is very essential in its interior. Besides that, the building is also declared to be a Low Energy Office (LEO); however this showcase building has some deficiencies in design and construction to claim the building as a low energy office.

The methodologies of the research are by case study and fieldwork measurement using environmental data equipment. The collected data are analyzed via graphs and computer analysis using SUNTOOL program. Through results, it found out that the fully-glazed wall which without any external shading devices that act as the building envelope affects the daylighting and thermal performances in the interiors. Therefore, the researcher finally comes out with design recommendations which are; i) to reduce height of the glazing, ii) to use highly performance tinted-glass for the glazing wall and iii) to add external shading devices, which hope to improve the daylighting and thermal performances in the building, and thus the design is responsive to its climate.

KAJIAN TERHADAP PENCAHAYAAN AND PERSEMBAHAN TERMA BAGI REKABENTUK YANG BERTINDAKBALAS DENGAN IKLIM : UNIT CONTOH BANGUNAN C.E.O., PULAU PINANG

ABSTRAK

Rekabentuk yang bertindakbalas dengan iklim adalah sebahagian penting dalam rangkakerja alam sekitar yang dibangunkan untuk mengurangkan impak terhadap alam sekitar dan menyediakan keselesaan untuk manusia. Matlamat penyelidikan ini adalah untuk mengkaji rekabentuk yang bertindakbalas dengan iklim terutamanya di dalam penggunaan *pencahayaan dan persembahan terma* melalui fungsi alat penghadang matahari dan salutan bangunan, untuk keselesaan pengguna di dalam persekitaran dalaman mereka.

Kajian kes yang dipilih ialah unit contoh bangunan C.E.O yang terletak di taman bumbung di tingkat 8, Bangunan Krystal Point Corporate Park, Pulau Pinang. Bangunan ini memperkenalkan satu konsep baru iaitu 'SoHo' atau *Small Office Home Office* yang menggabungkan ruang rumah dan kerja di bawah satu bumbung dan maka dengan itu, keselesaan terma bagi ruang dalaman adalah sangat penting. Selain itu, bangunan ini juga mengesahkan bahawa ia adalah 'Low Energy Office' (LEO) atau bangunan pejabat bertenaga rendah, namun hakikatnya unit contoh ini mempunyai kekurangan dalam rekabentuk dan pembinaan untuk membuktikan kesahsiahannya.

Metodologi kajian ini adalah berdasarkan satu kajian rintis dan pengukuran data yang diambil dengan menggunakan beberapa alatan berkaitan. Keputusan penyelidikan mendapati bahawa unit contoh ini direkabentuk dengan dinding kaca-penuh sebagai salutan bangunan ditambah pula dengan tiadanya alat penghadang matahari, telah memberi kesan terhadap pencahayaan dan persembahan terma di ruang dalamnya. Maka dengan itu, penyelidik telah menyediakan beberapa

cadangan iaitu i) mengurangkan ketinggian kaca, ii) menggunakan kaca gelap berkuasa tinggi dan iii) menambah alat penghadang matahari luaran, yang mana diharapkan cadangan-cadangan ini dapat memperbaiki pencahayaan dan persembahan terma bagi bangunan ini, sekaligus dapat membuktikan bahawa rekabentuk ini mampu bertindakbalas dengan baik terhadap iklimnya.

Chapter 1

BACKGROUND

INTRODUCTION

1.1 BACKGROUND STUDY

As a developing country and facing the ups and downs of economics' growth, the developments of building construction are still mushrooming and Malaysia starts introducing many types of building design which are becoming more contemporary and elegant by its physical look. All these contemporary and intelligent buildings are definitely using active design methods to control its indoor environment such as air-conditioning and lighting.

In the same situation however, due to the scenario of *energy crisis* happen currently, as well as the *environmental crisis*, government starts looking for other alternatives to reduce as many as possible the consumption of energy in every effort and also rethinking of the importance of environment inclusive matters in building design and construction and it is towards a sustainable development. The building will then not only look elegantly outside but also environmental-friendly inside. The benefit will not only for present utilization but for future generation as well as to keep healthy living surroundings and save the world's environment.

