Original Paper

Comparison of the Air Temperature Measured on Site Using Forcibly and Naturally Aspirated Shelters

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A comparison of air temperature data collected on site using forcibly aspirated and naturally aspirated shelters clarified the differences and their causes. The air temperature measured using a naturally aspirated shelter was approximately 0.4 ℃ higher than that measured using a forcibly aspirated shelter. The diurnal difference in the air temperature due to the difference in the shelter was larger than the nocturnal one, which was presumably due to the strong solar radiation. The strong wind may have accounted for the small difference in air temperature. When employing a naturally aspirated shelter in the survey of the air temperature, the wind speed and amount of solar radiation should be taken into consideration in analyzing the data.

I INTRODUCTION

The urban heat island phenomenon has been studied worldwide with the objective of limiting thermal pollution in urban areas [1-6]. When studying the urban heat island phenomenon, the air temperature should be measured. Various types of equipment are used for measuring the air temperature. The Japan Meteorological Agency currently employs a forcibly aspirated shelter when measuring air temperature. The use of this shelter for air temperature measurements provides the most precise data but requires electricity at the point of use. On the other hand, the use of a naturally aspirated shelter is convenient when long-term monitoring at many sites is conducted or when monitoring is conducted at a site where it is difficult to secure a power supply. Some fundamental studies to evaluate shelters have been conducted at experimental sites [7-8]. In contrast, in the present study, we compared and analyzed air temperature data collected in the survey to mitigate the heat island phenomenon in order to evaluate the air temperature data collected at actual monitoring sites. The findings are reported below.

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II MATERIALS AND METHODS

1 Survey sites and air temperature measurement

Air temperatures were measured at two sites (A and B) in the southern part of Nishinomiya City, Hyogo Prefecture, Japan. Nishinomiya City is located between Osaka City (population 2,634,000/ 222 km^2) and Kobe City (population 1,520,000/ 551 km^2). The southern part of Nishinomiya City is an intensive industrial zone with dense population that is categorized as urban. The locations of the sites are shown in Fig. 1. Site A is approximately 150 m away from Site B. The elevations of the two sites are 0 m above sea level. The condition for the measurement of air temperature is summarized as follows:

Site A: The air temperature was measured on the concrete roof of a four-story building (about 17 m above the ground) using a forcibly aspirated shelter. The air temperature was measured using a thermometer certified by the Japan Meteorological Agency. The air temperature measured at Site A is identified as reference data because a forcibly aspirated shelter was used.

Site B: The air temperature was measured on the ground (about 1.5m above ground) where a thermometer shelter was installed. The thermometer shelter was naturally aspirated. The air temperature was measured using a thermometer calibrated with a thermostat.

