Energy efficient strategies for JSX building in Jakarta, Indonesia

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ABSTRACT

Regular escalation of the state electricity price gives an impact to the increase of operational cost of any high-rise building in Indonesia. To be a rental office, the twin 31-floor buildings of Jakarta Stock Exchange (JSX) or Bursa Effect Jakarta (BEJ - in Indonesian terms) had no exception. The twin buildings were suffered from the impact of the state electricity price escalation. To reduce the bill, the building manager had to reduce the buildings' energy consumption, and to consider tenants' necessities for indoor comfort at the same time. To do this, a number of strategies had been employed in the buildings. However, one of the most successful strategies was that by setting chilled water temperature of the central air-conditioned system, 1°C higher. By employing this strategy, building electricity bill had been reduced into some extent, whilst at the same time indoor thermal conditions had been maintained comfortable. This paper discusses the above matter and shows the way the buildings reduce their energy consumption without sacrificing occupants' thermal comfort.

1. INTRODUCTION

1.1 Background

A number of rental office buildings in Jakarta have adopted the US standard for thermal comfort (ASHRAE 55-1992). They provide the indoor temperatures to be between 22 and 25°C T_o as recommended by the standard to meet comfortable indoor environment, which was originally intended for the American people during the summer.

Even though, many buildings were putting their indoor temperatures even lower. It could be 21 to 23°C or less. This has created some problems for the buildings. The buildings have to pay more electricity bills than that when indoor temperatures were higher. A thermal comfort study done by Karyono (1995) revealed that the predicted mean vote (PMV) measured by a thermal comfort meter was higher than the subjects' actual mean vote (AMV), and this has created higher building energy consumption.

A number of thermal comfort studies in the humid tropical region show that people were still tolerated to the higher thermal conditions (Tanabe and Kimura, 1987; Busch, 1990; de Dear et al, 1991; Karyono, 1996a,b). A thermal comfort study done by Karyono in Jakarta (Karyono, 2000) shows that most of the office workers were found to be still comfortable in the room temperatures between 26.7 and 28.6°C. Nicol (2002) argued that international thermal comfort standards might not fit tropical buildings. They propose lower temperatures than what the tropical people need.

1.2 Aims of study

The aim of this study is to find out the way to reduce energy consumption in the Jakarta Stock Exchange (JSX) building without sacrificing occupants' thermal comfort. They are several ways to do so. However, this study attempts only to achieve the goal by means of modifying the chilled water temperatures at the building air conditioning (AC) system.

To assess whether occupants were still comfortable with their thermal environment when the chilled water temperatures were changed, thermal comfort assessment was then conducted.

2. THEORITICAL ANALYSIS

In general, reducing cooling load in building can only be done by means of a modification on its envelopes, like installing sun's shading devices. It is likely impossible to reduce cooling load from internal loads, such as from human bodies, artificial lighting, electricity appliances, etc. Modification on building's AC system like shifting up indoor air temperatures as this study attempted to, on the other hand, will take a risk in creating discomfortable indoor environment.

Study on building energy use in 12 multi-story rental office buildings in Jakarta between 1999 and 2000 by Bahri (Bahri, 2001) shows that, on average, about 50% energy were used for AC system, 36% for lighting and fittings, 11% for elevators and other buildings' mechanical equipments, and the rest of 3% for others needs.

Considering the above finding, any attempt to reduce building consumption in its AC system – which make about 50% to the average of total building energy consumption, would be of valuable

3. METHODOLOGY

Since this study is looking for practical strategies to reduce building energy consumption without sacrificing occupants' thermal comfort, any attempt to achieve the goal must be considering the total amount of energy to be saved, and also the levels of occupants' thermal comfort to be achieved.

The main point to be highlighted in this study is the role of chiller, as part of the central air conditioning system (Fig. 1). The JSX building used a water-cooled chiller, with a cooling capacity of 900 TR (ton refrigeration) and was refrigerated by R-134a refrigerant liquid.

Chiller received circulated chilled water from cooling coils of air-handling unit (AHU) plants as 'chilled water return' (CHWR), with temperature of about 13.5°C. This water is then circulated through refrigerant plant to reduce its temperature to be about 5.5°C. This chilled water is ready to be sent to the cooling coils of AHU to cool the office rooms, and is called a 'chilled water supply' (CHWS). After absorbing

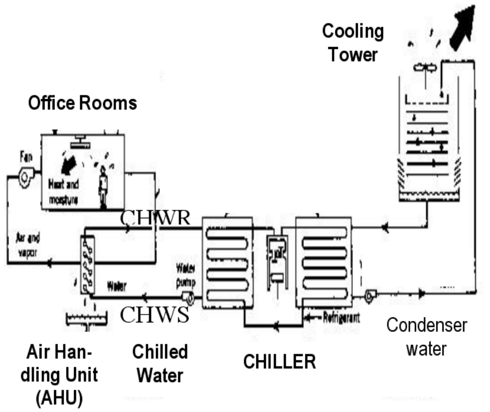

Figure 1: Central air conditioning system of the buildings (Stein et al., 1986).

some heat from the AHU plants, this water is again circulated back to the chiller as CHWR and the cycle moved on.