Towards a sustainable development, building design and construction starts introducing many terms that relates to the environment. The 'Climate Responsive Design' is namely a term that has been so called to explain the design that respond to the local climate and consider the climate factors like air temperature and solar radiation. The aspect of design is moreover to corresponding to the climate and to apply the natural environment elements in the building design or so called passive design. It is to fully utilize the natural daylight and ventilation in the building, not only by

conceptual design but must be physically works on site successfully. As Malaysia is fortunate to receive sunlight all year round, the daylight is an advantage to be utilized. Daylight has a causal relationship with thermal performances in the indoor space in which partly the solar radiations that come from the direct sunlight can cause overheating and it can increase the air-conditioning load.

Apart from it, towards the introduction of energy efficiency design in a way of reducing energy consumption, building design in Malaysia has come out with another term of 'Low Energy' building. The concept of *low energy office (LEO)* derived after the Ministry of Energy, Communication and Water and currently working with Ministry of Housing and Local Government have introduced into the Uniform Building By-Law the Energy Efficient Building Code MS 1525:2001. These are all due to the energy crisis that has been critical currently. Thus, the LEO building is definitely a way or another to support the energy efficiency (EE) in office building and it would be significant and become a reality. The theory of low energy building however similar to the idea of climate responsive design whereby in general, to reduce energy consumption is first to design it with the solution of utilizing natural environment and respond to the local climatic condition, and thus the usage of energy in building can be reduced.

Therefore, this research has come out to perceive the concept of 'Climate Responsive Design' in relation to 'Low Energy' building in one case study. Figure 1.1 illustrates the background study as an overview of the research.

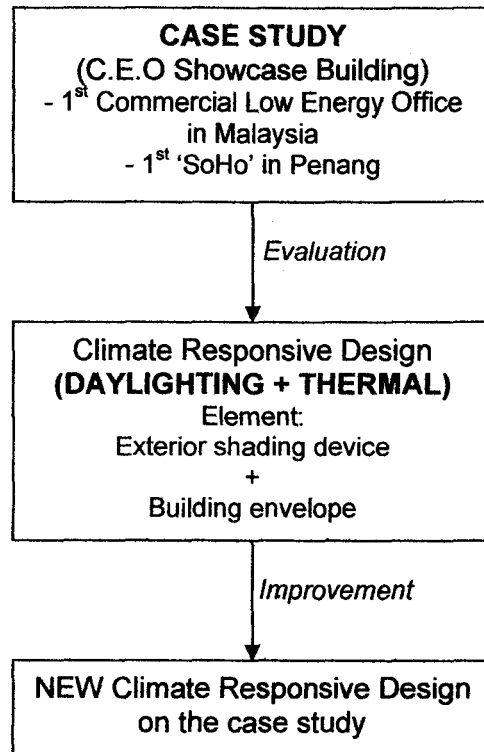


Figure 1.1 Background Study

The case study is the showcase building for the C.E.O building design. The C.E.O is a new office that has a high potential to go far as this building is placed to be the first commercially *low energy office* (LEO) building developed by a private sector in Malaysia. The building is different from the MECW (Ministry of Energy, Communication and Water) building in Putrajaya that has been built as the first LEO building in Malaysia, developed by government as a demonstration building that integrates energy efficient design features.

Besides that, this C.E.O building is also introducing another special feature which is the concept of "SoHo" or *Small office Home office* that is the first one in Penang. It is a new approach in nowadays business scenario where working and living are housed under one roof.

The show unit will be studied and evaluated comprehensively on its *Climate Responsive Design* approach that focusing only on *Daylighting and Thermal*

Performance. The criteria of environmental-friendly living is essential in designing a “SoHo” because it is a place where people expect to work productively and also to live-in in comfort. The application of daylighting is important in every building for safety reason and also for task performance. Besides that, the natural light and good thermal condition are always important in “SoHo” and LEO design to provide ‘comfortable’ living condition with a minimum and meaningful input of artificial lighting.

The building envelope and also the shading design would be the most beneficial features to be studied as these both elements are giving a big impact to the building. Shading device is a superb passive design method that can be applied to filter the direct sunlight to prevent the amount of extensive glare but more prominently to avoid excessive heat gains into the interiors. Whilst, the building envelope has the influence to filter or delay or even totally block the extreme outdoor climatic conditions from coming inside.

Therefore the final output of the research will be the proposal for *improvements*, for a better daylighting design features and thermal performance approach as to portray a good example for the real building. Thus, the C.E.O building will be truly applying the concept of Climate Responsive Design in Daylighting and Thermal Performance and even more vital in achieving its objective as a commercial low energy office and also to fulfill the concept of “SoHo” at the same time.