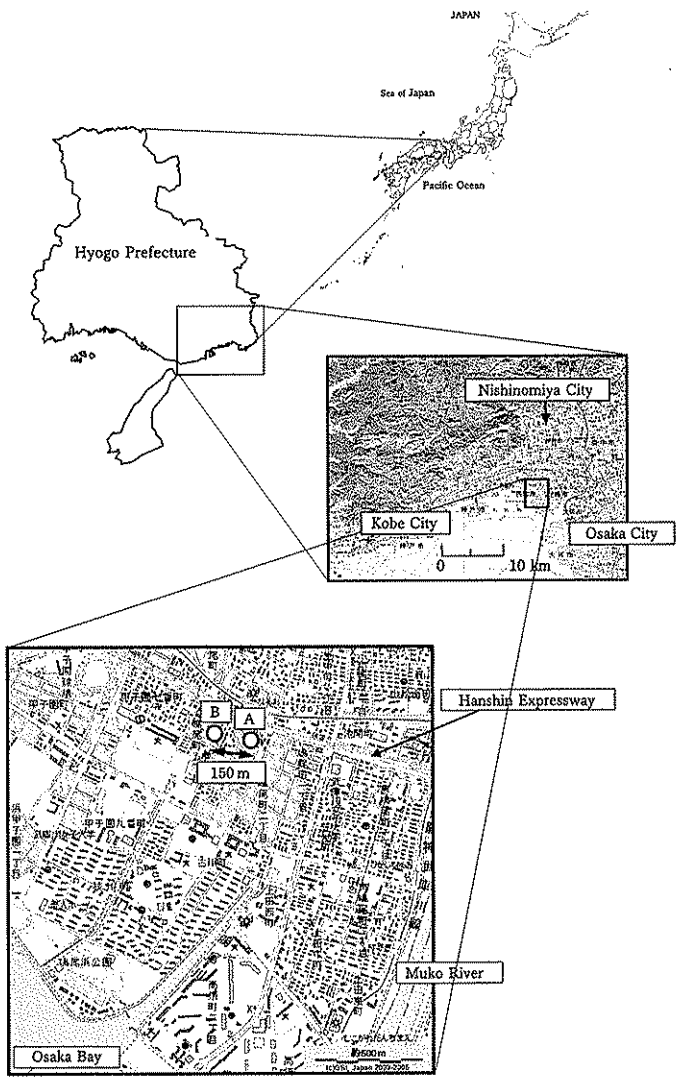

Figure 1 Location of survey sites.

2 Wind velocity

The wind velocity was measured at Site A. The condition for the measurement of wind velocity is summarized as follows: the wind velocity was measured on the concrete roof of the same building (about 25m above ground) as that used for the air temperature measurement using an ultrasonic anemometer.

3 Survey period and data acquisition

Data measured from July – October 2005 were used for analyses. All of the parameters were measured hourly.

III RESULTS AND DISCUSSION

1 Comparison of the air temperatures measured at two sites

1.1 For all data

Figure 2 shows the relationship of the air temperature measured at Site B with that at Site A. The slope was 1.03, which is quite close to the 1:1 line, and the intercept was 0.23, showing that the air temperature at Site B was 0.23℃ higher than that at Site A. Taking the difference in the height of the measurement sites (17m and 1.5m above the ground) into account, a difference of 0.23℃ can be concluded to be quite small.

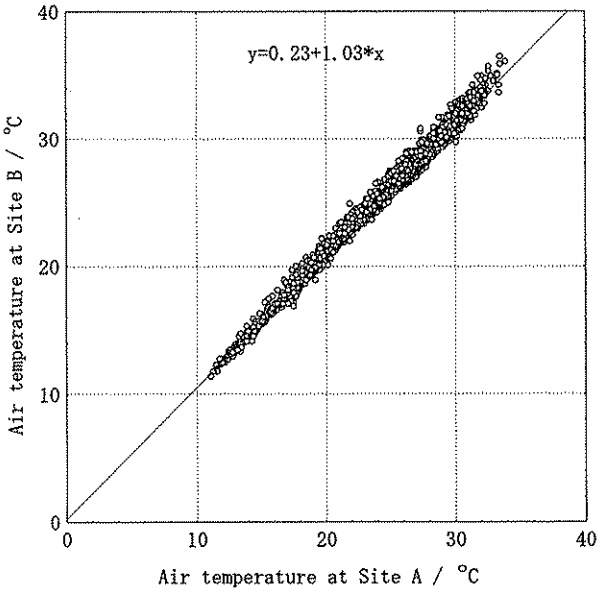

Figure 2 Relationship of the air temperature measured at Site B with the air temperature measured at Site A for all data.

1.2 For diurnal and nocturnal data

Figure 3 shows the diurnal and nocturnal relationships of the air temperature at Site B with the air temperature at Site A. The slopes in the diurnal and nocturnal relationships were 1.02 and 1.01, respectively, approximately the same and quite close to the 1:1 line, while the diurnal and nocturnal intercepts were 0.72 and 0.50, respectively; thus the diurnal air temperature tends to be measured higher than the nocturnal air temperature at Site B.

In addition, as for the diurnal air temperature, the variation from the approximation curve was larger than the nocturnal air temperature.

