BUILDING ENERGY EFFICIENCY OF THE CHANCELLOR COMPLEX OF UNIVERSITI TEKNOLOGI PETRONAS

SALEHUDIN BIN MD. SHAARANI

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by

Salehudin Md. Shaarani

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Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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Approved by,

(Dr. Mohd. Faris Khamidi)

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

(SALEHUDIN MD. SHAARANI)

ABSTRACT

The purpose of this study is to investigate and determine the building energy index (BEI) of the Chancellor Hall in Universiti Teknologi PETRONAS (UTP) and the performance of the envelope to prevent heat gain into the building. This was done by doing an on-site assessment to acquire an actual performance data. The findings from the research were compared to the optimal values set by the Malaysian Ministry of Energy, Water and Communication (MEWC). It was found that the BEI meets the requirement set by the MEWC but the performance of the envelope in preventing heat gain into the building does not meet the requirement. Several ways to improve the building efficiency of the Chancellor Hall are proposed in this research.

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2. Group Partner: Mohd. Hafez Abdul Malik
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6. Family and friends

TABLE OF CONTENT

LIST OF TABLES AND FIGURES

LIST OF TABLES **PAGE**

LIST OF FIGURES **PAGE**

CHAPTER 1

INTRODUCTION

1.1 PROBLEM STATEMENT

Global warming threats to the environment need urgent attention by all fraction of society all over the world. About one-third of the world's energy is consumed by buildings. It is expected to grow from 45% from 2002 to 2025 (Azni Zain Ahmed, 2008).

Buildings have a greater impact on greenhouse gas emission than vehicles in most develop countries. The impact is even greater for countries with hot and humid climate. For instance Malaysia has been experiencing dramatic growth in the number of air conditioners from 13,251 units in 1970 to 253,399 in 1991. The number is expected to increase to 1,511,276 in the year 2020.

Universiti Teknologi PETRONAS (UTP) was one of the nine winners of the Aga Khan Award for Architecture which was held on 4 September 2007 for its ultra-modern structure that was rich in subtle traditional textile designs. Even with the award, no energy efficiency audit have been done to tell where the buildings stand in terms of the building energy efficiency index.

1.2 OBJECTIVES

The study aims establish the actual energy performance of the building. The objectives are as follows.

1. Investigate and determine the building energy index (BEI) for the Chancellor Hall in UTP.
2. Compare the findings from the research to the optimal BEI set by the Malaysian Ministry of Energy, Water and Communication (MEWC)
3. Evaluate the actual performance of the building envelope using on-site field measurement.
4. Propose ways to improve the building efficiency of the Chancellor Hall if required.

1.3 SCOPE OF STUDIES

In this study the energy consumption of the Chancellor Hall will be monitored. The area of study that will be concentrated on is the power usage of the air conditioning and its efficiency.

Related to air-conditioning and the efficiency certain parameters such as the thermal transfer value of the building will be included. Further explanation will be on chapter 2.

1.4 RISK ASSESMENT

All work will be done based on the Health, Safety and Environment (HSE) rules and regulations. The main objective of the policy and rules is to prevent unwanted accidents in the laboratory or any possible high risks places involving students or any personnel.

Hazard can be defined as a potentially harmful situation, although not usually the event itself. There are three causes of hazard are as follows.

a) Natural – which is caused by a natural process
b) Man made – hazards created by human
c) Activity related – some hazards are created by the undertaking of certain activity and the cessation of the activity will negate the risk.

An assessment known as Hazards Assessment will be done before entering the specific location.

CHAPTER 2

LITERATURE REVIEW

2.1 CURRENT ISSUES

The energy demand in Asia is expected to grow by 2.75% per year until 2030 (Azni Zain Ahmad). The United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) stressed that 12% of the energy consumption can be reduced by using energy efficiency measures and renewable energy. ESCAP pointed that to have a high energy security, the countries need to ensure their energy supplies are available, sufficient, affordable and sustainable.

2.2 DESIGN ASPECTS

An energy-efficient building must have good design, efficient materials and equipment, and technology. Good design involves installation of high performance windows, well-insulated walls, and a properly sealed ductwork to keep heat isolated.

Another aspect to be looked into when designing a sustainable building is the location of the building. For instance a building near seaside has natural ventilation. Thus when applicable certain location does not need air conditioning.

Also, the region has to be taken into consideration since different region have different optimal comfortable temperature zone. The comfortable temperature in Malaysia is between 24.5°C to 28.0°C (M.H Abdul Samad, 2008)

There are several parameters that have to be included when designing an air-conditioned energy efficient building.

a) Overall thermal transfer value (OTTV) for roof, façade and envelope.

b) Building energy index (BEI)

c) Illuminance

Certain details have to be looked into when designing the air conditioning of a building. Followings are the specification stated in the Malaysian Standard: code of practice on energy efficiency and use of renewable energy for non-residential building (MS 1525:2007) for an optimum comfort for the occupants.

Comfort room temperature: 23 to 26 °C

Recommended design relative humidity: 55% - 70%

Recommended air movement: 0.15 m/s – 0.50 m/s

Maximum air movement: 0.7 m/s

Building energy index: 135 kWh/m^2

2.3 OVERALL THERMAL TRANSFER VALUE (OTTV)

The main objective of this criterion is to minimize solar heat gain into building. This will result in a more efficient building because the cooling load of the air conditioner is less disturbed by solar heat gain.

The OTTV considerations only apply to air conditioned building. Air conditioned area of more than 4,000 m^2 should have an OTTV of 50 W/m^2 or less.

According to the MS 1525:2007 the OTTV can be calculated as follows

$$OTTV = (A_{o1} \times OTTV_1 + A_{o2} \times OTTV_2 \ldots \times A_{on} \times OTTV_n) / (A_{o1} + A_{o2} \ldots + A_{on}) \qquad \text{..equation1}$$

A_{oi} = gross exterior wall area for orientation i

$OTTV_i$ = OTTV value for orientation i from equation 2

$$OTTV_i = 15\,\alpha\,(1-WWR)U_w + 6(WWR)\,U_F + (194 \times CF \times WWR \times SC) \qquad \text{..equation2}$$

WWR = window-to-gross exterior wall area ratio for the orientation under consideration

α = solar absorptive of the opaque wall

U_w = thermal transmittance of the opaque wall $(W/M^2\,K)$

U_F = thermal transmittance of fenestration system $(W/M^2\,K)$

CF = solar correction factor (table 4 of MS1535:2007)

SC = shading coefficient of the fenestration system.

2.4 STANDARDS AND BUILDING ENERGY INDEX (BEI)

The average BEI for Malaysia is 269kWh/m^2/yr. Recommended BEI for Malaysia was 135kWh/m^2/yr introduced by MEWC in the year 1989. The guideline was then revised in the year 2007. At present it is named Malaysian Standard: code of practice on energy efficiency and use of renewable energy for non-residential building (MS 1525:2001). Brief descriptions of the purpose are as follows:

a) Design of new and existing building that reduces the use of energy without constraining the building function.

b) Provide criteria and minimum standards for energy efficiency in the design

c) Provide guidance for designs that demonstrates good professional judgment and exceeds minimum standard criteria.

