6.8 **EFFECTS OF BUILDING-HEIGHT HETEROGENEITY ON AREA-AVERAGED TRANSFER VELOCITY IN THE STREET SURFACE -WIND TUNNEL EXPERIMENTS USING SALINITY CHANGE TECHNIQUE**

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1. INTRODUCTION

As a parameterization of turbulent fluxes in urban canopy layer, the resistance network in the canyon has been studied with heat balance method (Kawai and Kanda 2003), with naphthalene sublimation technique (Barlow and Belcher 2002), and with our water evaporation technique using filter paper (Narita 2003). This filter paper method is useful to examine the effect of canyon geometry on transfer velocity in two-dimensional models and also to compare the local difference of transfer velocity between the kinds of surfaces in homogeneous cubic array. About heterogeneous building arrangements, however, it is difficult to investigate the spatial-averaged transfer velocity using this technique because of a problem of edge effects and spatial representativeness. In this study, an experimental method to estimate the area-averaged transfer velocity was newly devised and tried to clarify the effect of heterogeneity of building height in wind tunnel experiments.

2. SALINTY CHANGE TECHNIQUE

In this method (Narita *et al.* 1986), the water evaporation rate is measured not by weight loss but by salinity change of saltwater. A square vessel (600×600mm) with 50mm depth was buried in wind tunnel working section as the rim-top matched to surrounding surface. The building models are arranged within it, then fill the vessel with saltwater to bathe the foot of them (Figure 1). After half and hour, stop wind tunnel fan, and remove the building models from the vessel. Then, stir the saltwater in the vessel sufficiently, and take it into four sample bottles. The salinity of these samples were measured with inductively coupled salinometer (accuracy : 0.003‰) as well as samples of initially poured saltwater. From the salinity-change, evaporation rate was calculated as follows.

$$\boldsymbol{hS = (h - E)S'}$$

$$\therefore \boldsymbol{E = h(S' - S)/S'}$$

where $\boldsymbol{E}$ is evaporation depth (mm), $\boldsymbol{h}$ is initial salt water depth (mm), $\boldsymbol{S}$ is initial salinity (‰), and $\boldsymbol{S'}$ is final salinity (‰). Accuracy of evaporation measurement is estimated as follows.

$$\Delta \boldsymbol{S} = \boldsymbol{S'} - \boldsymbol{S}$$

$$\delta \boldsymbol{E} = \delta \boldsymbol{h} \Delta \boldsymbol{S}/\boldsymbol{S'} + \boldsymbol{h}\delta(\Delta \boldsymbol{S}/\boldsymbol{S'})$$

$$\cong \delta \boldsymbol{h} \Delta \boldsymbol{S}/\boldsymbol{S'} + \boldsymbol{h}\delta(\Delta \boldsymbol{S})/\boldsymbol{S'}$$

Experimental condition is $\boldsymbol{S'}$=35‰, $\boldsymbol{h}$=50mm, and if measuring error is assumed $\delta\boldsymbol{h}$=0.5mm, and $\delta(\Delta\boldsymbol{S})$=0.0042 ‰ , then $\delta\boldsymbol{E}/\boldsymbol{E}$ becomes 2.5% when $\boldsymbol{E}$=0.4 mm. In this technique, measuring term is not the weight loss but concentration change, so handling mistakes like spill-water doesn't bring about fatal error.

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The transfer velocity $\boldsymbol{Wt}$ (ms^{-1}) is calculated by following equation:

$$\boldsymbol{Wt} = \boldsymbol{E_r} / (\rho_s - \rho_a)$$

where $\boldsymbol{E_r}$ is evaporation flux ($kgm^{-2}s^{-1}$), ρ_s is water vapor density (kgm^{-3}) at street level calculated from saturated vapor pressure of salt water surface, and ρ_a is the water vapor density (kgm^{-3}) in the free stream above. To determine ρ_s, surface temperature of salt water was measured by L-shaped fine thermocouple under conditions enveloped with thin water film by surface tension. In calculation of ρ_s, vapor pressure drop by salinity was taken into account. The wind tunnel used here has no control system about temperature and humidity. Then, as a reference, evaporation rate from small eight vessels upstream were also measured simultaneously in every case (Figure 2). All results were analyzed as a ratio of transfer velocity ($\boldsymbol{Wt}$) to this reference value ($\boldsymbol{Wt_0}$). Wind speed is $1.2ms^{-1}$ at the top of boundary layer and depth of the boundary layer is 350mm.

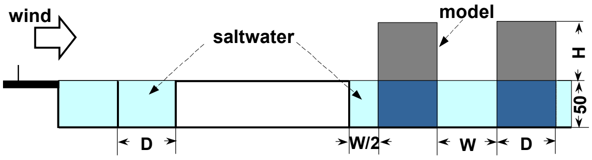

Fig.1 Detailed cross section of sampling area

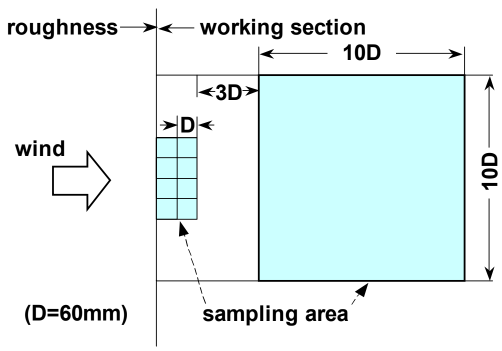

Fig.2 Plane view of working section

3. Results

3.1 *Area-averaged Wt in constant building-height*

Figure 3 shows model arrangements under building height constant. The basic model dimension is 60mm (=D) cubic. Series 1s-(array number) are building density variation (λ_p : plane area density of building). Case 1s-6, 2s-3, and 3s-2 are variation of model dimension under constant λ_p. The area-averaged $\boldsymbol{Wt}$ was measured in three kind of model height (H) ; 0.5D, D, and 1.5D for every arrangements.

