Wind-tunnel Experiments of Snowdrift Formation behind an Elevated Building at Syowa Station, Antarctica

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南極昭和基地のピロティ形式建物周辺の吹きだまり性状に関する風洞模型実験

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要旨：模型雪に活性白土を使用した風洞模型実験（縮尺100分の1）で，南極昭和基地で調査された高床式建物後方の吹きだまり形状の再現の可能性を検討した．その結果，風洞内風速 5.0 m/s，風洞の運転時間2.5時間で現地の吹きだまり形状を再現することができた．今後，同様の実験方法で，建物周辺の吹きだまりを少なくするための建物形状の検討が可能であることを示した．

Abstract: To study snowdrift formation behind elevated buildings, wind-tunnel experiments were carried out, using activated clay particles to simulate snow, on a 1/100 scale model of the observation hut at Syowa Station. The similitude of snowdrift for the model and the actual prototype was obtained precisely when the tunnel wind-speed and the wind duration were 5.0 m/s and 2.5 hours, respectively. This modeling technique using activated clay particles is proved to be useful for further studies on the most appropriate shape and dimensions of elevated buildings to prevent snowdrift.

1. Introduction

Elevated buildings have been constructed in Antarctica to minimize snowdrift around them, but the most effective shapes and dimensions of buildings were not examined sufficiently because of difficulties in the field studies which necessitate a long experiment time and a great cost. These difficulties can be overcome, however, by simulation studies of snowdrift formation behind elevated buildings, varying the shape and dimensions of the buildings. In simulation studies, it is necessary to verify a similitude between models and real buildings.

In 1978 MITSUHASHI (1982a) measured snowdrift formation behind elevated buildings at Syowa Station, where the daily mean wind speed during snowstorms was 15.6 m/s at a height of 10 m from the snow surface. A total storm duration of 1190 hours was obtained between April 7 and September 22, 1978. On the other hand, ANNO and KONISHI (1981) reported that the use of activated clay particles in modeling gave a precise similitude of snowdrift formation behind obstacles. These two reports enable us to conduct modeling experiments on the formation of snowdrift behind the elevated building at Syowa Station.

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2. Modeling Apparatus and Procedure

2. 1. Model snow

ANNO and KONISHI (1981) reported that activated clay particles were the most suitable model snow for a small-scale drift modeling in which the scale ratio between the model and the real ranges from 1/100 to 1/500. They pointed out three reasons for selecting activated clay particles: 1) Clay diameter of 1.5 μm is equivalent to the diameter of natural snow particles for the scale of 1/100 to 1/500; 2) The angle of repose is roughly equal to that of natural snow particles; 3) The cohesion of clay particles is easily controllable by adjusting their water content close to the water content of natural snow particles.

Accordingly, the present authors selected the activated clay particles as model snow, since the scale of this modeling experiment is 1/100. The details of clay particles are as follows: The bulk and pure densities are 0.65 and 2.5 g/cm^3, respectively; the water content is 8.5%; the mode diameter is 1.5 μm; and the angle of repose ranges from 45° to 50°.

2. 2. Experimental wind tunnel

The wind tunnel used in this experiment is a snowdrift wind tunnel which is called "SNOWIT" by ANNO (ANNO and TOMABECHI, 1985). The SNOWIT is a simple closed-circuit wind tunnel shown in Figs. 1 and 2. The testing section of the wind tunnel has a square cross section (40×40 cm), which provides sufficient room to model a snowdrift behind a small-scale obstruction. In order to start the model snow drifting in the testing section, an axial fan motor (1.5 kW) is fitted as shown in Fig. 2. The wind speed at the center of the testing section reaches to the maximum of 16 m/s. Model-snow particles are fed by compressed air, from a model-snow feeder to the ejecting nozzle fitted in the windward side of the testing section. The rate of ejection of activated clay particles is 70 g/min.