Some additions were made in the year 2007. The additions are as follows:

a) Encourage the application of renewable energy in new and existing building to minimize non-renewable energy sources. (MS 1525:2007)

2.5 COGENERATION AND GAS DISTRICT COOLING (GDC)

Cogeneration is a process that converts fuel into thermal and electricity energy. The UTP GDC was commissioned in April 2003 to supply both chilled water and electricity to UTP campus in Tronoh Perak.

The cogeneration system is more efficient than combined-cycle power plant. The efficiency of the cogeneration system is 70% where as the efficiency of a combined cycle power plant is 50-60%.

Some detail information of the GDC are as follows.

1.	Chilled water production:	4000 RT
2.	Electricity generation:	8.4 MW
3.	Operator:	Makhostia Sdn. Bhd.
4.	Major equipments :	2 Units of Gas Turbines (Solar Taurus 60)
		2 Units of Heat Recovery Steam Generators (Vickers Hoskin)
		1 Unit of Auxiliary Gas Boilers (Vickers Hoskin)
		2 Units of Steam Absorbtion Chillers (Ebara)
		4 Units of Air Cooled (Electric) Chillers (Dunham Bus)

5. UTP DISTRIC COOLING SYSTEM

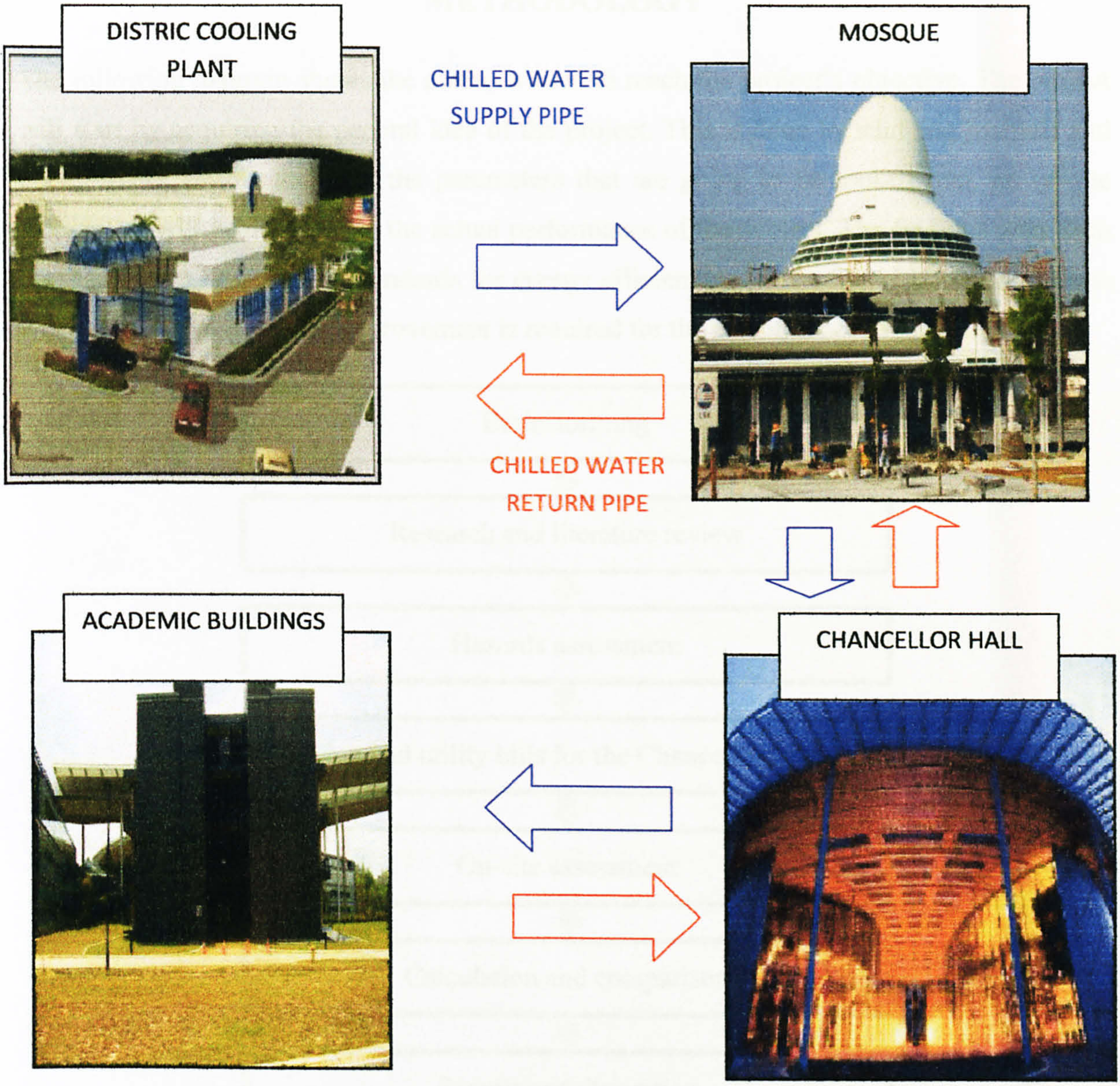
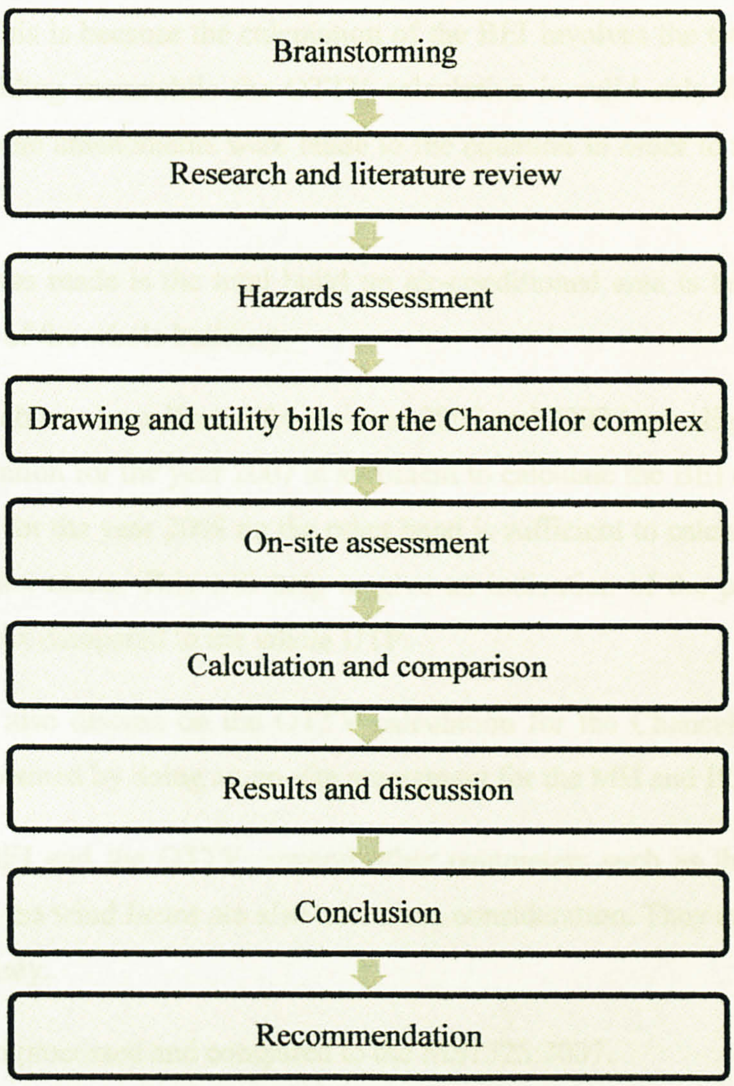


