FIELD MEASUREMENT OF OUTDOOR MICROCLIMATES IN A RESIDENTIAL AREA HAVING LEAFY CANOPIES IN SEASONALLY HOT AND HUMID CLIMATE

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Abstract

Microclimates were investigated in the outdoor spaces in a residential area containing a leafy canopy during summer. The effects of the spatial forms and materials, particularly tall trees, in an outdoor space on microclimate were examined. A good thermal radiant field in which MRT was lower than air temperature was shown to form in spaces having high overhead leaf coverage and low sunny ground shape factor. Groves of trees contributed to the reduction of air temperature in inflowing wind. However, air temperature again increased upon passing through the central passage, where the ground was sun-exposed and MRT increased during the day.

Key words: Microclimate, Field measurement, Trees

1. INTRODUCTION

Urbanization produces changes in the spatial forms and materials of outdoor spaces and results in the formation of peculiar microclimates. In the Kanto region in Japan, which has a seasonally hot and humid climate, the outdoor thermal environment worsens in summer, becoming uncomfortable outdoor spaces in the daytime. Under such circumstances, outdoor spaces are not conducive for leisure or activities.

The outdoor microclimate needs to be considered when planning urban block development in order to improve the thermal environments of both outdoor space and urban area. Tall trees can grow sufficiently well in the Kanto region, because there has an Asian Monsoon climate. The effects of tall trees on microclimate are expected to provide mechanisms for improving thermal environment.

In the present study, outdoor microclimate is investigated in a residential area containing many tall trees in the outdoor space. The effects of the spatial forms and materials, particularly tall trees, in an outdoor space on microclimate were examined.

2. SUMMARY OF FIELD MEASUREMENT

2.1. Residential area for field measurement

The residential area examined in the present study is located in a suburb of Tokyo, Japan, in an area of 1029 square meters containing five houses (Figs. 1 and 2). Tall deciduous trees, cherry trees and zelkova

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trees are present in the area. A grove of trees exists in the south of the area, situated on a downhill slope.

The east side street of the area is lined with cherry trees. All of the houses are two-storey wood panel construction. A north-south passage in this area is paved with water-permeable blocks. The courtyards of each house are covered with soil or lawn.

2.2. Conditions measured in the field measurements

Microclimate measurement points are indicated on the map of the residential area shown in Fig.2. Air temperature, relative humidity, wind direction, wind velocity and thermal radiant field were measured as elements of microclimate over the entire area, including in the grove on the south side. Field measurements were conducted during three weeks in each of the years 1999, 2000 and 2001. The measurement methods and periods are shown in Table1.

<Thermal radiant field> Thermal radiant field was measured using a spherical thermography recording system, which was developed previously by the author’s group. This system can record the radiant temperature distribution of all surfaces around the recording point as a spherical panorama. Spherical thermographs were all captured at a height of about 1.2 m, which corresponds to the height of the average person’s chest. Recording times were approximately 8 am, 12 am and 6 pm.

<Wind environment> The wind environment was measured using fixed-point measurement of wind direction and velocity at several points in the area over approximately two weeks. Measurement sensors were installed at a height of 1.5~1.8 m.

<Air temperature and Humidity distribution> Air temperature and relative humidity measurement points were located throughout the area. Measurements were conducted over the same period as for wind environment measurements. The measurement sensor was installed at a height of 1.2~1.8 m. In addition, wind direction, wind velocity, air temperature and relative humidity were measured on a footbridge at a height of 6.5 m, which is located to the east of the area, as a reference point of the inflow of wind into the area.

3. RESULTS

3.1. Relationship between spatial form and thermal radiant field

This section takes the surface temperature distribution and thermal radiant field formed in the area, and then examines the relationship between spatial form and thermal radiant field. Several indices were selected as

<table>
<thead>
<tr>
<th>Table1 Measurement contents and periods</th>
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<tbody>
<tr>
<td>Subjects</td>
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<tr>
<td>----------------------------------</td>
</tr>
<tr>
<td>Air temperature</td>
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<tr>
<td>Relative humidity</td>
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<tr>
<td>Wind velocity</td>
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<tr>
<td>Wind direction and velocity</td>
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<tr>
<td>Ground surface temperature</td>
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<tr>
<td>Surface temperature distribution</td>
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<tr>
<td>Vertical quantity of total solar radiation</td>
</tr>
</tbody>
</table>

Investigation period:

(1). 1999/7/26~ 8/11 (2). 2000/7/28~ 8/10 (3). 2001/7/28~ 8/10

<Vertical quantity of total solar radiation> Vertical quantity of total solar radiation 911W/m²

1999/8/3 12:12, Air temperature 33.9 °C, Vertical quantity of total solar radiation 889W/m²

Fig.3 Surface temperature distribution of the area (2000/7/31 12 am )

Fig.4 Spherical thermograph under the cherry tree (P17)
indicators of spatial form characteristics: Overhead Leaf Coverage Ratio (the ratio of leaf areas in fisheye photo of upper direction taken by equidistance projection), sky factor, building wall shape factor, greenery shape factor, sunny ground shape factor and shaded ground shape factor.