The results were summarized in Figure 4, as a change due to the street canyon geometry (W/H). In the variation within same plane size arrangement, $\boldsymbol{Wt}$ has a slight peak in **W/H**=1.0-1.5. On the contrary, the effect of model assembling was not simple, and variation patterns were different for model height.

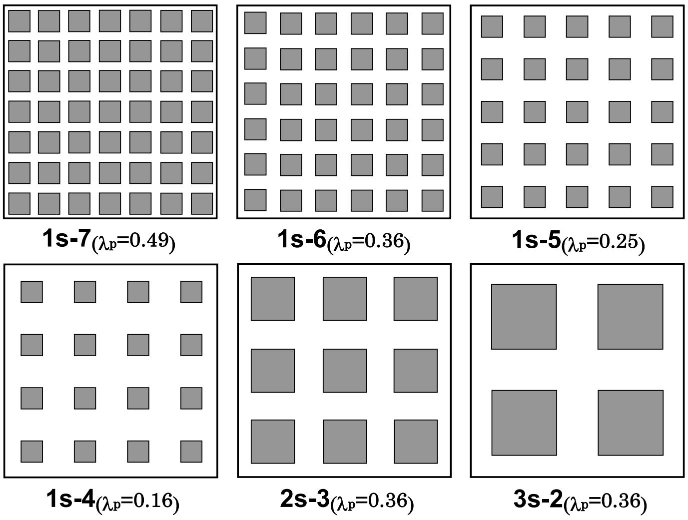

Fig.3 Model arrangements for building density variation and building dimension variation under model-height constant

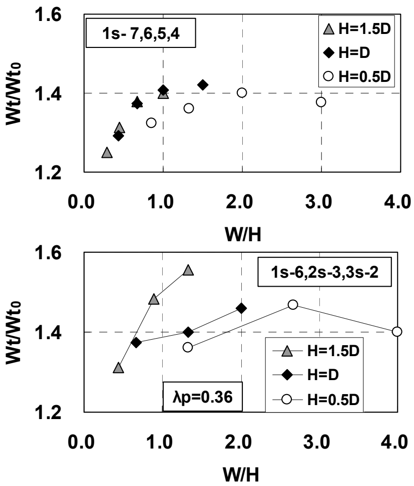

Fig.4 Change of *Wt* due to W/H – variation of model density (upper), variation of model dimension (lower)

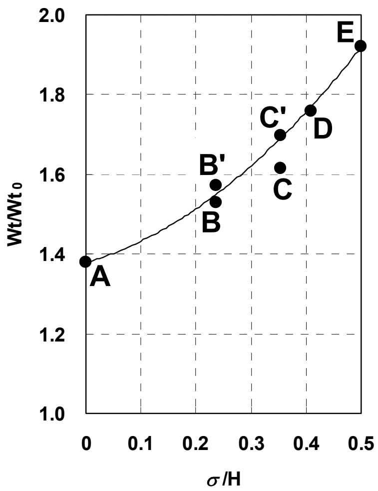

Fig.6 Relationship between *Wt* of street and normalized standard deviation (σ) of model height

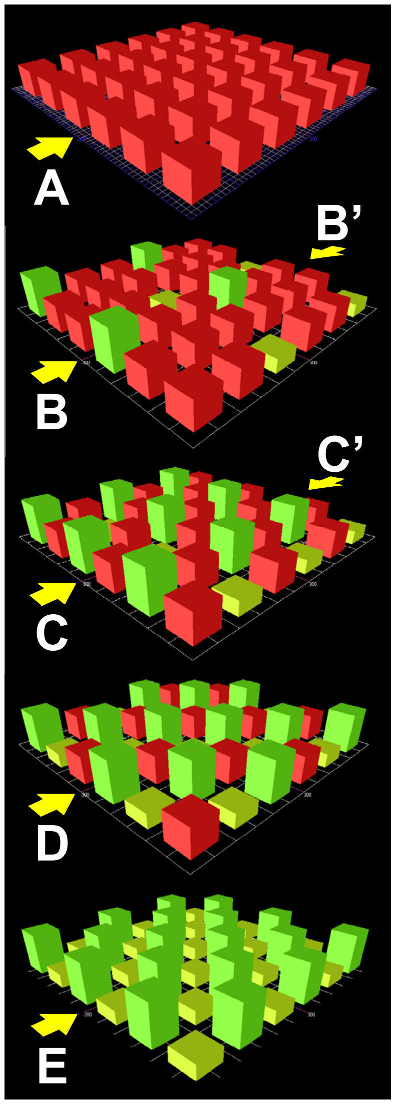

Fig.5 Perspective of model arrangements for building-height heterogeneity

3.2 *Effects of building-height heterogeneity*

To create building-height heterogeneity, concerning the regular cubic array, we make a replacement of several cubic models by half height or one and half height models (Figure 5). Here, all arrangements have same average height and same λ_p. Figure 6 shows the difference of the ***Wt*** of street due to the deviation of the model height is at most 40%. This means that morphological modeling of complicated city structure by regular cubic array to which has equivalent average height and λ_p is not appropriate for the estimation of area-averaged transfer velocity.

4. CONCLUDING REMARKS

Though salinity change technique is available for only about street surface not including wall and roof surfaces, it is excellent in area-averaged investigations especially for the heterogeneous morphology. Using this technique, it was confirmed that the vertical heterogeneity of buildings has much greater effects on area-averaged transfer velocity than that of horizontal variation under building-height constant.

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