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SNOWDRIFTING AROUND GROUPS OF ANTARCTIC BUILDINGS

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ABSTRACT

Modelling of Antarctic snowdrifting was conducted in a turbulent boundary layer wind tunnel. Snowdrifting around groups of buildings for Antarctic environment was investigated. The effect of changing the height dimension and the relative spacing of the buildings on snowdrift formation was studied for both on-ground and above-ground configurations. The findings of this research were used to formulate building guidelines which provide valuable information for Antarctic building designers.

KEY WORDS: **Antarctic Building, Snowdrift Modelling, Turbulent Boundary Layer Wind, Wind Tunnel**

INTRODUCTION

Antarctic buildings have suffered from a range of problems caused by snowdrift accumulation, including blocked doors, windows, fire escapes, accessways and ventilation ducts, buildings being pushed off their footings and even complete inundation. Hence it is important that snowdrifting studies form part of the design process of proposed buildings in Antarctica.

To overcome some of the problems of on-site construction in the harsh Antarctic environment, a modular building system has been proposed (Rohde, 1990). The component buildings are based on the extended dimensions of a shipping container and may be constructed and completely fitted out in their country of origin. The buildings may then be shipped to Antarctica and transported to the site by sled or helicopter. Any number of modules may be arranged on site to form a small semi-permanent station. The buildings are easily relocatable if the site is found to be unsuitable.

The aim of this research was to investigate the snowdrifting formation around groups of three modular buildings. The work is a continuation of the study described in Kwok et al. (1991).

SIMILARITY OF MODEL AND PROTOYPE

Snow particle movement in Antarctica is initiated and dominated by a turbulent boundary layer wind. Due to the relatively small size of the buildings to be modelled, it was found to be neccessary to use the model scale of 1/50 in order to obtain reasonably sized model snowdrifts. Hence a 1/50 scale model of turbulent boundary layer wind flow over Category 2 open country terrain (AS.1170.2-1989) was generated in the Snowdrift Wind Tunnel (Kim et al. 1989). This flow simulates the summer conditions at a typical coastal site of Australian Antarctic Territory.

The model snow particle used was sodium bicarbonate, having a particle density of 1300 kg/m^3. It was selected from 12 different particles tested in the Snowdrift Wind Tunnel to ascertain which particle most accurately reproduced the snowdrift around the Observation Hut of the Japanese Shyowa Station in Antarctica (Kim et al. 1989). When the model snow was added to the wind tunnel, the modified flow characteristics closely resembled those of flow over a Category 1 exposed open country terrain (AS 1170.2-1989), thus simulating the winter conditions at a typical coastal site of Australian Antarctic Territory (Kim et. al 1989).

A 1/50 scale model of the Observation Hut was tested in the Snowdrift Wind Tunnel (Kim et al. 1992), and the results were found to be in good agreement with the prototype data collected by Mitsuhashi (1982). A number of similarity criteria were explored, including geometric similarity, similarity of surface and airborne particle motion and similarity of particle, fluid and inertia forces. The conventional densimetric and geometric, and the threshold densimetric particulate and geometric Froude numbers were calculated for a range of prototype conditions.

There were good agreements between the model and prototype snowdrift shapes despite mismatches in the threshold densimetrical geometric and conventional geometric Froude numbers. This appeared to confirm the general belief held by Anno (1984, 1989), Isyumov and Mikitiuk (1989) and Peterka and Petersen (1989) that strict Froude number scaling can be relaxed in the simulation of snowdrifting in some circumstances.

A number of time scaling relationships proposed by other researchers were investigated. Anno (1984) proposed the following dimensionless time:

$$\frac{T\ Q\ \eta}{\rho_p\ B^2} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where T = storm duration (hours), Q = snow drift rate, η = object's collection coefficient of particles, ρ_p = density of snow particles and B = representative length dimension.

The prototype and model snowdrift volumes are plotted against Equation 1 in Fig. 1. The prototype dimensionless time values were based on snow drift rates calculated from the mean wind speed measured during each individual storm. The model data were found to fall within the scatter of the protoype data, so Anno's time scaling was adopted for subsequent tests.

