HEAT LOAD CALCULATION AND ANALYSIS FOR COMMERCIAL BUILDING AIR CONDITIONING SYSTEM

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Parents who raised me up

Brothers and sister who were raised with me

Friends who shared the shoulders with me

Humanity

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ABSTRACT

Air conditioning system consume more than 50% of total commercial building energy consumption such as hotel, office, shopping mall and hospital in Malaysia. Solar heat through fenestration particularly on vertical surfaces play as major role in determining the thermal performance of a building. Maximum solar heat gain factors (SHGFs) has been used to estimate the peak heat load. This project describes the procedure of peak heat load calculation by using overall thermal transfer value (OTTV) and hourly analysis program (HAP) to obtain the heat load profile. A 33 story hotel building layout and envelope is being used and further optimization on the building envelope configuration has been done to observe the result. This research have showed how building envelop configuration affect the building cooling load requirement and apply in decision making base on the return of investment (ROI). The hourly analysis program result have showed that hotel air conditioning system operated at 80% or higher cooling capacity (Peak load) only during 1pm to 3pm and most of the time plant room is operate at Part Load condition. Plant room energy consumption and return of investment (ROI) analysis help in decision making on the particular building envelope configuration. The result showed that ROI period increase with the quantity of double glazed with low-E glass applied in hotel envelope and it is more cost effective if this type of glass is being apply at non shaded external surface. This study also carry out ROI evaluation and comparison for the plant room that with and without variable speed drive (VSD), the result showed that VSD plant room only take around 2 years to get the return of the initial investment cost.

ABSTRAK

Di Malaysia, kegunaan tenaga sistem penghawa dingin bangunan komersial seperti hotel, pejabat, pusat membeli-belah dan hospital adalah lebih daripada 50% tenaga daripada jumlah kegunaan tenaga seluruh bangunan. Haba solar yang melalui perbukaan cermin tingkap terutamanya permukaan menegak memainkan peranan yang penting untuk menentukan prestasi haba sebuah bangunan. Faktor maksimum peruntukan haba solar telah diguna untuk menganggarkan kuasa haba maksimum yang diperolehi oleh bangunan. Projek ini menerangkan prosedur penganggaran peruntukan kuasa haba maksimum sebuah bangunan dengan cara megunakan nilai keseluruhan pemindahan haba (OTTV) dan jugak megunakan program simulasi yang mengira peruntukan haba setiap jam (HAP) untuk mendapatkan profil peruntukan haba bagunan. Pelan sebuah bagunan hotel sedia ada dan sampul bangunan telah di gunakan dan pengoptimuman terhadap konfigurasi sampul bangunan dijalankan untuk memerhati pengubahan peruntukan kuasa haba bagunan tersebut. Kajian ini menunjukan bagaimana konfigurasi sampul bangunan menjejas kuasa penyejukan yang diperlukan dan jugak keputusan yand dibuat berdarsakan pulangan pelaburan. Program simulasi yang mengira peruntukan haba setiap jam (HAP) telah menunjukan bahawa sistem penyaman udara hotel tersebut hanya beada di 80% atau lebih daripada kapasiti penyejukanya pada jam 1pm hingga 3pm sahaja dan kebanyakan masa bagunan hanya ada pada keadaan separa daripada kapasiti penyejukanya. Analisis penggunaan tenaga bilik penyejuk dan pulangan pelaburan bantu membuat keputusan terhadap konfigurasi sampul bangunan. Keputusan menunjukan tempoh pulangan pelaburan menigkat dengan kegunaan kuantiti kaca double glazed dengan low-E di sampul hotel dan ia lebih kos efektif jika digunakan di permukaan dinding yang tidak berlorek. Kajian ini jugak menjalankan penilaian dan pernadingan tempoh pulangan pelaburan bagi bilik penyejuk dengan dan tanpa variable speed drive (VSD), keputusan menunjukkan bilik penyejuk dengan VSD hanya ambil hampil 2 tahun utuk mendapatkan balik kos pelaburan permulaan.

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LIST OF ABBREVIATION

OTTV	-	Overall Thermal Transfer Value
TD	-	Difference Between Interior and Exterior (K)
TD_{eq}	-	Equivalent Temperature Difference (K)
WWR	-	Window-to-Wall Ratio
SF	-	Solar Factor of Fenestration
SC	-	Shading Coefficient of Fenestration (Dimensionless)
Uw	-	U-Value of Opaque Wall (W/m2.K)
Uf	-	U-Value of Fenestration (W/m2.K)
COP	-	Coefficient of Performance
RPM	-	Revolution Per Minuets
FAN_{EFF}	-	Fan efficiency
$PUMP_{EFF}$	-	Pump efficiency
SHGFs-	-	Solar Heat Gain Factors
ROI	-	Return of Investment
HAP	-	Hourly Analysis Program
AHU	-	Air Handling Unit
FCU	-	Fan Coil Unit
VAV	-	Variable Air Volume
DX	-	Direct Expansion
ACMV	-	Air Conditioning and Mechanical Ventilation
PID	-	Proportional–Integral–Derivative
BAS	-	Building Automated System
RT	-	Refrigerant Tonnage (12,000 btu)

