

are modeled with space objects, and there is information about the schedule of internal gain and air conditioning. In this tool, object information is established in the dialog of the BIM software.

Making a model for building thermal simulation

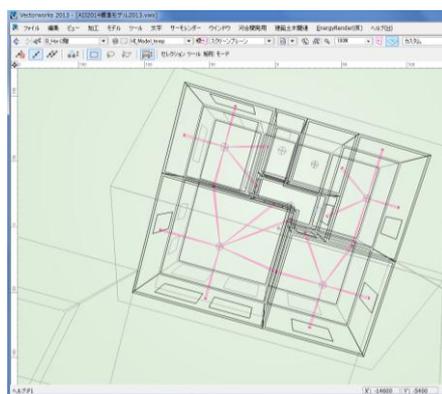
The BIM model input by users is converted into data for building thermal simulation as shown in Fig. 2. This pre-processing method is implemented as follows:

- Objects on selected layers are integrated into a layer for simulation on BIM.
- Pre-processing method recognizes spaces and defines objects by vertical zones. The vertical zone is defined based on the height of the space object. This method can extract a connection between rooms and each building parts even when the building has split floors and open ceiling spaces.
- Walls, roofs, and windows are converted into 3-D polygons. A wall object belonging to more than one vertical zone is converted into several polygons separately. Then, a slab object is converted into several polygons corresponding to the relation between the upper and lower floor plan. Converted 3-D polygon data are output as information on coordinates and geometry into text data.
- Relation between rooms and each building part is analyzed and output automatically by seeking rooms adjacent to each polygon.

Input data visualization for building thermal simulation

In building thermal simulation, users have to define many pieces of simulation information, namely the material information on all polygons, and the schedule information in all rooms. It is difficult for users to input and define all this information completely and quickly. Sometimes, mistakes in inputting information cause simulation failure and misunderstanding. The user's special modeling may

(a) Linkage check with adjacent rooms by displaying linkage between room and walls



In this figure, objects except in 2nd floor: Displayed by gray color.
Linkage of rooms in 1st floor: Not displayed

(b) Check of inputted material

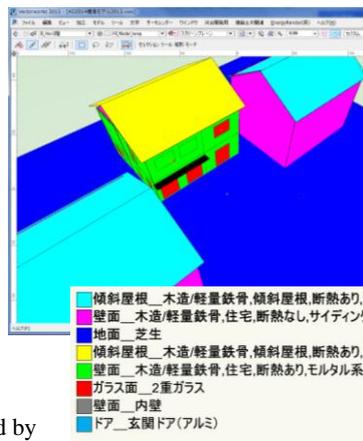


Figure 3. Input data visualization for building thermal simulation

cause a failure in extracting a connection between rooms. This tool visualizes these input data on BIM software. Visualized input data for each room are stacked by layers, and users can switch and see information about arbitrary rooms or parts by changing layer visibility (Fig. 3).

BUILDING THERMAL SIMULATION CONSIDERING SURROUNDING GEOMETRY

The geometry surrounding the site affects the direct and sky solar radiation transmitted in windows due to its shading. Long-wave radiation received on the building's external surface is important, when the radiative cooling effect is effective. We have developed a coupling simulation method between the outdoor thermal environment simulation and the building thermal simulation. However, the previous method cannot be applied to long periods or annual simulation. In addition, Higuchi(2001) shows the calculation method of solar and long-wave radiation for building thermal simulation. In this study, by inputting the calculation result of solar and long-wave radiation into the building's external surface, the building thermal simulation for a long period is enabled.

Calculation of solar radiation

In the calculation of direct solar radiation, ray tracing is carried out in the direction of the sun (Fig.4). In the calculation of sky solar radiation and long-wave radiation, rays (normal set: $256 \text{ rays}/2\pi$) are released from points isotropically. This study assumes that sky solar radiation distributes isotropically. It is calculated from the sky view factor, which is calculated from ray-tracing and horizontal sky solar radiation in the weather data. Points for ray tracing are set on each polygon (Fig.4). Ray tracing is performed from each set point. The resolution of ray tracing is determined based on the building part. Users can improve the accuracy of radiation calculation in the thermally weak part of the building, such as a window.

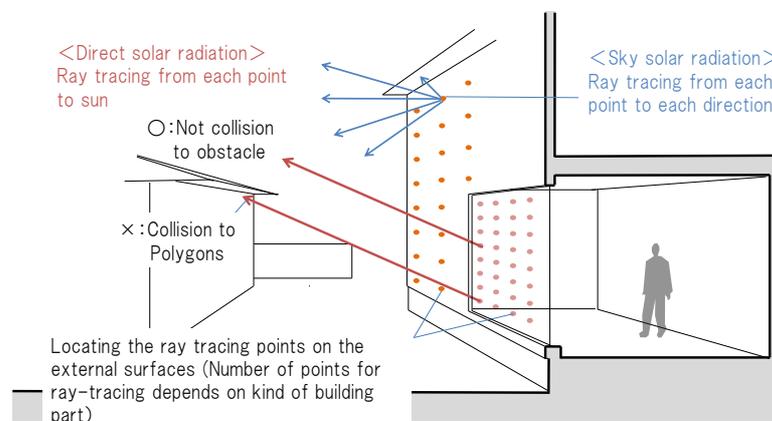


Figure 4. Calculation method of solar radiation and long-wave radiation on building external surface

Calculation of long-wave radiation

Long-wave radiation is calculated using Brunt's formula. This study assumes that the surface temperature on the surrounding external surface is equal to the outdoor air temperature.