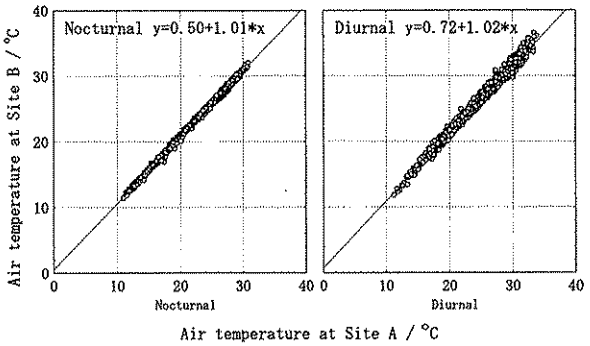

Figure 3 Diurnal and nocturnal relationships of air temperature at Site B with the air temperature at Site A.

2 Difference in the air temperatures measured at two sites

2.1 For all data

Figure 4 shows the relationship of the difference in the air temperatures due to the difference in the shelter (Site B – Site A) with the air temperature at Site A. The difference in the air temperature tends to be larger as the air temperature increases.

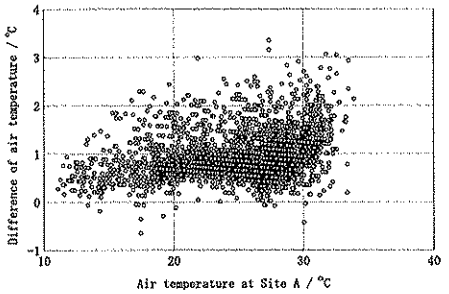

Figure 4 Relationship of the difference in air temperatures due to the difference in shelter (Site B –Site A) with the air temperature at Site A.

2.2 Diurnal variation

Figure 5 shows the diurnal variation of the difference in the air temperatures due to the difference in the shelter. A clear diurnal change, namely, a larger difference and variation in daytime than at nighttime, was observed.

This would be due to following reasons:

(1) Solar radiation is strong during the day.

(2) A thermometer shelter with natural aspiration, i.e., a naturally aspirated shelter, has a larger heat capacity.

(3) Aspiration is insufficient in the naturally aspirated shelter under some conditions.

Aspiration in a naturally aspirated shelter is dependent on the natural wind. Therefore, the wind velocity could be used as a factor to evaluate the aspiration efficiency. This will be mentioned in the next section.

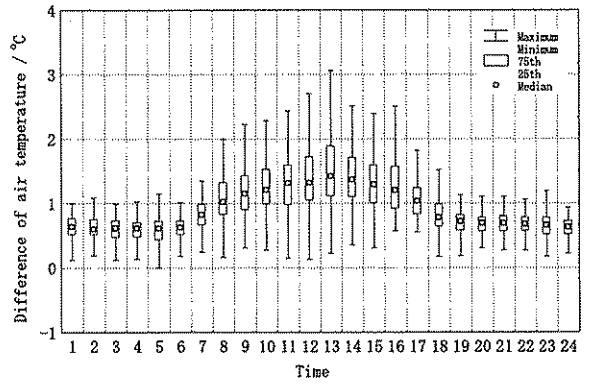

Figure 5 Diurnal variation of the difference in air temperatures due to the difference in shelter (Site B – Site A) .

2.3 Dependence on wind speed

2.3.1 For all data

Figure 6 shows the relationship of the difference in the air temperatures due to the difference in the shelter (Site B – Site A) with the wind speed at Site

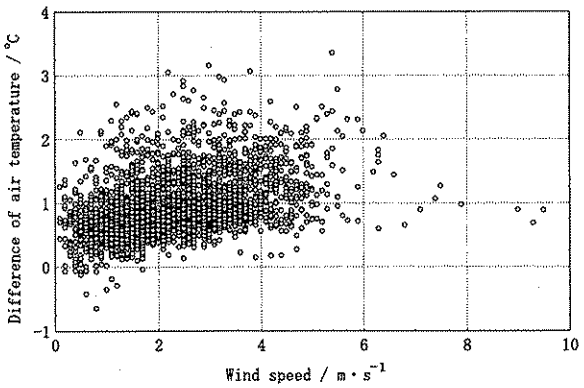

Figure 6 Relationship of the difference in air temperatures due to the difference in shelter (Site B –Site A) with the wind speed at Site A.