Figure 1 : UTP DISTRIC COOLING SYSTEM

CHAPTER 3

METHODOLOGY

The following diagram shows the methods used to reach the project's objective. The project will start by acquiring the general idea of the project. This is done by studying journals and books. After getting to know the parameters that are going to be looked into, an on-site assessment will be done to see the actual performance of the subject. The findings were then compared to the Malaysian Standards for energy efficient buildings. Some recommendations will be discussed if further improvement is required for the performance of the building.



CHAPTER 4

RESULTS AND DISCUSSION

The following paragraphs are some brief description on what will be discussed in this chapter.

The Chancellor Complex is basically consists of 3 major parts. They are the Main Hall, Information Resource Center and the Undercroft. For the purpose of this study only the performance of the Main Hall and the Information Resource Center will be discussed.

Generally speaking the two parameters which are the BEI and the OTTV do not correlate with each other. This is because the calculation of the BEI involves the total electricity used for the whole building meanwhile the OTTV calculation is valid only for air conditioned buildings. Thus some amendments were made to the equation in order to relate the BEI and the OTTV.

The change that was made is the total build up air-conditioned area is taken instead of the total build up area of the whole building.

The data that was able to be collected for the year 2007 and 2008 have slight difference in its usage. The information for the year 2007 is sufficient to calculate the BEI of the whole UTP. The data obtained for the year 2008 on the other hand is sufficient to calculate the BEI of the Chancellor Complex alone. This will help to give an indication of the performance of the Chancellor Complex compared to the whole UTP.

This chapter will also discuss on the OTTV calculation for the Chancellor Complex. The actual OTTV is obtained by doing an on-site assessment for the MH and IRC.

Aside from the BEI and the OTTV, several other parameters such as the air temperature, humidity and also the wind factor are also taken into consideration. They are to be the control measure for the study.

All the data is then processed and compared to the MS1525:2007.

4.1 Chilled water and electricity supplied to UTP for the year 2007

The table below shows the chilled water and electricity supplied to UTP for the year 2007. The important data to be noted here is the total electricity supplied to UTP for the whole year. The information is essential to calculate the BEI of the whole UTP.

Month	Chilled Water (RTH)	Electricity (kWh)
Jan	749,921	1,894,632
Feb	738,467	2,031,482
March	961,138	2,403,631
April	949,052	2,478,098
May	1,028,278	2,488,354
June	821,722	1,770,037
July	661,770	1,779,030
August	854,897	2,435,734
September	757,030	2,229,424
October	836,809	2,380,176
November	940,758	2,621,006
December	907,504	2,141,482

TABLE 1: Chilled water and electricity supplied to UTP for the year 2007

Total electricity supplied to UTP (year 2007) = 26,653,086 kWh/year

4.2 Electricity supplied to the Chancellor Complex for the year 2008

The data collected were only for the electricity supplied for air conditioning and the fans. Some assumptions were made to establish the total electricity supplied to the building.

4.2.1 Main hall (MH)

The total energy consumption of the Air Handling Units' (AHU) fan power and their MV fans was 401,598 kWh/year.

Assuming that 60% of a building's energy usage is for the air conditioning, thus the estimated energy usage of the MH was 669,330 kWh/year.

4.2.2 Information recourse center (IRC)

The total energy consumption of the Air Handling Units' (AHU) fan power and their MV fans was 1,238,283 kWh/year.

Assuming that 60% of a building's energy usage is for the air conditioning, thus the estimated energy usage of the IRC was 2,063,805 kWh/year.

4.2.3 Total build up area

In order to calculate the BEI of a building, the total build up area had to be measured.

4.2.3.1 Build up area of the UTP

Area = 92,600 m^2

4.2.3.2 Build up area of the Main Hall (air-conditioned)

The gross areas taken are the hall area

Area = 7,606 m^2

4.2.3.3 Build up area of IRC (air-conditioned)

The gross areas taken are the basement, ground floor, 1st floor 2nd floor, 3rd floor and the offices on the top floor.

Area = 21,354 m^2

4.3 BEI calculation

The BEI calculation was divided into three parts. The calculations are as follows.

BEI = Annual total energy consumption / area

4.4.1 BEI of the whole UTP

This was done by using the data from the year 2007. Refer 4.1 and 4.2.3.1.

BEI = 287 kWh/m^2

4.4.2 BEI of the Main Hall (MH)

BEI = 88 kWh/m^2

4.4.3 BEI of the Information Resource Center (IRC)

BEI = 97 kWh/m^2

4.4 OTTV calculation

To calculate this parameter, data on the material used for the walls and windows are required.

The U value which is the transmittance value will be calculated beforehand since it is required for the OTTV calculation.

An on-site evaluation will be conducted for the OTTV. Instead of using equation 2 to calculate OTTVi, the following equation will be used.

Equation 3

$$OTTVi = ((1-WWR) \times Uw \times TDeg) + (WWR \times Ug \times DT) + (WWR \times SC \times SHGC \times ESR)$$

Where

WWR	=	window to overall wall ratio
Uw	=	thermal conductance (U-value) of an opaque wall ($W/m^{2}{}^{\circ}c$)
TDeg	=	equivalent temperature difference of an opaque wall (°c)
Ug	=	thermal conductance of the glazing ($W/m^{2}{}^{\circ}c$)

DT	=	temperature difference of glazing window (°c)
SC	=	shading coefficient of shading device
SHGC or CF	=	solar heat gain coefficient of glazing
ESR	=	effective solar radiation (W/m^2) = 194 W/m^2