EXPERIMENTAL ARRANGEMENTS

Three sets of three identical models were constructed (see Fig. 2). The models in Set 1 had prototype dimensions L x B x H_r of 6m x 3.6m x

2.8m. Set 1 was used as the reference. Each of the three models in Set 2 had dimensions L x B x 1.5H_r and each of the three models in Set 3 had dimensions L x B x 2H_r. The effect of varying the spacing between the models was investigated by testing each set with gaps between the models of b/B = 0.33, 0.5 and 1.0 (where b = width of gap between buildings). The sets of models were tested both on the ground and at the height of h/H_r = 0.32 (where h = distance between ground and base of building). For all tests the long axes of the buildings were perpendicular to the oncoming flow.

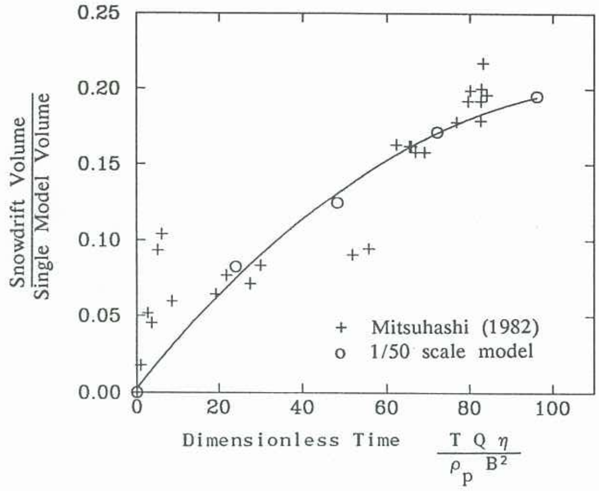
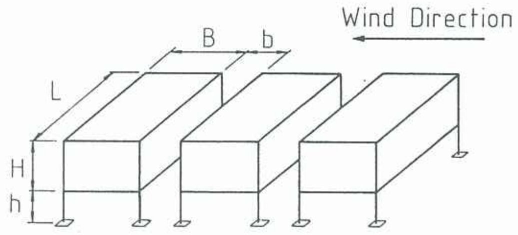


Fig. 1 Comparison of prototype and model data



Dimen-sion	Model Set		
	1	2	3
L	6.0	6.0	6.0
B	3.6	3.6	3.6
H	2.8	4.2	5.6

Fig. 2 Prototype dimensions (m)

Approximately 80 kg of sodium bicarbonate was introduced into the wind tunnel. The internal temperature of the wind tunnel ranged from 27°C to 37°C and the relative humidity ranged from 48% to 65%. The snow drift rate within the 0.6 m high working section of the wind tunnel was determined by a vacuum trap apparatus to be 0.125 kg/m.sec. The wind velocity at a reference height of 10 m in prototype (200 mm height at 1/50 model scale) at the centre of the working section was maintained at approximately 6 m/s. The duration of each wind tunnel test run was 4 hours, comprised of four 60 minute stages. This test length was chosen because it empirically gave model snowdrifts of a suitable size for comparison. If the testing had continued an equilibrium state would eventually have been reached, but there does not appear to be sufficient prototype data for comparison at present. The prototype time period that corresponds to this 4 hour test time depends on the prototype parameters used in Anno's (1984) proposed dimensionless time.

Contour images of the snowdrift shapes around the model were generated by a grid projection type Moiré fringe camera with a focal length of 1.8 m. The size of the area photographed was 900 mm x 600 mm and the measuring sensitivity was 5 mm height. The image was monitored by a closed-circuit television camera. After each test stage, the contour image was captured by a frame grabber, processed and saved on a computer hard disk. The grabbed images were then digitised and processed with contour analysing software which produces three-dimensional perspective or isometric surface representations for output to the computer monitor, printer, or plotter. The program also determined the volume of snowdrift by integration using a trapezoidal rule.

RESULTS AND DISCUSSION

Tables I-III show the computer-generated side views of the snowdrift formations around the models at the end of the 4 hour testing period. These images give qualitative information about the shape and postioning of the snowdrifts. In all cases the largest drift formed in the lee of the group of models. In the on-ground configuration snow particles also collected between the buildings, but for the largest gap width of b/B = 1.0 this effect was minimal. Larger gap widths might further reduce the accumulation between the buildings. However, a limiting value would eventually be reached beyond which the buildings would act independently and form their own snowdrifts.