1.2 PROBLEM STATEMENT

As the C.E.O building introduces a new concept of environmental design and energy efficiency approach, the showcase building should also implementing a genuine design and construction to represent a good example for the clients and buyers to experience the real surrounding, not only to impress them by attractive interior designs and physical outlook.

To meet the two special features, which is the integration of Climate Responsive Design and Low Energy Office concept, this showcase building actually has some deficiencies in its building construction and design. Through observation on the showcase building, below are the deficient of what need to be analyzed further:

1. The application of low energy office concept is not totally efficient.
2. The excessive daylighting into the interior.
3. The function of the passive design method; exterior shading is not applicable.
4. The building envelope does not help reducing the heat coming inside.
5. The comforts of the occupant are not at the optimum level under natural building performance.

1.3 RESEARCH AIM

The research aims to study the Climate Responsive Design of the office building especially on the application of daylighting design and thermal performance via the shading devices and building envelope's function for the benefit of user's comfort in their working and living internal environment.

1.4 OBJECTIVES

Objectives of the study:

1. To analyse the natural building performance *without* the intervention of active building control methods (without air conditioning and artificial lighting) in terms of indoor air temperature and indoor illumination.
2. To analyse the difference and compare the environmental performance in terms of daylight and indoor air temperatures of the units given the same area, volume and outdoor conditions but with a difference in the building envelope and internal shading devices.
3. To analyse the causal relationship between the air temperature and daylight in achieving a comfort sensation in the interior.

1.5 SCOPE OF RESEARCH

The scope of the research is initially to ensure that the study will be more focused and contained. The scopes consist of:

1. Location

The selected case study is the showcase units of C.E.O Building which is located at the roof top garden at Level 8 of Krystal Point Corporate Park, Pulau Pinang.

2. Building Design and Concept

The showcase unit is an office building that applies the concept of 'low energy' design. Architecturally, it is a contemporary with a corporate and elegant looking. The internal layout is to serve the "SoHo" functions. The real project has not been built yet, thus the show unit is partially the indicator to the real building design and construction.

3. Space

The showcase has two units:

1. Unit A (corner unit)
2. Unit B (intermediate unit)

4. Environmental Data

In this research, the environmental data collected are focused on:

1. Indoor air temperatures and immediate outdoor air temperatures
2. Indoor natural illumination and immediate outdoor natural illumination

1.6 HYPOTHESIS OF RESEARCH

Through early readings and observations, the hypotheses of the research are expected as below:

Hypothesis 1 : The building envelope is expected to affect the thermal comfort to the interiors.

Hypothesis 2 : The size of the glazing wall is expected to affect the indoor temperature and illumination.

Hypothesis 3 : The material properties (type) of glazing is expected to produce undesirable heat gain and affects light transmission into the interiors.

Hypothesis 4 : The different orientation of the façade will give different direct sunlight penetration into the interiors.

Hypothesis 5 : No external shading devices are expected to result excessive glare and uncontrolled direct sunlight penetration into the interiors.

Through the hypotheses above, Unit A is expected to be warmer compared to Unit B.

1.7 RESEARCH SIGNIFICANCE

This research is initially significance as a knowledge contribution to the field of academic and also perhaps more importance as a study of technical design for the real life project of C.E.O building, which will be constructed real soon. It would benefits to the owner of the project to explain their primary concept of low energy building with environmental design approach. The implementation of the low energy concept to the showcase building is very much appropriate to show the integrity of the real building.

The research would be a reference to the real project due to some studies made that can improve the technical and construction part of the real project. The research is also benefited to the clients or buyers, for them to understand a new concept of 'C.E.O' and as a worth buying sentiment. Whilst the research is also essential to other parties such as to the professionals in building industries, developers, suppliers as well as students and other individuals for them to aware and understand of the latest trend of building design and construction.

1.8 OVERVIEW OF RESEARCH

This research consists of six (6) chapters in order to fulfill the objectives and answers the hypothesis mentioned earlier. The overviews of the chapters are as below:

- Chapter 1 :** An introduction of the research that explains the background study, problem statements, aim and objectives, scope of research, hypothesis as well as the research significance.
- Chapter 2 :** Literature review that spells out the definition of terms and elaborations related to the climate responsive design, daylight, and related subjects that describe the research's topic.
- Chapter 3 :** Methodology part that enlightens the methods and techniques to

achieve the objective via method of data collection, tools and equipment, time of research, method of analysis and also the limitation of the research.

