Hotel Design and Energy Consumption

Bin Su

Abstract—A hotel mainly uses its energy on water heating, space heating, refrigeration, space cooling, cooking, lighting and other building services. A number of 4-5 stars hotels in Auckland city are selected for this study. Comparing with the energy used for others, the energy used for the interior space thermal control (e.g. internal space heating) is more closely related to the hotel building itself. This study not only investigates relationship between annual energy and energy consumption and building design data but also relationships between winter extra energy consumption and building design data. This study is to identify the major design factors that significantly impact hotel energy consumption for improving the future hotel design for energy efficient.

Keywords—hotel building design, building energy, building passive design, energy efficiency.

I. INTRODUCTION

HOTELS are the big energy users, and are thus likely to gain the greatest benefits from improved energy efficiency (Issacs 1996). The previous study showed that an average hotel used most of its energy on heating and refrigeration in New Zealand. An average hotel used its energy on space heating (31%), water heating (22%), refrigeration (9%), cooking (12%) and lighting (3%). Average annual energy consumption per bed (22167MJ) is more than other accommodation categories such as Bed and Breakfast (11200MJ), motel (5122MJ), and Backpacker (7613MJ) [1].

For minimizing impacts of different hotel facilities and climates, a number of Auckland 4-5 stars with a central air-conditioning system for space heating and cooling, which use both electricity and gas, are selected for this study.

This study focuses on the relationships between hotel building designs and energy consumption.

II. ENERGY CONSUMPTION DATA

Table 1 shows energy consumption data of sample hotels. The sample hotels annually use more electricity than gas. The sample hotels use 17% more energy per guestroom during winter than summer. In account of room occupancy, the hotels use 40% more energy per guestroom during winter than summer. Fig. 1 shows the mean occupancy of the sample hotels. The summer mean occupancy (73%) is higher than winter (61%) of the sample hotels. The sample hotels variously use 19% more energy during winter than summer.

Total winter months' energy consumptions of all the hotels are more than 25% of total annual energy consumption for the 25% time of year (see Fig. 2). Total three summer months' energy consumptions of all the hotels are less than 25% of annual total energy consumption for the 25% time of year (see Fig. 3).

The mean ratio of total winter energy to total annual energy is 28% and the mean ratio of total summer energy to total annual energy is 23% for the 25% time of a year. The mean winter energy consumption per guestroom during the winter is 17% more than summer when the winter occupancy is lower than the summer occupancy. Tailing the occupancies into account, the mean winter energy consumption per guestroom during the winter is 40% more than summer. Generally the Auckland summer is comfort as the summer temperatures are rarely over 28°C. Auckland has a temperate climate with comfortable warm and dry summer, the summer temperatures are rarely over 28°C, and mild and wet winters, the winter temperatures are rarely below 5°C. Using 17°C as a base temperature, Auckland Heating Degree Days is 1017 and Cooling Degree Days is 381 [3]. Commonly an Auckland building uses more energy during the winter than summer as the space heating energy consumption is more than the space cooling energy consumption for thermal controls. The Auckland hotel building thermal design should more focus on winter thermal performance and indoor thermal comfort for energy efficiency [4].

The national and international energy surveys for the hotel sector commonly use kWh/room/year as the units to present the energy used in the hotels. The mean energy data use per room in the national energy survey can be used to show the general profile of energy used in the hotel business. Using different units to compare the energy used in different hotels may lead to different results. The question is what energy unit is appropriate to be used to present or compare energy consumptions or energy efficiency related to the different hotel building designs, especially to compare the energy used for internal space heating and cooling. The mean energy used for space heating and cooling per unit of the volume indoor space is more appropriately used for the comparison of building thermal design for energy efficiency. This study uses annual and winter consumption per m² of indoor space per day (kWh/m²/day) as basic energy data for this study, and also uses the difference of energy consumption in winter months and other months, which represents extra winter energy consumption mainly including space heating energy and other extra energy consumption related to the winter indoor thermal conditions.

III. BUILDING DESIGN AND ENERGY DATA

A. Ratio of Building Surface to Volume

The ratio of building surface to volume of sample hotels are in the ranges of 0.045 to 0.372 with a mean ratio of 0.124. Only two hotels' ratios are higher than 0.3 [5]. The ratio of building surface to volume for a multi-story residential building with the permanent heating should be less than 0.3 for saving space heating energy. An increase in annual and winter energy consumptions is associated with an upward trend in the ratios of building surface to volume of the sample hotels (see Fig. 4-5). An increase in extra winter energy consumption is associated with an upward trend in the ratios of building surface to volume of the sample hotels (see Fig. 6). A building with a low ratio of building surface to volume has a small external surface area per unit of indoor space from which to lose heat to the outdoors, and uses less energy for space heating and other appliances, which can be affected by indoor thermal conditions during the winter.

An increase in summer energy consumption is associated with an upward trend in the ratios of building surface to volume of the sample hotels (see Fig. 7). A building with a low ratio of building surface to volume has a small external surface area per unit of indoor space from which to get heat gain to the indoors, and uses less energy for space cooling during the summer.

An increase in ratio of winter to annual energy is associated with an upward trend in the ratios of building surface to volume of the sample hotels (see Fig. 8). An increase in ratios of summer to annual energy is associated with a downward trend in the ratios of building surface to volume of the sample hotels.