This closed chilled water cycle will be the main intention of this study. The rise of CHWS temperatures will reduce buildings' energy consumption, since the refrigeration plants will absorb less heat from the chilled water cycle.

3.1 Reducing building cooling load by shifting up chilled water temperature

The current temperatures setting of the CHWS in these buildings was 5.5°C. This setting will be shifted up to 5.5°C and then to 6°C to see how much energy in the building can be reduced, and how many degrees centigrade the indoor air temperature will be affected. Shifting up CHWS temperatures will affect to the increase of blowers' rotation speeds at the AHU plants. There will be a maximum speed of rotation in which further increase of CHWS temperatures will no longer affect its rotation. At this point, any increase of CHWS temperature will raise rooms' temperatures markedly, which may create unwanted thermal environments for the occupants. Considering this fact, shifting up CHWS temperatures should be limited at a point where AHU blower reaches its maximum rotation speed.

In the case of JSX buildings where many occupants were expatriates who came from cold countries, shifting up CHWS temperatures is not allowed to be affecting to the raise of room temperatures over than 24°C, Changing CHWS setting temperatures was done from the chiller control panels' room. Along with this, outdoor temperatures were measured by means of sling thermometer to get the dry and wet bulb temperatures.

3.2 Measuring occupants' thermal sensations

To check whether shifting up CHWS temperatures by 1^{o}C may create such a discomfortable environment for the occupants, a thermal comfort assessment was carried out to measure occupants' thermal comfort. Seven-scale thermal sensation votes recommended by ISO-7730 (ISO, 1994) were distributed to 30 subjects to see their thermal responses.

3.3 Measuring rooms' luminance levels

To make sure that buildings were performed well in providing all physical comforts, indoor luminance levels were also measured. A digital lux-meter had been used for this purpose. The indoor luminance values were not further analysed to draw any conclusion in this study. The measurement was intended only to see whether reducing energy consumption in these buildings did not sacrifice occupants' visual comfort.

4. DATA AND ANALYSIS

This study was carried out between 1999 and 2001. Each of the twin buildings comprise of 31 floors. Each floor had 2,400 m^2 in size that made a total floor area of the twin buildings was 146,700 m^2. Monthly buildings' energy consumption measured between June 1999 and May 2000 was 2175 MWh/month or about 22.7 kWh/m^2/month.

4.1 Outdoors' climatic parameters

Outdoors air temperatures were recorded in three categories: slightly below 29^{o}C (early office hours, 8.00 to 10.00 hours), between 29 and 31^{o}C (from 10.00 to 12.00 hours.), and between 31 and 33^{o}C (after 12.00 to 16.00 hours). The amount of energy being saved was a function of the outdoors' temperatures and the values of CHWS temperatures. When the CHWS temperatures were shifted up, degrees of changes on indoor temperatures was also depended on the outdoor temperatures. Figure 2 and 3 show the correlation amongst them. The outdoor relative humidity were found to be between 80 and 85%.

4.2 Indoors climatic parameters

By using a sling thermometer and a digital anemometer, dry and the bulb temperatures were measured along with the indoor air velocities. All measurements were taken in all floors.

Eight spots at each floor were taken for the DBT, WBT and air velocity measurements. The measurements were taken along with the shifting up of CHWS temperatures. There were three groups of indoor climatic parameters' values: (a) when CHWS temperature was 5.5^{o}C, (b) when CHWS temperature was 6.0^{o}C, and (c) when CHWS temperature was 6.5^{o}C.

The average air velocities measured in those spots were between 1.0 and 2.0 m/s. By using a psychometric chart, the mean rooms' relative humidity was found to be between 55 and 60%.

The range of indoor's luminance level of these buildings were between 300 and 500 lux which felt within the standard of a luminance level for office buildings.

4.3 Thermal sensation votes

Due to the problem of working privacy, only 30 office workers working in these buildings were asked to give their thermal sensation votes. Subjects were sitting separately in various floors, were comprised of 21 males and 9 females. There were 11 respondents under 40 years of age, while the rest of 19 were over 40 years. The mean clothing values of subjects was estimated to be 0.7clo on average, and the mean metabolic rate was about 1.0 met. Assessing 30 subjects for their thermal votes, the actual mean vote (AMV) of the subjects was found to be -

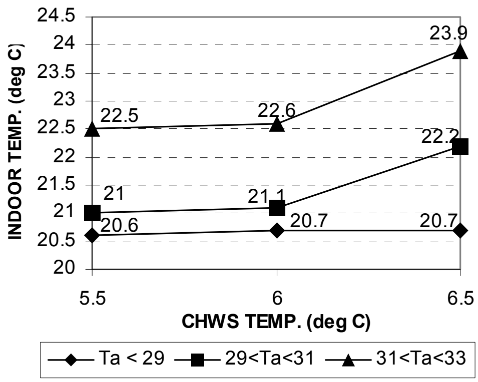

Figure 2: Indoor temperatures as a function of CHWS and ambient temperatures.