Chapter 4 : The explanation of the Case Study: CEO Showcase building, that tells about the building background, design concept, space organization and description of its constructions.

Chapter 5 : The analysis part which lays out the analysis of the data collection from the previous chapter. The analysed data have been tabulated; graph-out and some diagrams are shown as results from computer simulation by 'SUNTOOL' program. Then the findings are found out and the hypotheses are also answered via the analysis done.

Chapter 6 : The final part of the research concluded the overall research. It includes the design recommendations as part of the design solutions. The design recommendations are also simulated in 3D modeling to perceive a clearer picture of the suggested proposals.

Figure 2.1 shows the chart of a conceptual working model as to recap the general idea of the research explained above.

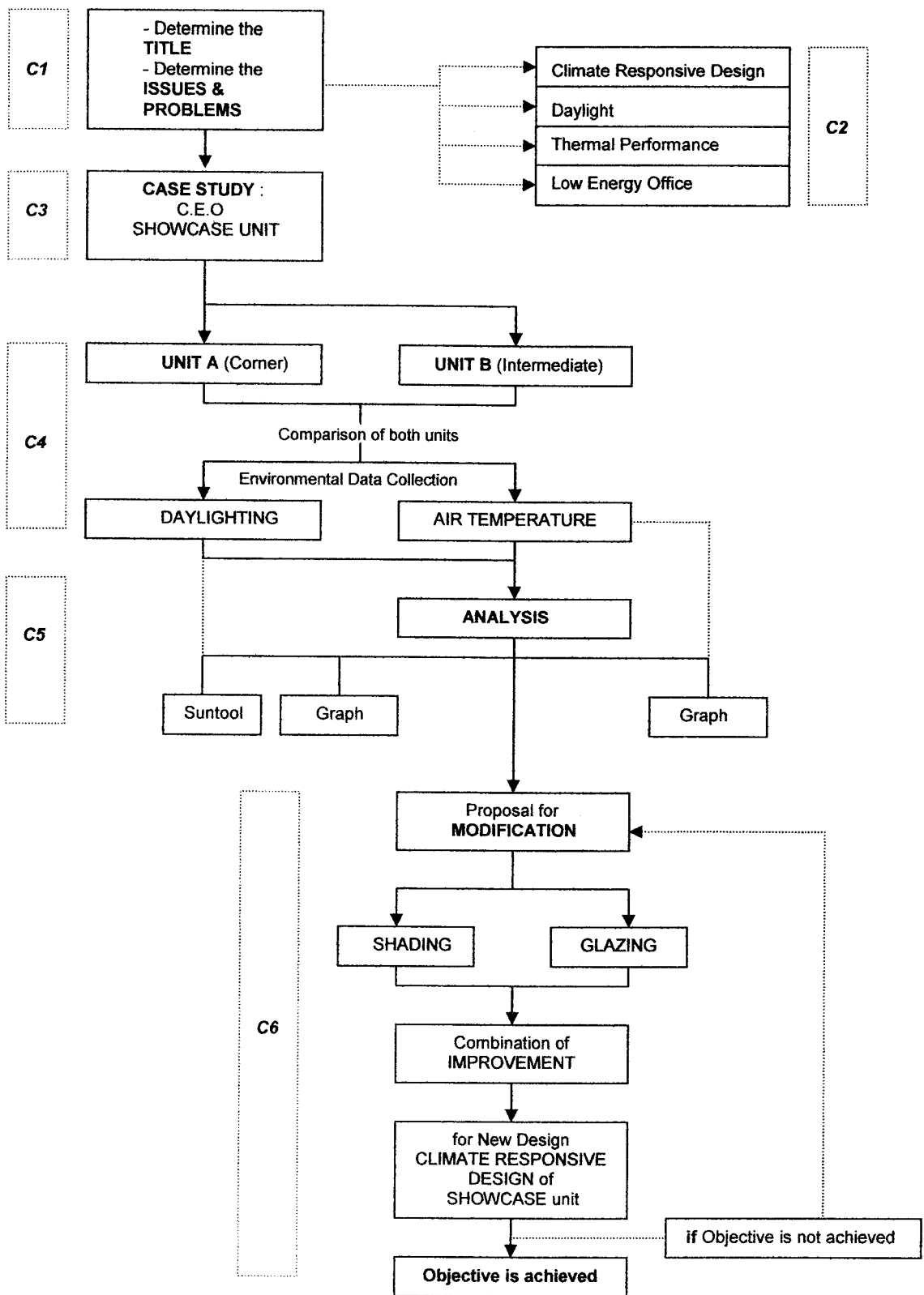


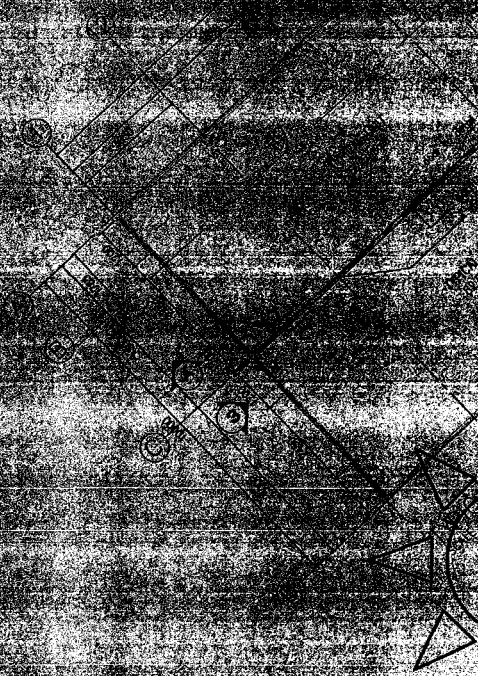
Figure 1.2 Conceptual Working Model Chart

1.9 SUMMARY

Chapter 1 explains the purpose of the research. It clarifies a general layout of the research that consists of a background study, problem statement aim, objectives, scope of study, hypothesis and research significance and also the overview of the overall research.

Chapter 2

DAYLIGHTING AND
THERMAL PERFORMANCE OF
CLIMATE RESPONSIVE BUILDINGS



DAYLIGHTING AND THERMAL PERFORMANCE FOR CLIMATE RESPONSIVE DESIGN

2.1 INTRODUCTION

In this chapter, there are elaboration of key words such as Climate Responsive Design, Daylighting and *etc.* There are further explanations of their terminologies, basic features of subjects related, and a precedent study for a better understanding.

2.2 CLIMATE RESPONSIVE DESIGN

2.2.1 Definition

Climate Responsive Design is “based on the way a building form and structure moderates the indoor climate for human goof and well-being” (Hyde, 2000). Climate Responsive Design is therefore an integral part of the environmental framework that is being developed to reduce negative environmental impacts and provide for human-being.

