Study on building performance considering climate characteristics for university facility in Japan

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Abstract. This study was investigated the building performance of each area for university facilities. The purpose is to propose optimal building performance for each area. As the background, the target building needs the energy-saving renovation. The target building has been built for 25 years and aged. In addition, the primary energy consumption of the target building is larger than the primary energy consumption of standard university facilities. Therefore, it is necessary to renovate buildings and facilities, and plans should be made to save more energy. This research method was examined changing the building performance for each area by using the Building Energy Simulation Tool (BEST) program of the energy simulation. Building performance is the thermal insulation of the outer wall and the type of glazing. As a result, In Ube, primary energy consumption tends to increase if thermal insulation performance is increased too much. In Sapporo, primary energy consumption tends to decrease as thermal insulation performance increases. In Naha, it turned out that increasing the thermal insulation performance is not effective.

1. Introduction
In Japan, more than 30% of the energy consumption is ultimately consumed by consumer appliances related to human activities. The building field is also human activity. The increase of energy consumption in this sector is larger than the increase in other sectors, therefore the promotion of energy conservation in this sector is importance. Building performance is greatly related to energy consumption. In addition, it is necessary to choose suitable building performance depending on the location and climate of the building. This study was investigated the building performance considering climate characteristics for the research building of the university by using the BEST program of the energy simulation.

2. Overview of target building
2.1. Overview of building
Photograph 1 shows the outer appearance of the building. Table 1 shows an overview of the building. The area of the building was 992m² and the total floor area was 6450m². The structure was RC construction, with 8 floors above ground and a basement. There was an entrance hall on the ground floor, part of which contains a stair well leading up to the second floor. The first and second floors used for holding meetings and discussions. The third floor and up used for conducting research and experiments. The target building has been built for 25 years and aged. Also the primary energy consumption of the target building was 1305 [MJ/m² • year](confirmed results for 2014). This is larger than the primary energy consumption of standard university facilities in Japan.
2.2 Overview of Equipment

Table 2 gives an overview of the equipment the building is furnished with and Table 3 gives an overview of the equipment used for heat source the building. The system run by a pair of heat pumps and a thermal storage tank. The cooling capacity of the heat pumps was 359 [kW] and the heating capacity was 294 [kW]. Hot/cold water volume was 735 [l/min]. COP at the time the heat pumps were designed was 2.38 for cooling and 1.95 for heating. The capacity of the thermal storage tank was 1700 [m³]. The air conditioning system includes a fan coil unit in each room. The ventilation system consists of No. 1 ventilation unit in the rooms and No. 3 ventilation unit in the restrooms. The lighting system consists primarily of fluorescent lighting equipment. There was one elevator that accommodates 15 people with a load capacity of 1000 [kg].

### Table 2. Overview of the equipment

| Heat source          | heat pump          | Thermal storage tank |
|----------------------|--------------------|----------------------|
| Air conditioning     | Fan coil unit      |                      |
| Ventilation          | No. 1 ventilation unit in the rooms | No. 3 ventilation unit in the restrooms |
| Lighting             | Fluorescent lighting |                    |
| Elevator             | One                | load capacity:1000 kg |

### Table 3. Overview of the heat pump

| Heat pump ability |   |
|-------------------|---|
| Cooling capacity : 359kW (outside temperature 33.3°C(DB), 60.4%(RH)) | Heating capacity : 294kW (outside temperature -4.0°C(DB)) |
| Hot/cold water volume : 735 l/min (cold water 13→6°C)(hot water 40→47°C) |

3. Overview of target areas

3.1 Location of target areas

In this study, because the weather data of Ube in Yamaguchi where the target building is located is insufficient, the weather data of Hofu in Yamaguchi with the most similar climate is used instead. Therefore, this study was examined three areas: Hofu in Yamaguchi, Sapporo in Hokkaido, which is a cold region, and Naha in Okinawa, which is a hot region. The locations of each region in Japan are shown in Figure 1 and 2. Sapporo is located in the northern part of Japan, and Naha is located in the southern part of Japan. Hofu and Ube are located slightly south of the center of Japan.
3.2. Climate characteristics of the target areas

Figure 3 and 4 show the average temperatures for Ube, Hofu, Sapporo, and Naha for each year (2009 to 2018) and month. Ube and Hofu were almost the same climate. Sapporo was an average temperature lower than other regions throughout the year, and the average temperature is below 0 [°C] in winter. Naha was the average temperature higher than other regions throughout the year, and the average temperature is exceeding 15 [°C]. Figure 5 and 6 show the total daylight hours for Hofu, Sapporo and Naha for each year (2009 to 2018) and month (There is no data of total daylight hours of Ube). Sapporo has less total summer daylight hours than other areas. In addition, Hofu has more summer daylight hours than other areas. From this, the average temperature in July and August in Hofu and Naha is almost the same because the total sunshine duration in July and August in Hofu is larger than that in Naha.
4. Examination of building performance

4.1. Overview of simulation
This study was examined the building performance using the BEST program of the energy simulation. Table 4 shows the version of the software and the manual. Table 5 shows the current building performance of the target building. The current building performance of the target building is single glazing 3 mm and the thermal insulation 25 mm for asphalt felt.