A. A strong wind (> 7 m/s) makes the difference in the air temperatures small, presumably due to effective ventilation by the strong wind. On the other hand, a moderate wind velocity (2 m/s<, < 6 m/s) provides a larger difference, while a weak wind velocity (< 2 m/s) provides a relatively smaller difference, although the weak wind velocity is supposed to lead to insufficient ventilation. This will be reported later in detail.

2.3.2 For diurnal and nocturnal data

Figure 7 shows diurnal and nocturnal relationships of the differences of the air temperature due to the difference in the shelter with the wind speed. Abundant data with a difference of more than 1℃ were observed in the diurnal relationship, while few data with a difference of more than 1 ℃ were observed in the nocturnal relationship.

Figure 8 shows histograms of the diurnal and nocturnal wind speed. The weak wind speed (< 2 m/s) accounted for 31.2% in the nocturnal histogram, while the weak wind speed accounted for only 17.7% . The reasons that the weak wind velocity provides a relatively smaller difference although the weak wind velocity is supposed to lead to insufficient ventilation could be explained by the following two observations:

(1) The nocturnal proportion of the weak wind speed is larger than the diurnal one.

(2) The nocturnal difference in the air temperatures due to the difference in the shelter is smaller than the diurnal one.

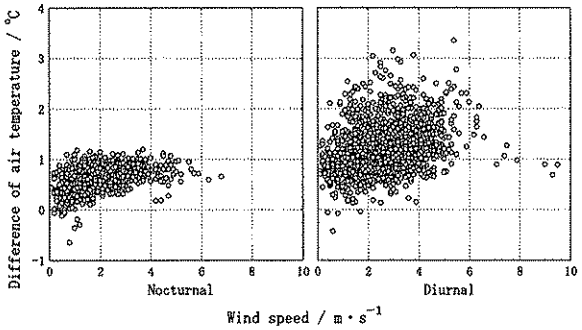

Figure 7 Diurnal and nocturnal relationships of the differences in air temperature due to the difference in shelter with the wind speed.

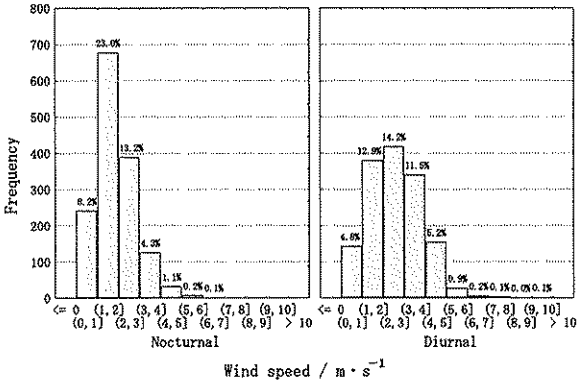

Figure 8 Histograms of the diurnal and nocturnal wind speed. (a~b] shows more than a and not more than b.

IV CONCLUSIONS

The air temperatures measured by using forcibly aspirated and naturally aspirated shelters were compared. The air temperatures collected in the survey of the urban heat island phenomena were used. The air temperature measured using a naturally aspirated shelter was approximately 0.4℃ higher than that measured using a forcibly aspirated shelter. The diurnal difference in the air temperature due to the difference in the shelter was larger than the nocturnal one. The strong wind may have accounted for the small difference in air temperature.

V ACKNOWLEDGEMENT

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「原著」

強制通風型シェルター及び自然通風型シェルターを用い測定された気温データの比較

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要　約

強制通風型シェルター及び自然通風型シェルターを用い測定された気温データを比較・検討した結果，両データの差及びその原因が明らかとなった．自然通風型シェルターを用いて測定された気温は強制通風型シェルターを用いて測定された気温よりも約0.4℃高かった．両データの差は夜間よりも昼間に大きく，これは昼間の強い日射によると考えられた．また，風速が大きくなると両データの差は小さくなった．自然通風シェルターを気温測定調査に用いる場合には，データを解析する際，風速及び日射量を考慮に入れる必要がある．