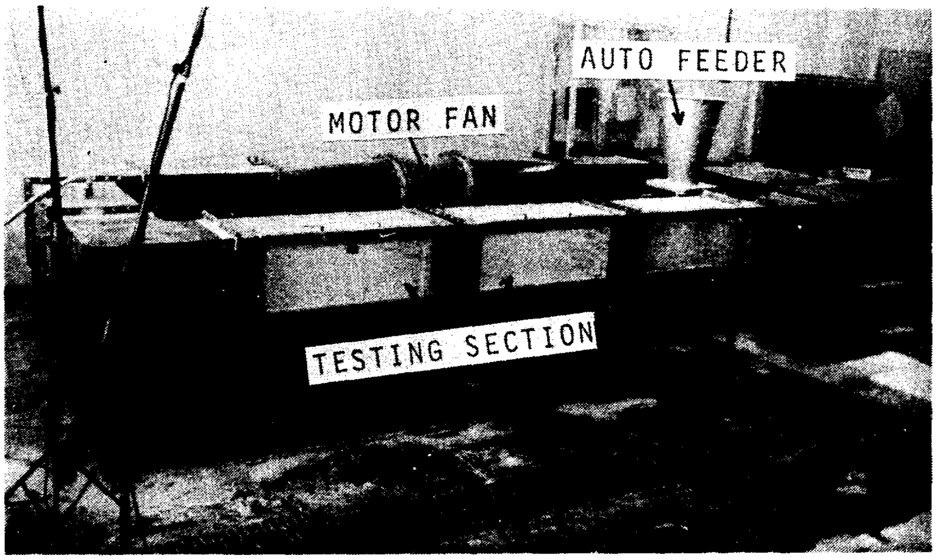

Fig. 1. Photo of the original SNOWIT.

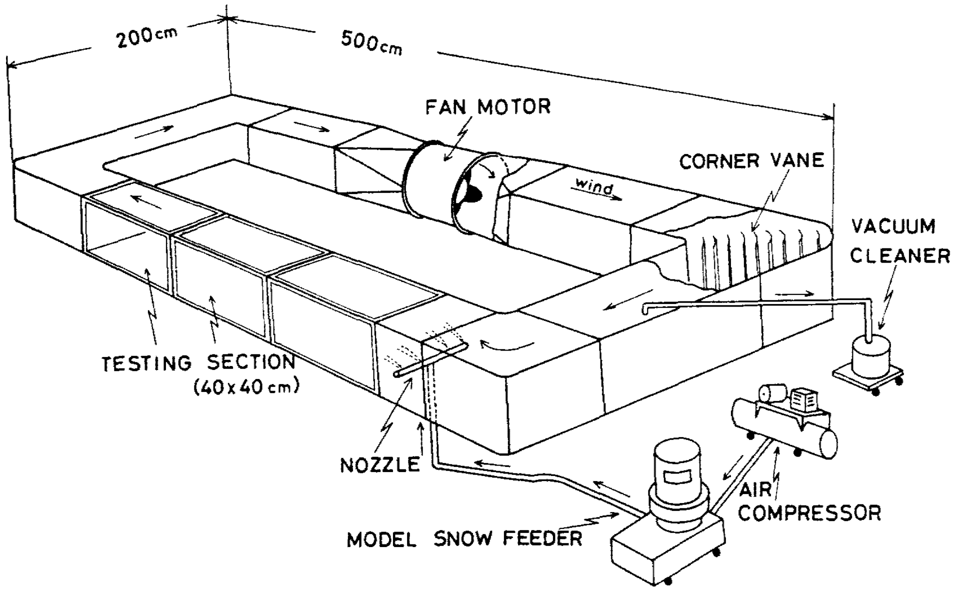

Fig. 2. Schematic view of the improved SNOWIT shown in Fig. 1.

2.3. Model elevated building

The building modeled in this experiment is the observation hut at Syowa Station (MITSUHASHI, 1982a). Figure 3 shows a schematic view of the scale model (1/100) made of balsa; the building is 230 mm in length, 60 mm in width, 45 mm in height, and 15 mm in height of the floor. The model set on a plywood was placed 2.5 m leeward from the ejecting nozzle in the testing section.

2.4. Measurements

Wind speed was measured by a hot-wire anemometer. The drift formed behind the model building was measured at intervals of 30 min by a moire camera; in moire photographs of snowdrift the difference between two black stripes is equivalent to 2 mm in drift height. Thus, drift contours were obtained easily and precisely from these stripes, and the volume was calculated using a planimeter.

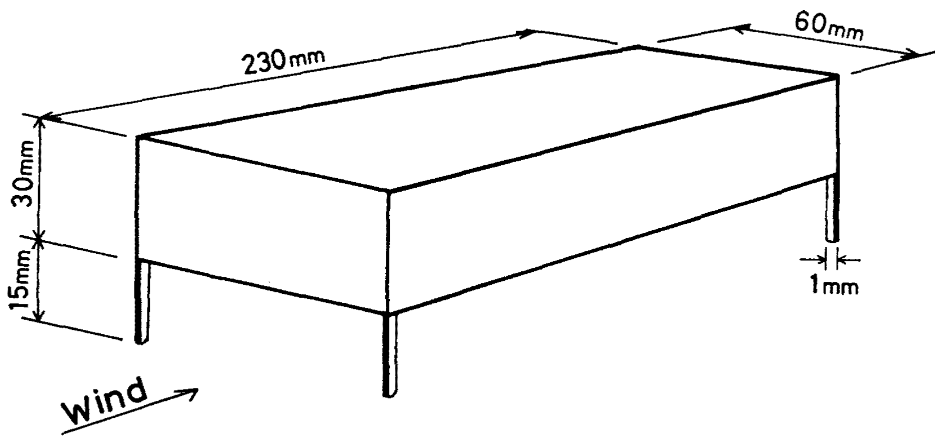

Fig. 3. Schematic view of the model building.