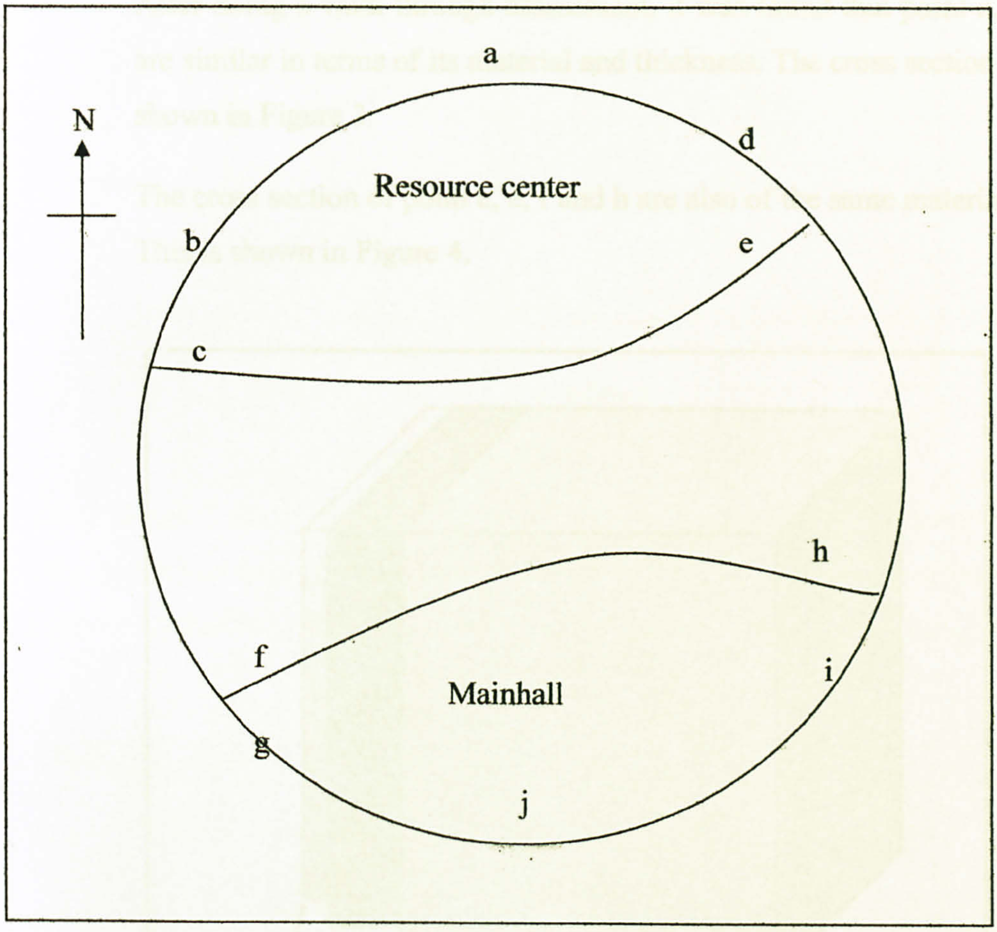


Figure 2: Chancellor complex (not to scale)

Certain procedures are prepared to perform the onsite analysis. The objective of the analysis is to evaluate the envelope performance by getting the OTTV.

Data such as air temperature, the surface temperature of the envelope and the relative humidity are collected for both indoor and outdoor.

The measurement will take place for every 45 minutes interval.

Theoretically, the sun will have the maximum effect on the top floor of the building since it is closer to the sun. Thus, all measurement will be done on the top floor where applicable.

4.4.1 U value calculation

The type of material and also the thickness are the key points to calculate the U value. As mentioned earlier Figure 2 shows the location where all data are taken.

After doing a walk through assessment, it was found that point a, b, d, g, i and j are similar in terms of its material and thickness. The cross section of the façade is shown in Figure 3.

The cross section of point c, e, f and h are also of the same material and thickness. This is shown in Figure 4.

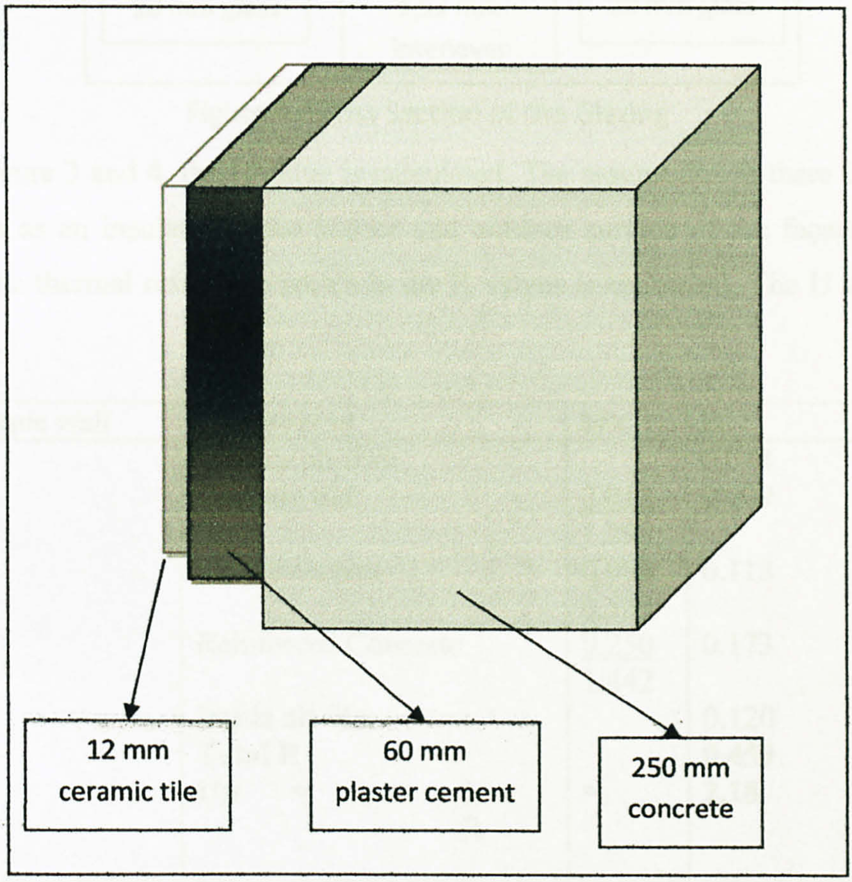


Figure 3: Cross Section for Opaque Wall

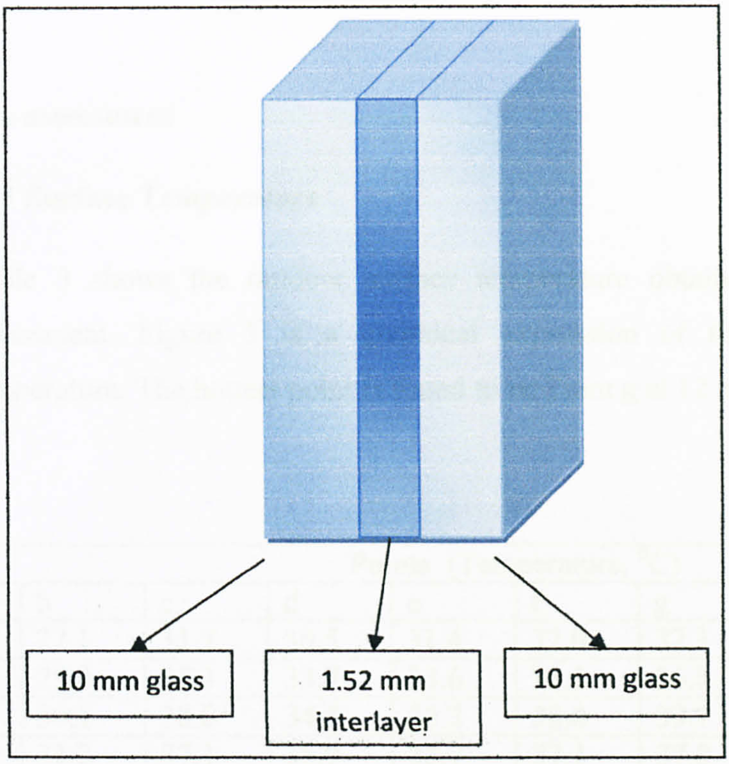


Figure 4: Cross Section of the Glazing

Based on figure 3 and 4, the U value is calculated. The assumption is there is a thin layer of air that acts as an insulator at the indoor and outdoor surface of the façade. Knowing the materials, the thermal resistance which is the R values is estimated. The U value is equal to 1/R.

