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Evaluation of reduction effect on thermal load inside and outside of concrete building with wooden decoration by numerical analysis

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Abstract

The thermal load reduction effect inside and outside a building with steel-reinforced concrete construction coated by heat-treated wooden decoration was estimated by actual measurement and numerical analysis. The model structure for actual measurement was built by using a steel-reinforced concrete cube (sides 3 m). The diurnal range of building body surface temperature and conductive heat flux and the thermal load inside building decreased upon covering the concrete building with wooden decoration. The insulation performance of the panel increased with the thickness of the wood. Thus, the important role played by wooden decoration is related to the thermal insulation of buildings.

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Keywords: Air conditioning load; Climate; Daily variation; Energy budget; Energy saving; Exterior design; Season; Thermal transmittance; Wooden cladding

1. Introduction

The heat island effect has become a serious problem in urban areas with the increase in the number of buildings using materials with large thermal capacity, such as concrete and asphalt. The absorption of solar radiation in the daytime and thermal radiation from the building to the night atmosphere are restrained by coatings, such as wood, that have low thermal capacity. With regard to the insulation repair of existing buildings, the installation of wood cladding is preferred in Japan. The authors evaluated the effect of the thermal load of a building on the interiors and exterior of the building for a concrete building model and real reinforced concrete building covered by wooden facing in the previous study [1-2]. The purpose of this study is to clarify the energy saving effect and the

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atmospheric thermal load when a building is coated by wooden facings of different shapes for summer and winter season. An objective building of the reinforced concrete which assumed a real building was used, and numerical analysis was performed.

2. Measurement building and method

Two cubic model buildings (sides 3 m) of reinforced concrete were built in the Forestry and Forest Products Research Institute (Tsukuba in Japan) to evaluate the effect of reduction in air-conditioning load when a building is covered by wooden facing. The wall, roof, and floor were considered to have a single-layered structure of reinforced concrete. The wall was 150 mm thick, and the roof and floor were 450 mm thick. A steel door was installed at the north aspect central part of each building. The air-conditioner was installed in the northern upper part of the indoor room. Two model buildings were constructed on the east and west sides. The building on the east was called "E" building, and that on the west was called "W" building. The two buildings were separated by a distance of 5 m. Building E was covered by wooden facing, except on its north side, and building W was not covered. A planar panel of 22 mm was prepared. For both buildings, the roof was standardized as a 30-mm-thick planar layer. A 35-mm-thick air layer was established between the concrete wall and wooden facing. All the end faces of each air layer were closed, and thus, each air layer formed a closed and independent space. Figure 1 shows the outline of the model buildings.

K-type thermocouples (wire diameter 0.32 mm) and heat flux meters were installed on the roof and the concrete walls to the north, south, east, and west to measure temperature distribution and the conductive heat flux in the thickness direction of the concrete. After concrete casting, a thermocouple was installed on the surface (indoor side and outdoor side) of the roof and on each of the four walls. In building E, thermocouples were installed in the wooden facing surface and the air layer between the concrete wall and wooden facing. In addition, thermocouples were installed at three locations inside the building to measure indoor temperature (ceiling, center, and floor). The surface temperature, conductive heat flux, and indoor temperature were recorded by a data logger at 1-min intervals. Figure 2 shows the installation locations of the sensors. As meteorological elements, the amount of global solar radiation, infrared radiation, air temperature, relative humidity, wind direction, wind speed, and precipitation were measured. Pyranometers were installed on the four walls and the roof of building E. Measurements were performed intermittently during summer and winter seasons.

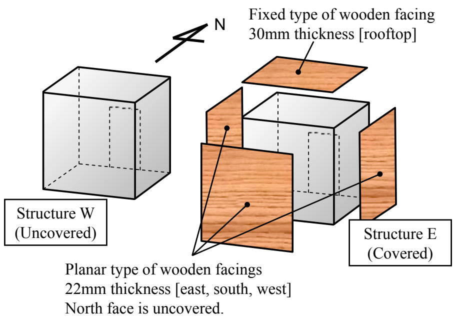

Fig.1. Outline of model buildings.

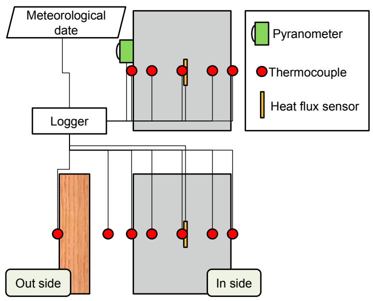

Fig. 2. Sensor locations.

3. Calculation model and method

Numerical analysis was performed assuming identical situations as those of the model structure to evaluate the effect of reduction in the air-conditioning load when wooden facing is employed for a building. Figure 3 shows the schematic drawing of the numerical model. Assuming that surfaces of the walls and roof top of the test box are sufficiently wide as compared to the thickness of each, the one-dimensional heat transfer model was applied to analyze temperature profile in the direction of thickness of each wall. The box consists of six walls, each of which consists of three layers of covering wood layer, air layer, and concrete slab layer, and the internal space of model structure. The temporal changes in temperature inside the concrete and the wood layers are calculated using the one-dimensional unsteady heat conduction equation. Each surface temperature value was calculated under the assumption of energy balance between radiation, convection, and conduction. A box model was adopted for predicting the air temperatures