TEST CALCULATIONS ASSUMING ARCHITECTURAL DESIGN IN AN ACTUAL SITE

This paper presents a calculation example involving a site in the urban district in Tsuchiura city, Japan. To demonstrate the effectiveness of the developed tool, which calculates building heat load or energy consumption considering surrounding geometry, this study compares the calculation results in two cases with and without surrounding geometry. Figures 5 and 6 show the calculation condition and results, respectively.

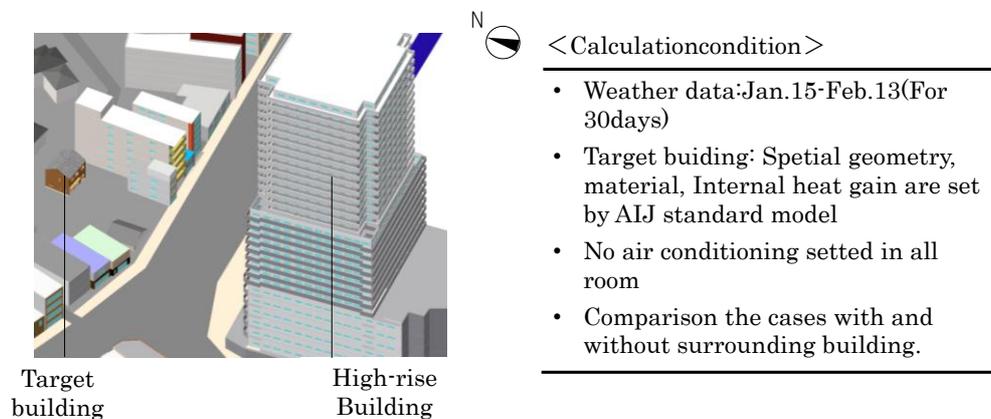


Figure 5. Test calculation condition

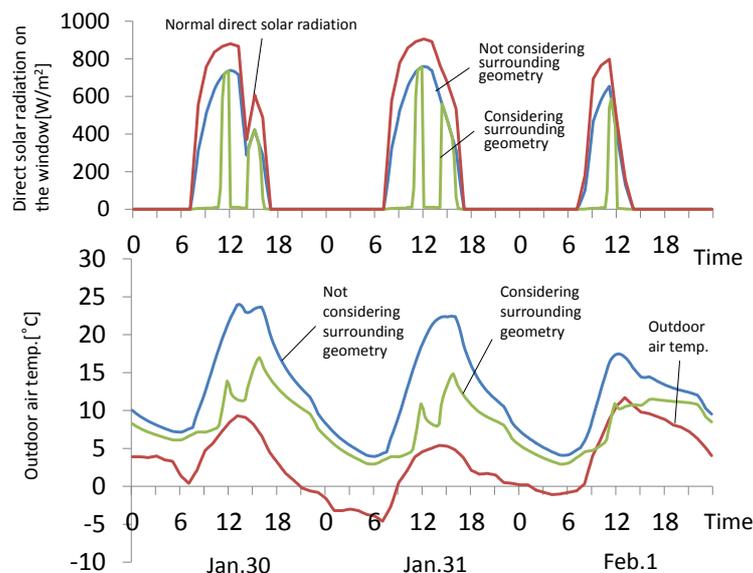


Figure 6. Comparison of calculation result between the case with and without surrounding geometry

As a result of comparison, the building on the east side of the target building and the high-rise building decreases solar radiation on the window of the target building, and the air temperature in the living room decreases by 7 °C. This calculation takes about 1 min on a personal computer. These results reproduce the air temperature variation derived from the shading effect of the surrounding geometry.

CONCLUSION

This study presented the outline of a simulation tool for users to understand the effect of surrounding geometry on building heat load and energy consumption. In this paper, the following items were developed.

- Method to generate models for building thermal simulation from BIM automatically
- Method to check simulation model that user input on BIM software
- Building thermal simulation that considers surrounding geometry

Moreover, as a result of a test calculation involving an actual site, it is confirmed that this tool shows good performance as a simulation tool for determining building volume and window layout. As a future task, we will implement detailed validation using the BESTEST model. We will also show the visualization method for users to understand the heat transfer process of buildings, and incorporate the feedback from the calculation into building design in the next study.

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