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Table 1: Energy Consumption Data of Hotels

<table>
<thead>
<tr>
<th>Energy</th>
<th>Mean</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual total</td>
<td>50932985 kWh</td>
<td>529431107 kWh</td>
</tr>
<tr>
<td>Annual per room</td>
<td>200319 kWh/room</td>
<td>205352 kWh/room</td>
</tr>
<tr>
<td>Winter/summer</td>
<td>27.8%</td>
<td>20.5%</td>
</tr>
<tr>
<td>Winter per m²</td>
<td>70 kWh/m²</td>
<td>25-148 kWh/m²</td>
</tr>
<tr>
<td>Summer per m²</td>
<td>530 kWh/m²</td>
<td>217-1000 kWh/m²</td>
</tr>
<tr>
<td>Summer per room</td>
<td>1360 kWh/room</td>
<td>500-2150 kWh/room</td>
</tr>
<tr>
<td>Summer per m²</td>
<td>35 kWh/m²</td>
<td>21-101 kWh/m²</td>
</tr>
<tr>
<td>Heating month/annual</td>
<td>45%</td>
<td>42-47%</td>
</tr>
</tbody>
</table>

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Fig. 1 Occupancy of sample hotels

Fig. 2 Ratio of total winter to annual energy consumptions

Fig. 3 Ratio of total summer to annual energy consumptions

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hotels (see Fig. 9). As winter energy consumption is a larger portion of annual energy consumption, it results in increase of total annual energy consumption.

B. Ratio of Wall Area to Building Volume

The ratios of wall to building surface area are in the ranges of 54% to 93% with a mean ratio of 77%, which is significantly higher than the mean ratio of 53% of home houses, based on the research related to the 200 Auckland houses [6]. As the wall area is the major portion of building surface area of sample hotels, an increase in annual winter and extra winter energy is also associated with an upward trend in the ratio of wall area to building volume of the sample hotels, which is similar as ratios of building surface to volume (see Fig. 10-12). The roof area is the smaller portion of building surface area to compare with the wall area. The upward heat loss through hotel roof is protected by the floor structures. The wall for most guestrooms is the only external wall for heat exchange with outdoor. Comparing with the roof, the wall thermal design more significantly impacts indoor thermal condition and energy efficiency for a multi-story hotel building.

C. Ratio of North Wall to Total Wall

The building with a good orientation has higher ratio of north wall to total wall area. There are not clear and strong relationships between annual, winter and extra winter energy consumption data and ratios of north wall to total wall (see Fig. 13-15). An increase in annual, winter and extra winter energy is not associated with a downward trend in the ratios of north wall to building volume of the sample hotels (see Fig. 16-18). A hotel building with large north wall area has more exposure surface area to the sun and also increasing surface area to lose heat. As the daily sun hours are much shorter than the nighttime and hotel building is thermally controlled by air-conditioning system, the negative impact of increasing north wall surface area to increase heat loss could weaken or override the positive impact of increasing north wall surface area to get more sun heat.

D. Ratio of Window to Wall Area

A window is commonly weak area with a much lower R value than the wall, which can negatively impact the indoor thermal conditions. An increase in annual and winter energy is associated with an upward trend in the ratios of north wall to building volume of the sample hotels (see Fig. 19-20). An increase in annual and winter energy is associated with an upward trend in the ratios of north wall to building volume of the sample hotels (see Fig. 21). An increase in annual and winter energy is associated with an upward trend in the ratios of north window to north wall of the sample hotels (see Fig. 22-23).

E. Ratio of Roof Area to Building Volume

For a multi-story hotel building design, the ratio of roof area to building volume decreases with increase of height of building. An increase in annual and winter energy is associated with an upward trend in the ratios of roof area to building volume of the sample hotels (see Fig. 24-25). Increasing the ratio of roof area to building volume can increasing the negative impact on winter indoor thermal conditions, which could result more winter and annual energy consumption.
Fig. 16 Annual energy and ratios of north wall to building volume

Fig. 17 Winter energy and ratios of north wall to building volume

Fig. 18 Extra winter energy and ratios of north wall to building volume

Fig. 19 Annual energy and ratios of window to wall area

Fig. 20 Winter energy and ratios of window to wall area

Fig. 21 Summer energy and ratio of window to wall area

Fig. 22 Annual energy and ratio of north window to north wall area

Fig. 23 Winter energy and ratio of north window to north wall area

Fig. 24 Annual energy and ratio of roof area to building volume

Fig. 25 Winter energy and ratio of roof area to building volume

REFERENCES

(1) S. Beattie, Energy use in the New Zealand accommodation sector, Lincoln Research and Tourism Research and Education Centre (LREC), Lincoln University, 2000.

(2) N. Iacono and N. Crocker, Commercial building energy survey: hotel, Centre for Building Performance Research, Victoria University of Wellington, 1996.

(3) L. Lind, "Ground Source Heat Pump Case Study (2010 Revision)," GNS Science Report 2010154. 35p.


IV. CONCLUSION

According to the monthly electricity and gas energy consumption data of 18 sample hotels, the mean total winter energy consumption, the mean winter energy consumption per room and the daily mean winter energy consumption per unit of indoor space are more than the summer when the mean winter occupancy is lower than the summer. An Auckland hotel building thermal design should more focus on the hotel winter thermal performance than the summer.

Actual monthly energy consumption and building design data of hotels can be used to investigate relationship between energy consumptions and building design data and identify the major design factors that significantly impact the hotel building thermal performance responded to the local climate and building energy consumption based on daily energy consumption data per cubic meter of indoor space volume.

For the multi-story 4-5 stars hotels with a regular or squarish form, and air-conditioning system, comparatively the ratio of building surface to volume is a more important design factor, which significantly impacts on building indoor thermal condition and energy efficiency. Reducing the surface area per unit indoor space should be a focus for hotel building thermal design for energy efficiency. The wall area is more important surface area for hotel indoor thermal comfort and the wall thermal function is critical for the hotel building thermal design for energy efficiency. Window area is weak thermal resistance surface area with a low R value. Ignoring window thermal design could damage the entire hotel building thermal design in terms of energy efficiency.