According to Hyde (2000) it is seen as a subset of environmental design which examines the holistic relationship between the building and environment. The architect’s boundary of responsibility can usefully be drawn around the building and site. It is a way of designing buildings and manipulating the environment within buildings by working with natural forces around the building rather than against them. Thus it concerns itself with climate (or perception of climate) as a major contextual generator, and with safe environments using minimal energy as its target.

2.2.2 Climate Responsive Design Consideration

As mentioned by Hyde (2000), Climate Responsive Design embodies several considerations which are;

- comfort control in warm climates by using the forces inherent in the weather through solar heating, winds and moisture changes
- the air movement generated by heat differential across a building between external sunward and shade sides
- air movement generated by air pressure differential across a building between windward and low pressure areas on the roof form
- air movement generated by air pressure differential across a building by moisture evaporation
- thermal courtyards on the sun side of buildings
- shade pergolas on the shade side of buildings
- greenhouses
- clerestoreys
- vegetation integral to the building

2.2.2.1 Climatic Design Approach

The climatic design approach according to Hyde (2000), place down these elements to look into. The elements are;

1. Ventilation
2. Heating
3. Cooling
4. Daylight
5. Artificial light
6. Shading

2.2.2.2 Climatic Design Features

Climatic design features which are also mentioned by Hyde (2000) are as below;

1. Louvered Windows
2. Shaped Gables
3. Shading Devices
4. Internal Courtyard
5. High ceiling
6. Portico (Porch)
7. Air-wells
8. Atrium

2.2.2.3 Climate Responsive Design Consideration for Hot-Humid Climates

Table 2.1 explained the considerations to design a building for hot-humid climates.