Snowdrift rate was measured by an oil-covered metal trap (60 mm in width and 0.1 mm in thickness). Collection efficiency of the obstacle was obtained by dividing the weight of a lee drift by the weight of the model snow particles which entered into the clearance between the model snow surface and the floor of the model building.

2.5. Model wind speed and storm duration

Investigators on the modeling criteria of snowdrift propose the Froude number as an important parameter. However, ANNO (1985) objected to the suitability of the Froude number as the modeling parameter, entitling it "Froude number paradoxes". Therefore, in this experiment we used Anno's modeling criteria instead of the Froude scaling.

ANNO (1984, 1985) proposed the following two equations for calculation of the ratios of wind speed and storm duration between the model experiment and the prototype (reality); the following equation is given for the wind speed relationship:

$$U_p/U_m=(A_m\cdot U^*_{pt})/(A_p\cdot U^*_{tm}) \tag{1}$$

where U(m/s) is the wind speed at a reference height, A is a coefficient of proportionality; U^*_t is the threshold friction speed; m and p are subscripts meaning the model and the real prototype, respectively.

With regard to the duration of storm, the following equation is given:

$$T_p/T_m=(Q_m\cdot\eta_m\cdot\rho_p\cdot F_{wp})/(Q_p\cdot\eta_p\cdot\rho_m\cdot F_{wm}) \tag{2}$$

where T(min) is the storm duration; Q(g/m·min) is the snowdrift rate; F_{wm} is the width of an obstacle; ρ (g/cm^3) is the bulk density of snow; η is the obstacle's collection efficiency for snow particles.

ANNO (1984) reported that U^*_{tm} for activated clay particles ejected into the testing section was 11.2 cm/s.

A_m is 0.44 from the authors' measurements when the model reference height was 20 cm in the experimental wind tunnel. MAKI (1974) reported that the actual threshold friction speed (U^*_{pt}) was about 20 cm/s, and the coefficient (A_p) was 0.0365 when the reference height was 6 m. On the other hand, the wind speed at the height of 10 m measured by MITSUHASHI (1982a) was about 1.2 times of the value at the height of 6 m. Consequently, the coefficient, A_p, becomes about 0.03 at the reference height of 10 m. From these data and eq. (1), the wind speed ratio (U_p/U_m) is 3.15. Thus, the actual wind speed of 15.6 m/s corresponds to the model value of 4.95 m/s in the center of the testing section of the wind tunnel.

MITSUHASHI (1982b) reported the following values; $Q=8288.3$ g/m·min, $\eta=0.5\%$, $\rho=0.3$ g/cm^3, and $F_w=6$ m. Corresponding values in our model experiment are: 22.4 g/m·min, about 18%, 0.65 g/cm^3 and 6cm. These values enable us to estimate the ratio of storm duration between the model and the reality, T_p/T_m, as 409.13. Thus, T_m is calculated as 2.64 hours. Thus the model wind speed of 4.95 m/s and the storm duration of 2.64 hours are to be used for modeling snowdrift.

3. Result

Figure 4 shows a model snowdrift formed behind the model building when the model wind speed was 5.0 m/s and the storm duration was 2.5 hours. Figure 5 shows the moire photograph of the snowdrift taken after the removal of the model. The