Table 4. The version of the soft and the manual

| The BEST program | Design tool                        |
|------------------|-----------------------------------|
| Soft             | The BEST program Design tool Ver3.0.0 (November, 2018) |
| Manual           | Manual of the BEST program Design tool (November, 2018) |

Table 5. Current building performance of the target building

| Building performance | Thermal transmittance(W/m²•K) |
|----------------------|------------------------------|
| Grazing type         | Single glazing 3mm           |
| Thermal insulation   | Asphalt felt 25mm            |

4.2. Examination conditions
Table 6 and 7 show the types of building performance each thermal transmittance in this simulation. We examined four types of grazings (B to E) and six types of grazings eight types of thermal insulations (① to ⑧). Multi-layer glazing was used and thickness of asphalt felt was changed in this study.

Table 6. Type of Grazing and thermal transmittance in this simulation

| Condition | Grazing type                                      | Thermal transmittance (W/m²•K) |
|-----------|---------------------------------------------------|-------------------------------|
| A         | Single glazing 3mm                                | Transparent Glazing 4.21      |
| B         | Multi-layer glazing 6mm (Air layer)               | High solar shading Low-E glazing 2.11 |
|           |                                                   | Transparent Glazing           |
| C         | Multi-layer glazing 6mm (Argon layer)             | High solar shading Low-E glazing 1.73 |
|           |                                                   | Transparent Glazing           |
| D         | Multi-layer glazing 12mm (Air layer)              | High solar shading Low-E glazing 1.47 |
|           |                                                   | Transparent Glazing           |
| E         | Multi-layer glazing 12mm (Argon layer)            | High solar shading Low-E glazing 1.16 |
|           |                                                   | Transparent Glazing           |
Table 7. Type of thermal insulation and thermal transmittance in this simulation

| Condition | Asphalt felt (mm) | Thermal transmittance (W/m²·K) |
|-----------|------------------|--------------------------------|
| 0         | 25               | 4.2                            |
| 1         | 50               | 1.44                           |
| 2         | 75               | 1.09                           |
| 3         | 100              | 0.87                           |
| 4         | 125              | 0.73                           |
| 5         | 150              | 0.62                           |
| 6         | 175              | 0.55                           |
| 7         | 200              | 0.49                           |

4.3. Simulation result

Figure 7 shows the primary energy consumption of the building and the actual value (2014) in the current building performance. In the case, Ube is 1240.9 [MJ / m²·year], Sapporo is 1298.5 [MJ / m²·year] and Naha is 1218.6 [MJ / m²·year]. Figure 8 to 10 show the primary energy consumption of air conditioners in the study results by region. As a result, Ube is the smallest combination of Thermal insulation ④ and grazing type C, 506.9 [MJ / m²·year]. In Ube, primary energy consumption tends to increase if thermal insulation performance is increased too much. Sapporo is the smallest combination of Thermal insulation ⑧ and grazing type C, 557.0 [MJ / m²·year]. In Sapporo, primary energy consumption tends to decrease as thermal insulation performance increases. Naha is the smallest combination of Thermal insulation 0mm and grazing type A, 493.0 [MJ / m²·year]. In Naha, it turned out that increasing the thermal insulation performance is not effective.

![Figure 7. Energy consumption of the building](image)

![Figure 8. Air-conditioning (Ube)](image)

![Figure 9. Air-conditioning (Sapporo)](image)

![Figure 10. Air-conditioning (Naha)](image)
5. Discussion
This study is only four types of glazings, so it is necessary to consider more types in the future. For example, making a high solar shielding glazing into a high solar acquisition glazing is mentioned. In addition, I changed the building performance with the current air conditioning equipment. Therefore, primary energy consumption may vary the area by the type of heat source equipment of the same capacity. For example, although the heat source equipment of the target building was a heat pump, its use in a cold area may reduce the efficiency. Therefore, it is necessary to select not only building performance but also optimal equipment by the region.

6. Conclusions
This study considered the characteristics of the region for the university research building and examined the optimum building performance. From the meteorological data, we grasped the regional characteristics of Ube and Hofu in Yamaguchi, Sapporo in Hokkaido, which is a cold region, and Naha in Okinawa, which is a heat region. Moreover, the optimum building performance for each area was determined from the examination by simulation. In addition, the correlation between building performance and primary energy consumption in each region was clarified.

References
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