a) Opaque wall	Component	b/k	R	
1)	Outside air film		0.044	
2)	Ceramic tile	$\frac{0.012}{1.298}$	0.009	
3)	Plaster cement	$\frac{0.060}{0.533}$	0.113	
4)	Reinforced Concrete	$\frac{0.250}{1.442}$	0.173	
5)	Inside air film		0.120	
	Total R		**0.459**	
	Uw = $\frac{1}{R}$	=	**2.18**	W/m^{2}K
b) Glazing	**Component**	**b/k**	**R**	
1)	Outside air film		0.044	
2)	Laminated glazing		0.000	
3)	Inside air film		0.120	
	Total R		**0.164**	
	Ug = $\frac{1}{R}$	=	**6.08**	W/m^{2}K

Table 2: U value calculation

4.4.2 On-site assessment

4.4.2.1 Surface Temperature

Table 3 shows the outdoor surface temperature obtained during the site assessment. Figure 5 is a graphical expression of the outdoor surface temperature. The hottest point is found to be Point g at 12 noon.

Time	Points (Temperature, ^{0}C)									
	a	b	c	d	e	f	g	h	i	j
10.30 am	30.1	27.1	31.7	30.5	31.4	32.0	32.3	31.4	30.0	32.5
11.15 am	33.0	29.4	35.3	33.7	33.6	35.3	36.8	33.6	30.5	35.7
12.00 pm	34.5	30.1	38.0	34.5	35.3	38.0	39.7	35.3	32.7	36.3
12.45 pm	34.7	31.2	37.1	35.9	35.7	37.1	37.8	35.7	32.3	36.8
1.30 pm	37.6	31.9	36.1	37.5	36.9	36.1	37.0	36.7	34.0	34.3

Table 3: Outdoor surface temperature

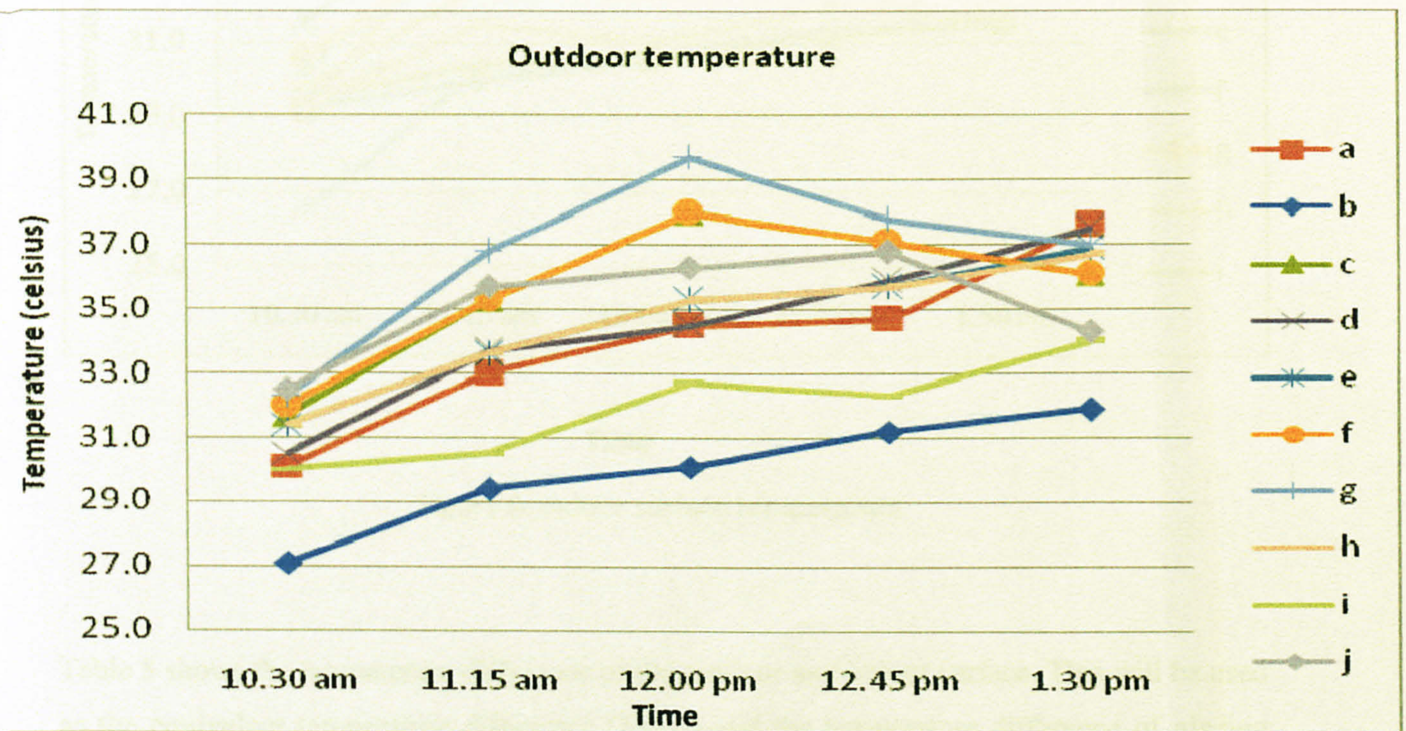


Figure 5: Outdoor surface temperature

Table 4 shows the indoor surface temperature obtained during the site assessment. Figure 6 is a graphical expression of the indoor surface temperature. The hottest point is found to be Point f at 12 noon.