Climate types	Adverse climatic elements	Climate methods	Response strategies
Hot humid	-Rain -Heat high -Humidity -Insulation	-Minimize heat gain -Maximize ventilation -Maximize shading	-Thin plan with axis east-west -Cross-ventilation, high ceiling -Ventilated roof -Window shading all year -Shaded verandah

Table 2.1 Climate types, climate modification strategies and building tactics for hot-humid climates.
(Source: Hyde, 2000)

2.2.3 Climate Responsive Design Analysis

Therefore, climatic analysis needs to be performed to obtain a more comprehensive and convincing review. It is a process that systematically relates to the local climate with building designs that work with nature.

United Nations (1971, cited by Heerwagen 2004) suggested a simple climatic analysis method called the Mahoney Tables. The tables are developed by Carl Mahoney to formulate design recommendations for tropical climate that relieve the occupants from climatic stress. The Mahoney Tables are a simple set of table meant for recording and analysis of climatic information. This method requires no knowledge of mathematics. It is simple to use, the user is led step by step for the climatic data to the type of specifications for a proposed building. Besides simplicity, the Mahoney Tables cover many aspects of building design for the tropics.

Heerwagen (2004) concluded that the Mahoney Tables should provide recommendations on the following subjects;

1. Building layouts
2. Spacing of buildings
3. Air movement provision
4. Size of openings in walls
5. Positions of openings
6. Walls and floor materials
7. Roofs material

2.2.4 Basic Thermal Comfort

Thermal comfort is defined by ASHRAE (2001) 'as that state of mind which expresses satisfaction with the thermal environment'.

Thermal comfort is therefore highly subjective. Not only is it subject to personal preference and acclimatisation, but internal and external temperature sensing is integrated such that the overall sensation may be pleasing or displeasing depending on whether the resulting effect is towards or away from the restoration of deep body temperature. A cold sensation will be pleasing when the body is overheated, but unpleasant when the core is already cold. At the same time, the temperature of the skin is by no means uniform. As well as variations caused by vasoregulation there are variations in different parts of the body which reflect the differences in vasculature and subcutaneous fat. The wearing of clothes also has a marked effect on the level and distribution of skin temperature. Thus, sensation from any particular part of the skin will depend on time, location and clothing, as well as the temperature of the surroundings.

How can we ensure that buildings will be thermally comfortable for their occupants? The obvious answer is to provide the "right" temperature for comfort.

1. One problem with this is that the "right" temperature will vary from person to person and from time to time depending on people's thermal experience.
2. Another problem is that other things effect how hot or cold we feel, in particular the humidity and the air movement in the space, how much clothing people are wearing and their metabolic rate (how hard they are working).

2.2.4.1 Factors of Thermal Comfort

Heerwagen (2004) explained in his book that there are two categories of factors that contribute to the thermal comfort. The factors are;

a. Environmental Factors

For the purposes of building design, comfort is defined negatively as the absence of any form of thermal stress. True comfort conditions will therefore require only minimal activation of any of the regulatory systems described above. It has been shown that bodily heat loss/gain is interdependently related to the following four environmental factors:

- Dry Bulb Temperature (DBT),
- Mean Radiant Temperature (MRT),
- Relative Humidity (RH) and
- Air Movement (Vel).

b Physiological Factors

In addition to environmental factors, there are two physiological factors that affect a person's thermal comfort, each of which vary between individuals and the activities to be performed within any particular space.

- Metabolic Rate (Met)
- Clothing Level (Clo)

2.3 DAYLIGHTING

2.3.1 Definition

As defined by Heerwagen (2004), daylight comes from the sun that diffused from the atmosphere, clouds and particles in the air. It comes in three components;

- a. Sky component (SC)
- b. External reflected component (ERC)
- c. Internal reflected component (IRC)

2.3.1.1 Aspects of Daylighting

Daylighting design exploits use of light from the sky as a whole. This is usually referred to as diffuse light. Light direct from the sun is approximately parallel and casts shadows, diffuse light flows in all directions and does not cast shadows.

Ander (2005) stated in his website's article that daylighting is also the controlled admission of natural light into a space through windows to reduce or eliminate electric lighting.

2.3.2 Benefits & Significance of Daylight

As mentioned by Syed Fadzil (2005), Malaysia receives a lot of daylight all year round and it is encouraged to utilize the daylight as a source for illumination in the interiors. Besides, daylight also benefit in the following subjects according to Ander (2005) in his website's article:

1. Flow of light and modeling of objects within the room

Rooms side-lit by daylight have a predominantly horizontal flow of light near the window which differs from the predominantly downward flow of light which occurs in many electric lighting systems. Most people regard the resulting modeling of objects within a room as more acceptable than that due to artificial downlighting alone.