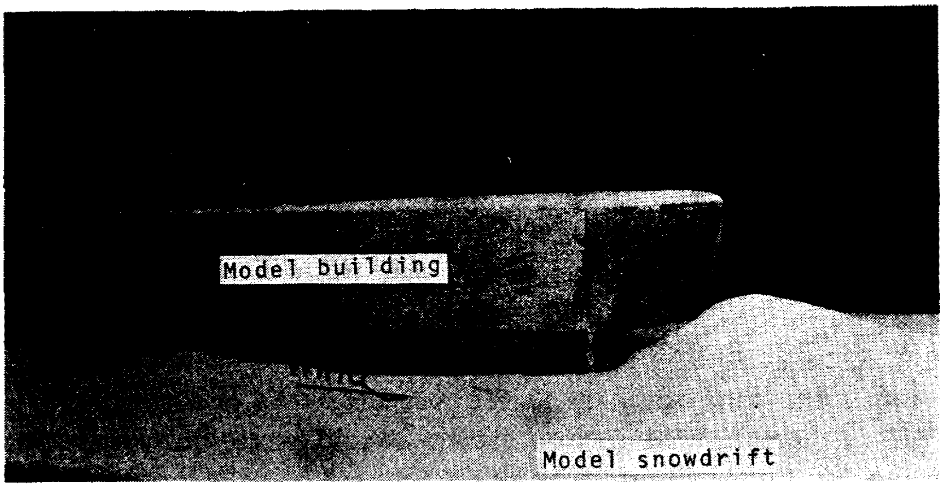

Fig. 4. Photo of a model snowdrift formed.

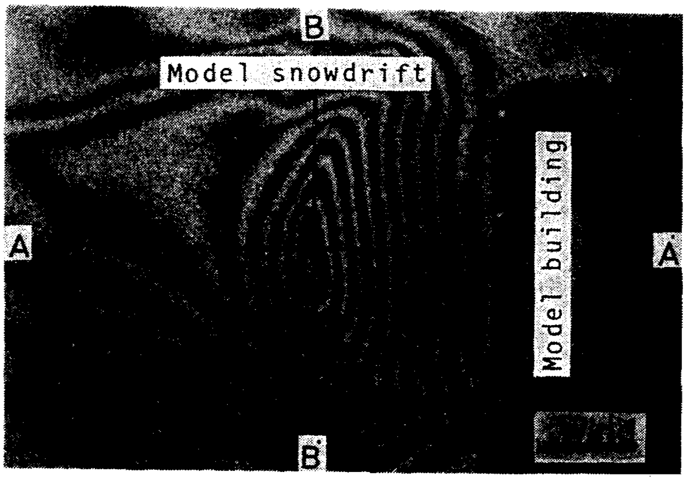

Fig. 5. Photo of the moire pattern of the model snowdrift measured.

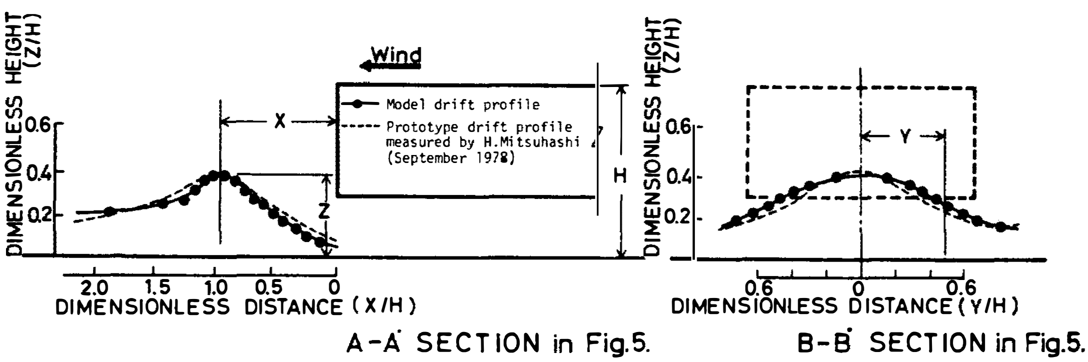

Fig. 6. A comparison of drift profiles between the model and its prototype (left: in the direction of wind; right: at right angles to it).

model drift profile was compared with the actual profile measured by MITSUHASHI (1982a) (Fig. 6). Figure 6 shows a close resemblance, because both crests are located at the distance of about 1.0 H, where H is the building height, and the height of the crests is about 0.4 H.

The volume of actual snowdrift over an area of 4×24 m in the leeward of the building was 63.072 m^3 measured on September 22 (MITSUHASHI, 1982a). In the model experiment, the snowdrift volume within the corresponding area of 4×24 cm was 51 cm^3 which was equivalent to 51 m^3 in reality. The snowdrift formed in our modeling experiment is almost equal to the real snowdrift in both shape and volume.

4. Conclusion

The present modeling experiment showed that the snowdrift formed behind the elevated building at Syowa Station, Antarctica, was simulated well by means of activated clay particles and Anno's modeling criteria. Therefore, on the basis of this pilot experiment the authors are now ready to conduct a series of modeling experiments on minimizing snowdrift, varying the shapes and dimensions of elevated buildings in order to predict the most effective floor height and length of the buildings.

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