Time	Points (Temperature, ^0C)									
	a	b	c	d	e	f	g	h	i	j
10.30 am	26.5	29.3	29.2	29.5	29.4	31.6	30.6	29.3	29.8	30.4
11.15 am	30.3	30.0	34.7	30.4	31.5	34.7	34.0	31.5	32.5	33.5
12.00 pm	30.7	30.6	37.5	30.6	31.0	37.5	34.3	31.0	32.3	34.0
12.45 pm	31.4	31.3	36.5	31.2	32.0	36.5	35.5	32.0	33.3	34.6
1.30 pm	31.6	31.5	36.2	31.6	31.7	36.2	35.6	31.7	33.5	34.8

Table 4: Indoor surface temperature

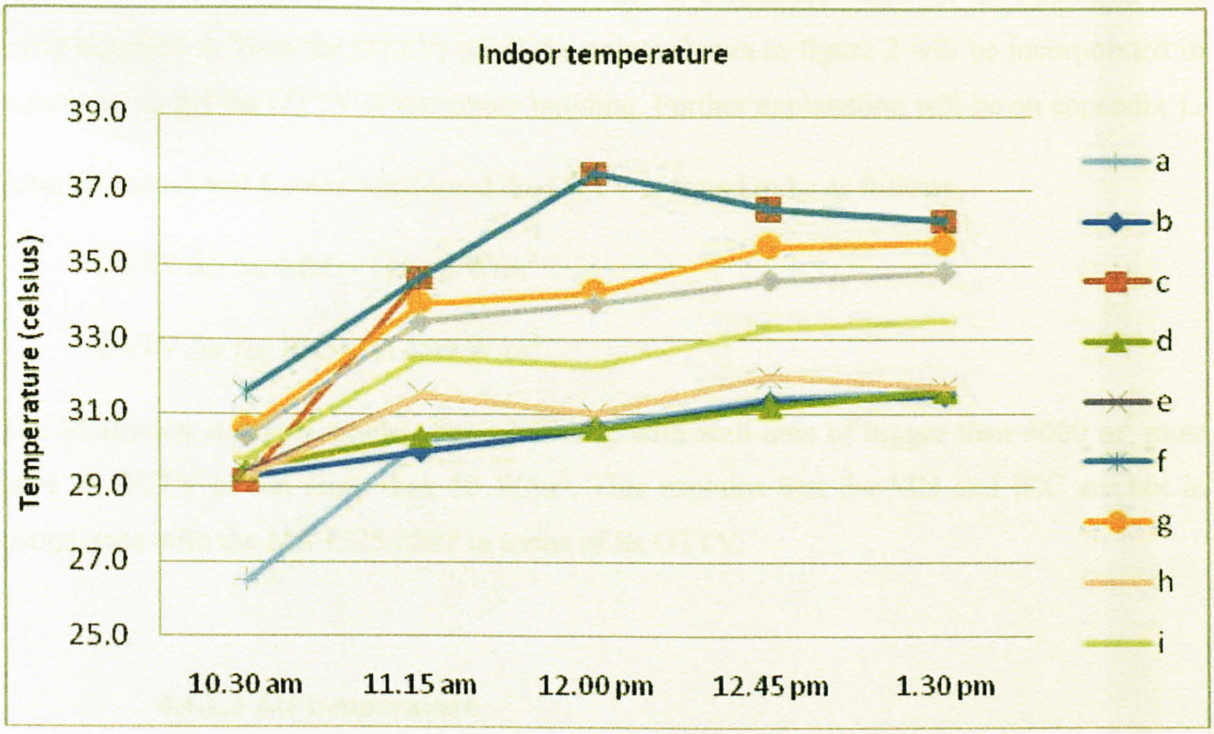


Figure 6: Indoor surface temperature

Table 5 shows the temperature difference of the outdoor and indoor surface. This will be used as the equivalent temperature difference (TDeq) and the temperature difference of glazing window (DT). The worst case scenario will taken into account which is the maximum temperature difference instead of the average temperature difference.

Time	Points (Temperature, ^0C)									
	a	b	c	d	e	f	g	h	i	j
10.30 am	3.6	-2.2	2.5	1.0	2.0	0.4	1.7	2.1	0.2	2.1
11.15 am	2.7	-0.6	0.6	3.3	2.1	0.6	2.8	2.1	-2.0	2.2
12.00 pm	3.8	-0.5	0.5	3.9	4.3	0.5	5.4	4.3	0.4	2.3
12.45 pm	3.3	-0.1	0.6	4.7	3.7	0.6	2.3	3.7	-1.0	2.2
1.30 pm	6.0	0.4	-0.1	5.9	5.2	-0.1	1.4	5.0	0.5	-0.5

Table 5: Temperature difference

TDeq = 5.9 ^0C

DT = 4.3 ^0C

After all measurements are done, the OTTVi will be calculated based on the measured data using equation 3. Then the OTTVi of all the points shown in figure 2 will be incorporated in equation 1 to get the OTTV of the whole building. Further explanation will be on appendix 1.

After all values and factors considered the OTTV is found to be as follows.

OTTV for the MH = 111.40 W/m^2

OTTV for the IRC = 114.99 W/m^2

The Malaysian standard requires for a building with wall area of bigger than 4000 m^2 must have an OTTV of not more than 50 W/m^2. This explains that the MH and IRC are not in compliance with the MS 1525:2007 in terms of its OTTV.

4.4.2.2 Air temperature

Table 6 and 7 shows the outdoor and indoor air temperature of the Chancellor Complex. The reading shows that most of the points having higher temperature than supposed for comfort room temperature which is 26 ^0C when the building is in passive state.

Time	Points (Temperature, ^{0}C)									
	a	b	c	d	e	f	g	h	i	j
10.30 am	26.9	26.5	26.7	30.0	28.4	26.6	27.6	27.4	31.1	27.8
11.15 am	28.9	27.7	28.5	30.2	28.5	28.5	29.9	28.5	31.5	29.5
12.00 pm	30.0	28.1	29.0	30.2	29.0	29.0	30.5	29.0	30.1	30.8
12.45 pm	30.4	29.2	29.7	30.9	29.8	29.7	30.3	29.8	31.4	31.0
1.30 pm	32.1	30.2	27.8	31.5	30.4	27.8	30.8	30.4	30.6	31.6
Average	29.7	28.3	28.3	30.6	29.2	28.3	29.8	29.0	30.9	30.1

Table 6: Outdoor air temperature

Time	Points (Temperature, ^{0}C)									
	a	b	c	d	e	f	g	h	i	j
10.30 am	25.9	26.2	25.2	25.5	25.5	26.0	24.7	24.1	24.3	24.1
11.15 am	26.1	26.6	27.5	26.0	25.0	27.5	25.9	25.0	25.0	25.0
12.00 pm	26.3	27.1	28.0	26.2	24.9	28.0	25.2	24.9	24.9	25.2
12.45 pm	26.7	27.1	28.4	26.3	25.1	28.4	26.2	25.1	25.3	25.7
1.30 pm	25.0	27.9	26.8	24.6	23.4	26.8	24.7	23.4	24.1	24.2
Average	26.0	27.0	27.2	25.7	24.8	27.3	25.3	24.5	24.7	24.8

Table 7: Indoor air temperature

4.4.2.3 Relative humidity

Table 8 and 9 are the relative humidity of the outdoor and indoor of the Chancellor Complex. At passive state, the average relative humidity is slightly higher than the recommended value in the MS 1525:2007 which is 70 %.