2. Variation of colour of natural lighting

Sunlight is warmer than overcast sky light which in turn is warmer than light from a clear north sky (the bluest light of all -but not for Malaysia). In general, daylight has no tendency to falsify, there will be the truest colour of rendition.

3. View of the outside world

While any view out of a building might be considered better than none most people prefer to see some natural features such as trees or grass when looking through a window rather than closely adjacent buildings. Various studies have shown that a view of the sky is considered important and that people located far away from windows feel penalized by a lack of sky view as well as lack of daylighting.

4. Variety of lighting with time of day, weather and season

In the 1950's a high proportion of glazing was often used in the external fabric of U.K school buildings. The following quotations give a good impression on this aspect of extensive use of fenestration and daylighting.

“Teaching staff often say that the pleasure of working in the post war school is not only that the light is good but also that the children are continually aware of the changing pattern of the world outside. They see the clouds move that the moon can be seen in the blue sky during the day that the rain comes from heavy billowing groups of clouds and that in fact, the external world is changing in an interesting and fascinating way” (Heerwagen, 2004)

5. *Possible net fuel cost savings for certain building types*

Significant savings in energy costs of commercial buildings can be achieved by increased daylighting which be more important than any related rise in the costs of heating by the artificial lightings and others.

6. *Free source*

Definitely, daylight is free and environmental friendly. It is free at day time.

2.3.3 **Problems of Daylight**

As mentioned by Ander (2005) the potential problems of daylight are due to these factors:

1. *Limited entry to a room*

In deep rooms, artificial lighting will probably be needed throughout the day in areas remote from windows, whether a view of the sky is available or not.

2. *Increased heat gains and losses through glass compared with heavier building fabric*

Overheating due to solar gains or low radiant temperatures and draughts is often associated with large glazing areas. Developments in the use of windows with reflective or absorbing glass and double or triple glazing can in principle greatly reduce such problems.

3. *Availability of daylight*

The availability of daylight are varies with time of day and month of the year. It also fluctuates throughout the day.

4. *Glare due to windows*

Bright windows areas seen from a generally gloomy interior can lead to sensation of glare particularly where the view is of a bright sky.

2.3.3.1 **Glare**

Glare in which there is no significant reduction in the ability to see, it is a result of excessive contrast or of light coming from the wrong direction. The contrast between the bright outside environment viewed through a window and the darkness of the interior spaces create glare.

According to Ismail (2005), there several types of glare:

1. *Disability Glare*

If we are in a building interior looking towards a window which is brightly lit due to sun or skylight we may have difficulty in seeing the details of objects adjacent to the window. This situation is likely to be due to disability glare. The light from a bright source undergoes scattering within the eye. This leads to what is called a ceiling luminance and it is this which is responsible for a reduction of contrast in the object of regard. The effect is more marked for older people whose ocular media are cloudier than those of younger people. And disability glare due to interior lighting is thought to be rare.

2. *Successive Glare*

This may occur when the source of disability glare is removed but vision continues to be affected due to the time required for adaptation of visual system.

3. *Reflected Glare*

This is common experience when using VDU screens.

4. *Veiling Glare*

This is due to reflections from shiny objects near the task or from certain types of paper which reduces the contrast of the type relative to the paper.

5. *Discomfort Glare*

This is due to extremes of luminance within the field of view. The eye muscles which control the pupil are thought to be in a state of oscillation as the eye struggles to adapt to the different luminance which are simultaneously in view.

2.3.4 Daylight Distribution

The entry of sunlight through a window may or may not be desirable and it depends very much on the visual task to be performed. The Figure 2.1 shows the daylight distribution into the room space via a window.