0.17, which means they were on the state of comfortable (AMV ± 0.5 is comfortable).

4.4 Shifting up chilled water and its affect to indoors air temperatures

Figure 2 shows the indoor temperatures as a function of CHWS and ambient temperatures. From this figure it can be seen that indoor temperatures were increased along with the increased of the CHWS temperatures and the ambient temperatures.

When ambient temperatures were slightly below 29°C, an increase of 1°C of CHWS temperatures (from 5.5°C to 6.5°C) affected to the increase of indoor temperatures from 20.6 to 20.7 (0.1°C up). In the ambient temperatures of between 29 and 31°C, shifting up 1°C of CHWS temperatures had increased the room temperatures from 21.0 to 22.2°C (1.2°C up). When the ambient temperatures were between 31 and 33°C, shifting up 1°C of CHWS temperatures had increased the indoor temperatures from 22.5 to 23.9°C (1.4°C up).

4.5 Shifting up chilled water and its affect to buildings' energy consumption

Figure 3 shows the hourly JSX buildings energy consumption as a function of CHWS and ambient temperatures (T_a)

From Figure 3 it can be seen when the outdoor (ambient) temperatures were slightly below 29°C, an increase of 1°C of CHWS temperatures had affected some energy reduction of 51 kW per hour. When ambient temperatures were between 29 and 31°C, shifting up 1°C of CHWS temperatures had reduced buildings' energy consumption by about 44 kWh per hour. While in the presence of ambient temperatures between 31 and 33°C, shifting up 1°C of CHWS temperatures had reduced around 101 kWh per hour buildings energy consumption. On average, shifting up CHWS temperatures by 1°C (from 5.5°C to 6.5°C) had reduced about 65.3 kWh energy consumption per hour in these buildings.

By assuming that during office hours throughout the year the ambient temperatures were between about 29 and 33°C, and the working hours is 10 hours a day for 25 days per month, shifting up 1°C of CHWS temperatures would reduce around 16250 kWh monthly. Considering the average total energy consumption in these twin buildings was 2.175 MW per month, the shifting up 1°C of CHWS temperatures would reduce some 7.5% of the total buildings energy consumption monthly.

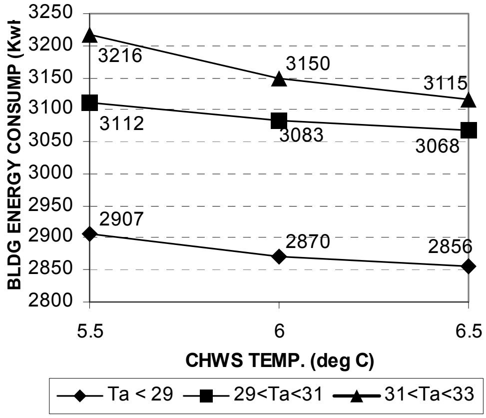

Figure 3: The hourly JSX buildings energy consumption as a function of CHWS and ambient temperatures (T_a).

5. CONCLUSIONS

Indoor temperatures were slightly increased by the shifting up of CHWS temperatures. The increase was small (0.1°C) when the ambient (outdoor) temperatures are low (at about 29°C), and it's getting higher (1.4°C) when the ambient temperatures are high (between 31 and 33°C).

By shifting up 1°C of CHWS temperatures, the lower the ambient temperatures, the lower the energy would be saved in the buildings. At lower ambient temperatures of about 29°C, an increase of 1°C of CHWS temperatures had reduced about 51 kWh as much energy per hour in the buildings. Whilst, at the ambient temperatures of between 29 and 31°C, shifting up 1°C of CHWS temperatures had reduced about 44 kWh per hour its buildings' energy consumption. At the ambient temperatures of between 31 and 33°C, shifting up 1°C of CHWS temperatures had reduced about 101 kWh per hour its buildings' energy consumption. On average, shifting up CHWS temperatures by 1°C (from 5.5 to 6.5°C) had reduced about 65.3 kWh energy consumption per hour in the buildings or about 16250 kWh per month, or about 7.5% of the total buildings energy consumption per month.

There are still some opportunities to reduce more energy in these buildings since this study was restricted to the increase of indoor temperatures below 24°C.

A thermal comfort study by Karyono (2000) in some selected multi-story office buildings in Jakarta showed that 90% subjects who worked in those buildings were still felt comfortable at the indoor temperature of 28.4°C. Therefore, shifting up indoors temperatures higher might be still tolerable, and it would save more energy in these buildings.

This study also shows that when CHWS temperature was shifting up by 1°C (from 5.5 to 6.5°C) subjects' actual mean vote (AMV) was -0.17. This means that there is still an opportunity to shift indoor temperature up until a certain point in which subjects' AMV would reach +0.5 (upper limit of comfortable range), and this would reduce more energy for cooling in these buildings.

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