Time	Points (Temperature, ^{0}C)									
	a	b	c	d	e	f	g	h	i	j
10.30 am	85.2	88.3	89.8	83.4	81.9	84.9	83.1	83.4	83.6	82.0
11.15 am	81.0	80.2	77.4	76.5	76.5	77.4	72.9	76.5	76.3	73.7
12.00 pm	74.8	83.7	72.7	74.6	73.6	72.7	73.3	73.6	73.9	74.1
12.45 pm	72.1	78.0	72.3	72.5	74.0	72.3	71.7	74.0	74.5	72.9
1.30 pm	71.9	75.0	66.2	71.2	72.2	66.2	72.0	72.2	72.4	73.6
Average	77.0	81.0	75.7	75.6	75.6	74.7	74.6	75.9	76.1	75.3

Table 8: Outdoor relative humidity

Time	Points (Temperature, ^{0}C)									
	a	b	c	d	e	f	g	h	i	j
10.30 am	79.3	83.6	72.3	80.4	79.2	73.2	74.0	76.5	77.7	73.9
11.15 am	79.7	80.0	70.2	81.2	75.4	70.2	71.4	75.4	74.5	72.4
12.00 pm	79.2	81.0	69.3	80.7	77.3	69.3	76.2	77.3	76.5	76.9
12.45 pm	79.1	80.2	70.5	78.6	78.3	70.5	73.5	78.3	77.5	77.0
1.30 pm	71.2	78.6	65.3	70.1	72.5	65.3	70.7	72.5	73.3	74.1
Average	77.7	80.7	69.5	78.2	76.5	69.7	73.2	76.0	75.9	74.9

Table 9: Indoor relative humidity

4.5 Relationship between the BEI and OTTV

As mentioned earlier in this chapter, the air-conditioned area is taken into consideration instead of the total buildup area. This is to establish the relationship between the BEI and the OTTV.

Altering this parameter gives a linear relationship between the BEI and the OTTV. This is because if the OTTV is low, then the BEI should also be low since not much cooling load is required for the building to achieve the required temperature.

A low value of BEI should indicate that the OTTV is good. The on-site assessment on the other hand shows that the OTTV is higher from the expected outcome.

This will give a simple assumption that the MH and the IRC are under-utilized.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

First of all, the average BEI for the whole UTP is obtained. Knowing the electricity supplied to UTP for the year 2007, the BEI was found to be 287 kWh/m^2. This value is far higher than the standards stated in MS 1525:2007 which is 135 kWh/m^2.

The chancellor complex consists of the main hall and the information resource center. Since the usage of the MH is not as often as the usage of the IRC, the calculation for the BEI is done separately to get an accurate finding.

Using the data obtained for the year 2008, the BEI of the MH is 88 kWh/m^2 and for the IRC is 97 kWh/m^2. It is noted that to some extent, the MH and the IRC meet the requirements of the MS1525:2007 in terms of its energy usage. The big difference in value between the BEI of the Chancellor Complex and the BEI of the whole UTP indicates that there are buildings in UTP that uses a very high amount of electricity.

Assuming that the energy usage of the year 2007 and 2008 is roughly the same, the findings suggests that there are buildings in UTP that have high BEI (more than 135 kWh/m^2). Further research has to be done to verify this statement.

The performance of the envelope seems to be poor since the requirement for the OTTV which is stated in the MS 1525:2007 is not met. The MH and the IRC have an OTTV of 111.40 W/m^2 and 114.99 W/m^2 respectively. Both of them are bigger than 50 W/m^2 which is the maximum value stated in the MS 1525:2007.

The established relationship between the BEI and OTTV indicates that the MH and IRC are under-utilized.

There are several ways to improve the BEI or the OTTV. To improve the OTTV material of the glazing can be changed. But this will induce a high cost since the Chancellor Complex has a big wall and glazing area. Thus improving the BEI may be more feasible. This can be achieved by developing a good energy management system, minimize loss in electrical power distribution, having efficient lighting and efficient air conditioning.

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APPENDIX 1

Onsite performance analysis of the building envelope

(Chancellor complex, University Technology PETRONAS)

Objective:
Acquire the actual performance of the envelope in preventing energy gain and

Subject :
Date :

Introduction:

Energy efficient building
According to H.Bathish from ECO energy Sdn Bhd in his article titled Sustainable Building Development-Theory and Practices, the followings are the main factors that can lead to design, build and operate energy efficient building

i.) Adopting integrated energy efficient building design.
ii.) Constructing and commissioning building with energy efficiency in mind to insure that the building satisfies the intended design objectives.
iii.) Operating and maintaining buildings at their highest possible energy efficiency level.
iv.) Carrying out building modification, retrofitting and renovation with energy efficiency in mind.

Adopting integrated energy efficient building design .
Strategies to be followed early during the conceptual design stage

i.) Thermal Comfort Strategy.
ii.) Use of Daylight and Visual Comfort Strategy.
iii.) Use of Natural Ventilation Strategy.
iv.) Indoor Air Quality Strategy.
v.) Specific Indoor Environment Requirement.

The strategies mentioned above will affect the following parameters.

a.) Building orientation and shape.
b.) Building envelope materials.
c.) Building construction and commissioning.
d.) Interior space planning and zoning.
e.) HVAC and its control strategy.
f.) Lighting and its control strategy.
g.) Building management and control system.
h.) Building Operations & Maintenance.

Overall thermal transfer value (OTTV)
Some of the parameters mentioned above will directly affect the OTTV of an air conditioned building. Low OTTV indicates a high performance of the envelope in preventing heat gain into the building.

OTTV calculation

$$\mathbf{OTTV} = \frac{\mathbf{Ao1 \times OTTV1 + Ao2 + OTTV2 \ldots\ldots\ldots + Aon\ X\ OTTVn}}{\mathbf{Ao1 + Ao2 + \ldots\ldots\ldots + Aon}}$$

Aoi	=	gross exterior wall area for orientation i
OTTVi	=	OTTV value for orientation i

<u>OTTV for orientation i</u>

For an on site measurement, the following equation will be used

$$OTTV_i = ((1-WWR) \times U_w \times TD_{eq}) + (WWR \times U_g \times DT) + (WWR \times SC \times SHGC \times ESR)$$

where

WWR	=	window to overall wall ratio
Uw	=	thermal conductance (U-value) of an opaque wall ($W/m^2{}^\circ c$)
Tdeq	=	equivalent temperature difference of an opaque wall (°c)
Ug	=	thermal conductance of the glazing ($W/m^2{}^\circ c$)
DT	=	temperature difference of glazing window (°c)
SC	=	shading coefficient of shading device
SHGC	=	solar heat gain coefficient of glazing
ESR	=	effective solar radiation (W/m^2)

Procedure :

Data to be collected for both indoor and outdoor include

1. Air temperature
2. Surface temperature of the envelop
3. Relative humidity

Figure 1 shows the points where the data are to be collected

Theoritically, the most affected area are the ones closest to the sun. Thus all measurements will be done on the top floor.

Measurement will be taken every 45 minutes.