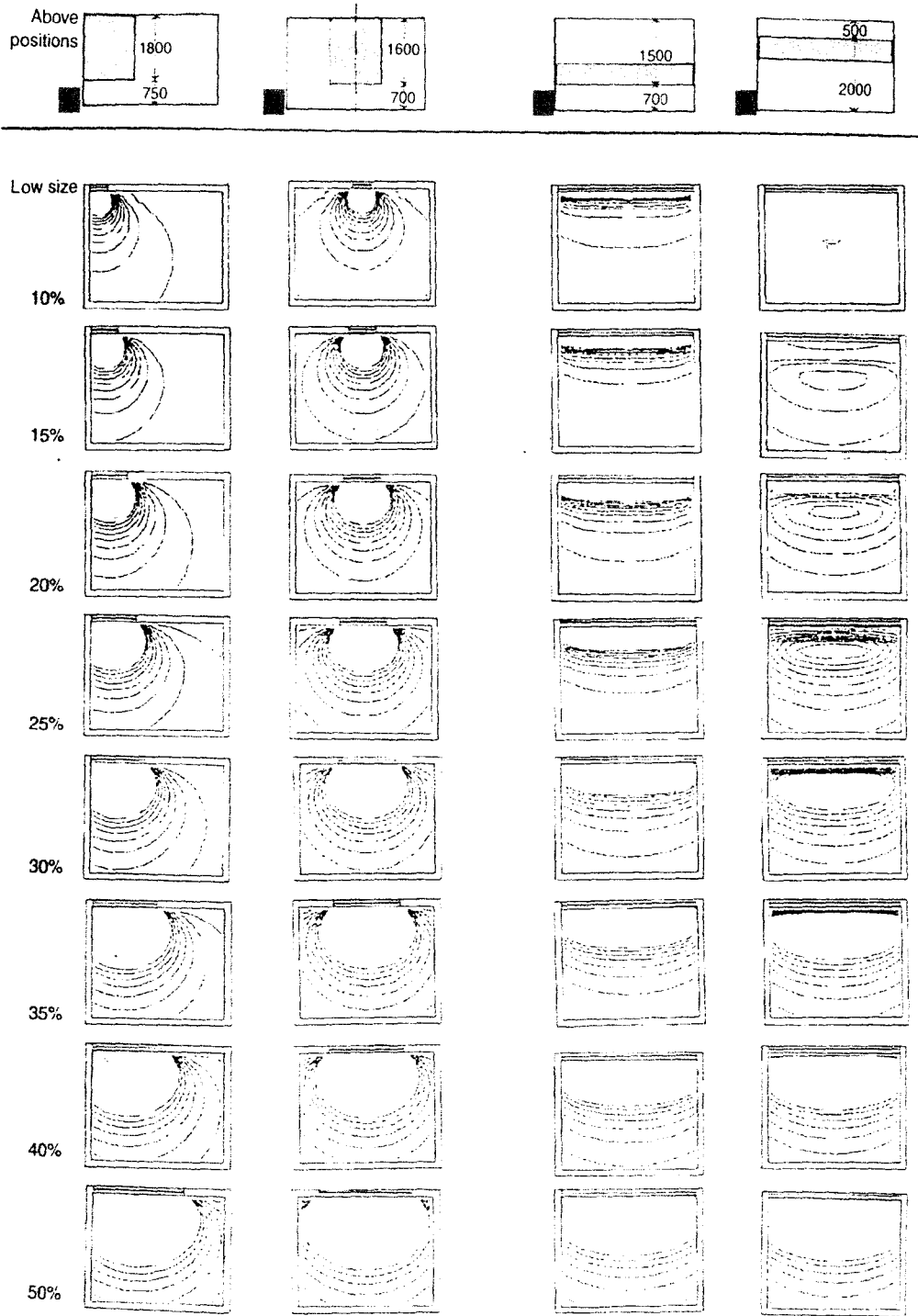


Figure 2.1 Study of Daylight Distribution
(Source: Szokolay, 2004)

Legend for Figure 2.1:

Window A : jamb fixed at side wall, width variable

Window B : centre of window on room centerline, width variable

Window C : full width, sill fixed, height variable

Window D : full width, window head fixed, height variable

Each variant is examined with sizes of 10-50% of wall area

Referring to Figure 2.1, Szokolay (2004) explained that the daylight distribution will be much depending to the *size* of the opening/ window and also *location* of the opening/ windows. Generally, the bigger the size of the opening the more distribution of the daylight is. The daylight will be even fairly distributed into the space if the opening located at the centre of the wall.

2.3.5 Basic Lighting Requirement

Every space need different amount of light level according to its activities and functions. Heerwagen (2004) stated in his book the requirement of light level (lux) according to its space.

Spaces	Required Lighting (LUX)
Lobby	200
Welcoming area	400
Counter	400
Lounge	200
Bedroom	100
Bed area	200
Bathroom	100
Kitchen	200
Preparation area	400
Store	200
Laundry area	200
Administration Office	400

Table 2.2 Lighting (Lux) Requirement Standard
(Source: Heerwagen, 2004)