LIST OF SYMBOLS

Q	-	Heat flow rate
k	-	Thermal conductivity of the material
A	-	Cross-sectional area
dT/dx	-	Temperature gradient
h	-	Coefficient of convection
T_∞	-	Outside temperature
T_s	-	Surface temperature
T	-	Absolute temperature of surface
σ	-	Stefan-Boltzmann constant
α	-	Solar absorption(dimensionless)
$\dot{V}$	-	Flow rate in CFM (for fan) and usgpm (for pump)
ω	-	Angular speed (in RPM)
P	-	Pressure for fan (inch of water gauge) or pump head for pump (in feet of water)
R	-	Thermal resistance (K/W)

CHAPTER 1

INTRODUCTION

1.1 Project Background

Over the past decade, construction industries at tropical countries have given much more attention on energy saving concepts. To ensure energy savings, the main key is to reduce air conditioner capacity in a building. This is achievable with a proper heat load calculation to be carried out to ensure energy saving without sacrificing the comfort level of the air conditioning system. In a tropical country, solar heat gain by the building through vertical and horizontal wall created much more impact than internal load such as heat rejected by human body, machine, equipment and lighting. The overall thermal transfer value (OTTV) on building envelopes has become the base reference that determine the building envelopes thermal performance. Xiaoxia Sang [1] has examined energy-efficient building envelop design decision making in Hong Kong and found out that there is a large potential of reducing building cooling energy during building envelop material selection and design.

In 2005, Lam et al. published a paper in which they described that building cooling load can be expresses in term of simple two-parameter linear regression equation involving OTTV and with the further long term data collection such as ambient temperature, global solar radiation on vertical and horizontal surface, a simulation technique can be carry out to obtain not only the maximum load but also the load profile of the building [2].

In Malaysia standard (MS: 1525), OTTV calculation is using the fix maximum solar heat gain factor that apply into OTTV calculation for standardize purpose so that OTTV value obtain is indicate the maximum amount of heat gain through the building envelop. In fact, OTTV value is varied time to time and the maximum heat gain through different walls orientation will not happen at the same time. ChutinanSinghpoo et al [3] conducted a study to predict value of overall thermal transfer value (OTTV) of building at different time in one day. A case study of sixth floor of Pienvichitr Building KhonKaen University, Thailand; the result show that OTTV varied time to time on the maximum happen at 02.00 pm. If the single value of OTTV obtained from MS: 1525 has been applied to estimate the building load, it may cause overdesign on total capacity in the air conditioning system.

On the other hand, Li and Lam [4] have carried out the research to develop a simple approach for estimation of solar heat gain where the maximum solar heat gain and average solar heat gain for OTTV are computed and compared. The research shows that surface which facing different directions have different maximum and average solar heat gain. This is meant that OTTV of the building is overestimated if by using a single value of solar heat gain.

Heat load calculations need consideration on the entire external and internal load. The load will change hourly due to variation of external temperature, solar heat gain, internal load and etc. The equation can be inserted in a programme such as M.S.Excel. However, the processes are tedious which involved many weather and internal load data that need to be inserted into the calculation. Hourly analysis programme (HAP) has been used for heat load calculation in the air conditioning system because will help to speed up the process. The build-in feature in HAP allows the user to obtain the entire building heat load and its profile in various type of buildings and applications.

1.2 Problem Statement

There are a lot of commercial building in Malaysia do not carry out a proper building heat load calculation. Most of the air conditioning system design capacity is only base on rules of thumbs (watt of cooling power require per unit area). Without a proper heat load calculation to determine the building envelope thermal performance and heat load profile, designer do not have enough information for decision making during the building design stage as a result mechanical and electrical consultant overdesign on the building system. Moreover, architect do not allocated enough design effort on the building envelop thermal performance. As a result, the construction and operation cost increase. Overall thermal transfer value (OTTV) calculation need to be done during building envelope design and materials selection. Such information need to be considered while designing the air conditioning system. In order to obtained heat load profile, energy consumption and cost analysis has to be carried out properly to achieved final decision.

1.3 Objective

The objectives of this study are as follows:

1. To obtain overall thermal transfer value (OTTV) for a commercial building with various sets of building envelop configuration and design.
2. To obtain building heat load profile and peak load of building space and plant room for a commercial building with various sets of building envelop configuration using hourly analysis programme (HAP).
3. To calculate and compare the energy consumption and return of investment (ROI) for various sets of building envelop configuration and air conditioning system. Heat load profile obtained from HAP is applied. ROI obtained will help to select most suitable building envelop configuration and air conditioning system design.

1.4 Chapter Organisation

This thesis is divided into 5 chapters. Chapter 1 introduce the background and objectives of the study. Chapter 2 is about the literature review on the previous research which related to the project in various areas. This will help to give a better understanding about project contents before dealing with the calculation and simulation. Chapter 3 describes the methodology needed for the project which include; how to extract the information from the floor plan and others specification. Format of OTTV calculation and summary of data need to define in to the hourly analysis programme. Chapter 4 gives the results and discussion of the OTTV, heat load profile. There are also discussion on difference building envelop configuration and air conditioning design that suitable base on the energy consumption and Return of Investment (ROI) obtained. Last but not least, Chapter 5 is the overall conclusion of the project. Furthermore, there are recommendations of future works is given as well.

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