論文の内容の要旨

論文題目

Integrated Analysis of Thermal Environment and Building Energy Use by Microclimate Simulation

(微気候シミュレーションを用いた熱環境と建物のエネルギー消費の統合的解析)

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This study is interested in how the heat rejection from air conditioners affects the outside thermal environment and the electricity consumption of air conditioners themselves. Thermal simulation and building energy analysis are carried out for nighttime and daytime individually. In order to estimate the feedback of the heat rejection to the cooling load, two software, EnergyPlus building energy program and Windperfect CFD software, are used in this study. It starts from EnergyPlus to estimate the heat rejection and energy consumption of buildings hourly. Then, the weather data of initial time point and the amount of heat rejection is input to Windperfect hourly to analyze the temperature distribution outside the buildings. Finally, the additional electric consumption of air conditioners caused by heat rejection from condensers is predicted by EnergyPlus again.

According to the survey of air conditioning use, the total amount of heat rejection from buildings in DaAn Ward on a summer day was shown on a map by cells with the resolution of 10m by 10m. The total heat rejection on a summer day in DaAn ward was found concentrated in the commercial zones of ChungHsiao, XiYin and HePing E. roads, and high-rise buildings on DunHua S. road. However, in the case of residential buildings, RenAi road and ChengYi, DaAn, and ChengKung public houses contributed large portion of heat rejection. Based on the heat rejection map, the Cheng-Kung public house, which is one of the typical types of public houses in Taiwan, is selected as the focus area to discuss the effect of heat rejection on cooling load in summer. The characteristics of the Cheng-Kung public house are high-rise building with high population density and the buildings there are equipped with lots of window type air conditioners.

The internal heat generation from lighting, house appliances and inhabitants plays an important role in heat balance of the residential buildings. The heat accumulated inside the buildings is

discharged outside when indoor space is cooled by air conditioners. In the nighttime case, three specified temperature were evaluated here to clarify the thermal environment around buildings. They are: (1) T_{am}, the ambient air temperature, (2) T_{ac}, the air temperature around air conditioners and (3) T_{bu}, the air temperature next to building envelope. The air around cooling systems that enters condensers directly affects the temperature of air discharge outside. The temperature next to building envelope has a key role in determining the building energy. The ambient air temperature within the urban canopy is of interest in this study. During daytime, the outside air temperature increased mainly due to two factors, convective heat from the surface of buildings and heat rejection from air conditioners. However, this study discusses the influence from the factor of heat rejection. In addition to the ambient temperature, the temperature increases on four sides of the buildings due to the heat rejection from air conditioners were analyzed.

The thermal environment became worse after sunset in the residential area since the people turns on the air conditioner after going home in summers. It was found from the simulation results that the average temperature around buildings increased gradually from 0.78°C (19:01-20:00) to the peak of 1.84°C (23:01-24:00) and reduced to 0.87°C (01:01-02:00). The feedback (penalty) of heat rejection to air conditioning load of the window type AC during 19:01-02:00 was 6.70 W/m^2, which was 10.7% of the total amount of heat rejection without considering the influence of heat rejection from air conditioners. The maximum increase of electric power for cooling was also found during 23:01-24:00 and the minimum was observed during 19:01-20:00.

Few people are at home and the percentage of people using air conditioner is much lower during daytime compared to the nighttime situation. However, solar radiation increases the surface temperature as well as the convection heat and then the temperature of air entering air conditioners increases. It was found from the simulation results that the average temperature around buildings increased gradually from 0.31°C (10:01-11:00) to the peak of 1.01°C (13:01-14:00) and reduced to 0.46°C (16:01-17:00). The feedback (penalty) of heat rejection to air conditioning load of the window type AC during 10:01-17:00 was 0.89 W/m^2, which was 3.8% of the total amount of heat rejection without considering the influence of heat rejection from air conditioners. The maximum increase of electric power for cooling was also found during 13:01-14:00 and the minimum was observed during 10:01-11:00.

Mitigation scenarios from the viewpoint of heat rejection management (1-3) and latent heat (4-5) were proposed to improve the thermal environment and alleviate the demand of building energy use. (1) N-S1 scenario: Split type air conditioners on each floor, (2) N-S2 scenario: Split type air conditioners every three floor. The same as a window type air conditioner, a split air conditioner absorbs the air nearby the condenser and exhaust heat outside by fan. The heat rejection of window/split type air conditioner is a process of sensible heating, adding heat from air without changing its humidity ratio. On the other hand, (3) N-CT scenario: Cooling towers on top of the buildings. The heat rejection process of cooling tower includes heating and humidifying. It simultaneously increases both the dry-bulb temperature and humidity ratio of the air. The heat exchange going from the initial to the final condition is broken into sensible and latent heat portions. Finally, (4) D-WF scenario: Water film on south wall and (5) D-MS scenario: Mist spray on south wall. Air can be humidified by injecting water or mist. When water or steam is injected to air, the change in moist air enthalpy and humidity ratio results in the reduction of air temperature.

In N-S1 scenario, it was found from the simulation results that the average temperature around buildings increased gradually from 0.61°C (19:01-20:00) to the peak of 1.22°C (23:01-24:00) and reduced to 0.45°C (01:01-02:00). The feedback (penalty) of heat rejection to air conditioning load of the window type AC during 19:01-02:00 was 4.26W/m^2, which is 6.8% of the total amount of heat rejection without considering the influence of heat rejection from air conditioners.

In N-S2 scenario, it was found from the simulation results that the average temperature around buildings increased gradually from 0.30°C (19:01-20:00) to the peak of 0.84°C (22:01-23:00) and reduced to 0.20°C (01:01-02:00). The feedback (penalty) of heat rejection to air conditioning load of the window type AC during 19:01-02:00 was 2.73W/m^2, which is 4.4% of the total amount of heat rejection without considering the influence of heat rejection from air conditioners.

In N-CT scenario, it was found from the simulation results that more than 80% of the heat was discharged in the form of latent heat at nighttime and the increase of temperature around buildings ranged 0.13°C-0.30°C. The obvious reduction of air temperature below the urban canopy was observed.

Water film (D-WF scenario) removed heat on the building wall directly and the wall surface temperature of buildings decreased. The average temperature decrease of south wall surface was 3.67°C-4.21°C. The temperature decrease around buildings was also observed from 0.14°C–0.38°C. Then, less building energy was consumed and heat rejection from air conditioners reduced. The average saving of electric consumption was 5.7% (1.36 W/m^2) for D-WF scenario during 10:01-17:00.

Mist spray (D-MS scenario) removed heat from the air next to the south wall directly. The wall surface temperature of buildings decreased due to the heat balance. The average decrease of south wall surface was 0.43°C-0.67°C. On the other hand, the temperature decrease around buildings was observed from 0.24°C-0.60°C. Then, less building energy use was needed and heat rejection reduced. The average electric consumption saving was 2.8% for D-MS scenario during 10:01-17:00, which was lower than the D-WF scenario.