U VALUE CALCULATION (IRC AND MH)

1) For wall

	Component	b/k	R
1	outside air film		0.044
2	ceramic tile	$\frac{0.012}{1.298}$	0.009
3	plaster cement	$\frac{0.060}{0.533}$	0.113
4	rc	$\frac{0.250}{1.442}$	0.173
5	inside air film		0.120
	Total R		**0.459**

Uw $= \frac{1}{R} =$ **2.18** W/m^2K

2) For glazing

	Component	b/k	R
1	outside air film		0.044
2	Laminated glazing		0.000
	inside air film		0.120
	Total R		**0.164**

Ug $= \frac{1}{R} =$ **6.08** W/m^2K

3) For glass wall SC = **0.82**

AREA/OVERALL U-VALUE CALCULATION

IRC

For South facing wall

concrete wall	Aw	=	0	x	0	=	0.00
glass	Af	=	79.32	x	21	=	1665.72
Gross wall area						=	**1665.72**

WWR = **1.0**

Overall Uw = **0.000** W/m^2K

For North facing wall

concrete wall	Awl	=	65.165	x	18.8	=	1225.10
glass	Af	=	65.165	x	2.2	=	143.36
Gross wall area						=	**1368.47**

WWR = **0.1**

Overall Uw = **2.178** W/m^2K

For East facing wall

concrete wall	Awl	=	32.5825	x	18.8	=	612.55
glass	Afl	=	39.66	x	21.0	=	832.86
	Af2	=	32.5825	x	2.2	=	71.68
Gross wall area						=	**1517.09**

WWR = **0.6**

Overall Uw = **2.178** W/m^2K

For West facing wall

concrete wall	Awl	=	32.5825	x	18.8	=	612.55
glass	Afl	=	39.66	x	21.0	=	832.86
	Af2	=	32.5825	x	2.2	=	71.68
Gross wall area						=	**1517.09**

WWR = **0.6**

Overall Uw = **2.178** W/m^2K

APPENDIX 4

OTTV CALCULATION
IRC

Solar absorvity		=	**0.5**	
For North facing wall	CF	=	**0.9**	
	OTTV	=	**169.32**	W/m^2
For South facing wall	CF	=	**0.92**	
	OTTV	=	**29.57**	W/m^2
For East facing wall	CF	=	**1.23**	
	OTTV	=	**137.44**	W/m^2
For West facing wall	CF	=	**0.94**	
	OTTV	=	**109.94**	W/m^2
For whole building	**OTTV**	=	**114.99**	W/m^2

AREA/OVERALL CALCULATION **U-VALUE**

MAIN HALL

For North facing wall

concrete wall	Aw	=	0	x	0	=	0.00
glass	Af	=	63.105	x	21	=	1325.21
Gross wall area						=	**1325.21**

WWR = **1.0**

Overall Uw = **0.000** W/m^2K

For South facing wall

concrete wall	Aw1	=	57.4	x	18.8	=	1079.12
glass	Af	=	57.4	x	2.2	=	126.28
Gross wall area						=	**1205.40**

WWR = **0.1**

Overall Uw = **2.178** W/m^2K

For East facing wall

concrete wall	Aw1	=	28.7	x	18.8	=	539.56
glass	Af1	=	31.55	x	21.0	=	662.55
	Af2	=	28.7	x	2.2	=	63.14
Gross wall area						=	**1265.25**

WWR = **0.6**

Overall Uw = **2.178** W/m^2K

For West facing wall

concrete wall	Aw1	=	28.7	x	18.8	=	539.56
glass	Af1	=	31.55	x	21.0	=	662.55
	Af2	=	28.7	x	2.2	=	63.14
Gross wall area						=	**1265.25**

WWR = **0.6**

Overall Uw = **2.178** W/m^2K

OTTV CALCULATION
MAIN HALL

Solar absorvity		=	**0.5**	
For South facing wall	CF	=	**0.92**	
	OTTV	=	**172.50**	W/m^2
For North facing wall	CF	=	**0.9**	
	OTTV	=	**28.27**	W/m^2
For East facing wall	CF	=	**1.23**	
	OTTV	=	**132.24**	W/m^2
For West facing wall	CF	=	**0.94**	
	OTTV	=	**105.78**	W/m^2
For whole building	**OTTV**	=	**111.40**	W/m^2

Type of Surface	**Thermal Resistance m^2 K/W**		
	5 mm	**20 mm**	**100 mm**
A Air Space Resistance (Ra) for Walls:			
Vertical air space (Heat flows horizontally)			
(a) High Emissivity	0.110	0.148	0.160
(b) Low Emissivity	0.250	0.578	0.606
B Air Space Resistance (Ra) for Roofs:			
1 Horizontal or Sloping air space (Heat flows downward)			
(a) High Emissivity			
(i) horizontal air space	0.110	0.148	0.174
(ii) sloped air space 22½^{o}	0.110	0.148	0.165
(iii) sloped air space 45^{o}	0.110	0.148	0.158
(b) Low Emissivity			
(i) horizontal air space	0.250	0.572	0.801
(ii) sloped air space 22½^{o}	0.250	0.571	0.595
(iii) sloped air space 45^{o}	0.250	0.570	0.391
C Attic space resistance (R attic)			
(a) High Emissivity		0.458	
(b) Low Emissivity		1.356	

APPENDIX 8

SOLAR CORRECTION FACTORS

Orientation	N	NE	E	SE	S	SW	W	NW
CF	0.9	1.09	1.23	1.13	0.92	0.9	0.94	0.9

APPENDIX 9

k-VALUES OF BASIC MATERIAL

Sr No.	Material	Density kg/m^3	k-value W/m^2 K
1	Asbestos cement sheet	1488	0.317
2	Asbestos insulating board	720	0.108
3	Asphalt, roofing	2240	1.226
4	Bitumen		1.298
5	Brick:		
	(a) dry (covered by plaster or tiles outside)	1760	0.807
	(b) common brickwall (brickwall directly exposed to weather outside)		1.154
6	Concrete	2400	1.442
		64	0.144
7	Concrete, light weight	960	0.303
		1120	0.346
		1280	0.476
8	Cork board	144	0.042
9	Fibre board	264	0.052
10	Fibre glass (see glass wool and mineral wool)		
11	Glass, sheet	2512	1.053
12	Glass wool, mat or quilt (dry)	32	0.035
13	Gypsum plaster board	880	0.17
14	Hard board:		
	(a) standard	1024	0.216
	(b) medium	640	0.123
15	Metals:		
	(a) aluminium alloy, typical	2672	211
	(b) copper, commercial	8784	385
	(c) steel	7840	47.6
			0.035 –
16	Mineral wool, felt	32 - 104	0.032
17	Plaster:		
	(a) gypsum	1216	0.37
	(b) perlite	616	0.115
	(c) sand/cement	1568	0.533
		640 -	0.202 –
	(d) vermiculite	960	0.303
18	Polystyrene, expanded	16	0.035
19	Polyurethane, foam	24	0.204
20	PVC flooring	1360	0.713
21	Soil, loosely packed	1200	0.375
22	Stone, tile:		
	(a) sand stone	2000	1.298
	(b) granite	2640	2.927
	(c) marble/terrazzo/ceramic/mosaic	2640	1.298
23	Tile, roof	1890	0.836
24	Timber:		
	(a) across grain soft-wood	608	0.125
	(b) hardwood	702	0.138
	(c) plywood	528	0.138