Figure 6 was constructed from spherical thermographs to indicate the relationship between spatial form and thermal radiant field. The vertical axis of the figure indicates differences in mean radiant temperature (MRT) and air temperature. MRT was calculated from the spherical thermograph. The other two axes indicate the indices listed above that represent spatial form characteristics. One axis represents Overhead Leaf Coverage Ratio, the other is sunny ground shape factor.

Figure 3 shows the surface temperature of the entire area at 12 am. This figure was constructed by projecting the recorded thermographs onto the CAD model. Figure 4 shows the spherical thermograph recorded at point P17, which is under the cherry tree on the central passage (Fig.5). These results indicate that tall trees contribute to keeping surface temperature under the crown at air temperature levels.

Figure 5 shows that the maximum difference in MRT between the measurement points was approximately 6°C. This figure also shows that good thermal radiant field, in which MRT was lower than air temperature, was formed in spaces with high overhead leaf coverage and low sunny ground shape factor.

3.2. Inflow wind and wind environment in the area

This section clarifies inflow wind and wind environment of the area through the measurement of wind direction and velocity at several points. The main wind direction in the area was from the south. Several days in which the wind blew in the main wind direction were selected for analysis. Mean wind velocity of the days were 1.0~1.8 m/s. Figure 7 shows wind roses classified with wind velocity ranges at the measurement points. Wind velocity ratios are also shown in this figure. The standard point of wind velocity ratio is point P14.

In the grove on the south side, the main wind direction was southwest. The wind roses at point P14 and P17 indicate that wind passed the grove on the south side, then flowed into the central passage of the residential area, and flowed along the passage.

The wind rose at point P2, which is in a space south of house A-2, indicates that wind blows mainly from southwest region outside of the residential area. At point P5, which is in a space south of house A-5, the main
wind direction is from the southeast and is different from that of the central passage. This is because the incoming wind passed the street in the east side of the area, then wind direction changed along the street. The wind velocity ratio of this point was relatively low. At point P1, which is between houses A-1 and A-2, wind traveled parallel to each house, with the wind mainly coming from the west. The wind velocity ratio at this point was the lowest of all the measurement points. From these results, wind was shown to blow from the surroundings of the area, which contain many trees, into the courtyard of each house.

3.3. Air temperature distribution across the area

Air temperature was measured at several points in the area, including in the grove on the south side, in order to investigate air temperature distribution across the entire area. Analysis was performed in four days in each of the years 2000 and 2001 when the sky was clear and mean wind velocity was 1.0~1.6m/s. Figure 8 shows air temperature differences between each measurement point and point P4 and P12, both of which were set as standard points. Differences in air temperature were averaged over the time periods, 9 am~12 am, 12 am~3 pm and 3 pm~6 pm.

At points P6 and P7, both of which are on the southern boundary of the area, air temperatures were high because the wind was coming from a sunny area with no trees. A clear trend became apparent that air temperature dropped gradually through the grove on the south side. Air temperatures at points P11 and P12 were 1.3°C lower than that at point P7. Along the central passage, where ground surface temperature becomes high during the day, air temperature again increased, becoming approximately 1°C higher than at the standard point. In the space to the south of each house, including each house’s courtyard, air temperatures were almost equal to the standard point, because wind that had passed through a leafy space in the surrounding areas flowed into these spaces.

The above results show that the trees contributed to drops in air temperature in inflowing wind. However, air temperature again increased through the central passage, where the ground was exposed to direct solar radiation and MRT increased during the day.

4. Conclusions

Microclimates were investigated in the outdoor spaces in a residential area containing a leafy canopy during summer.

(1) Spherical thermographs were recorded at several points in the area, and a good thermal radiant field in which MRT was lower than air temperature was shown to form in spaces having high overhead leaf coverage and low sunny ground shape factor.

(2) Wind passing through the grove of trees on the south side of the area flowed into the central passage of the residential area. In each house’s courtyard, wind flowed from the surrounding areas, which contained many trees.

(3) Groves of trees contributed to the reduction of air temperature in inflowing wind. However, air temperature again increased upon passing through the central passage, where the ground was sun-exposed and MRT increased during the day.

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References