Table I. Side views of snowdrift formations at end of testing: Model Set 1

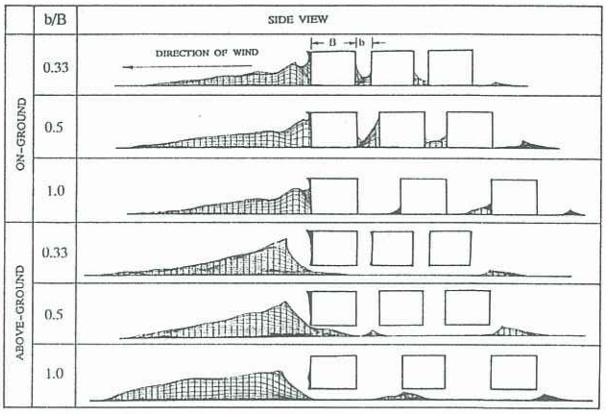


Table II. Side views of snowdrift formations at end of testing: Model Set 2

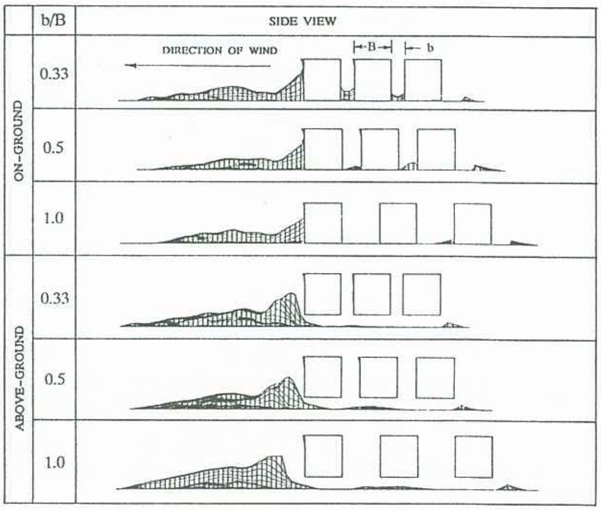
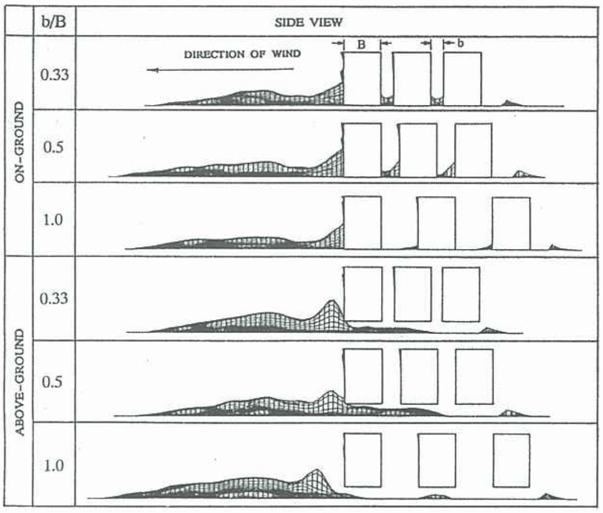


Table III. Side views of snowdrift formations at end of testing: Model Set 3



Figs. 3–5 show the snowdrift growth patterns around the three sets of models over the four hour test duration. For each set the snowdrift volumes have been normalised by dividing by the volume of a single model of that set. Anno's dimensionless time has been used, based on the values of particle density and snow drift rate given above and assuming $\eta = 1$.

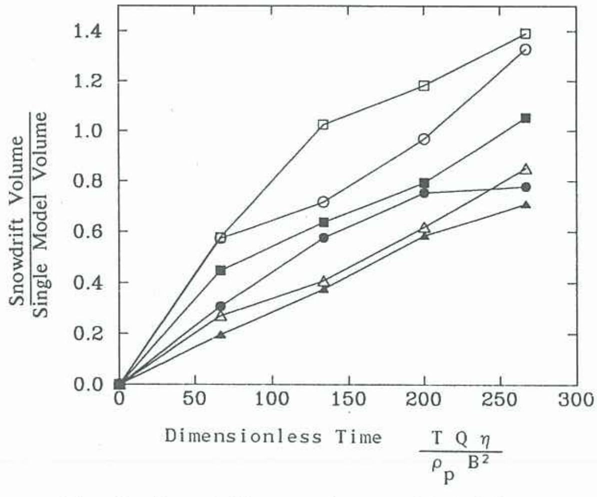


Fig. 3 Snowdrift growth rate: Model Set 1

Key	b/B	h/H_r
●	0.33	0
■	0.5	0
▲	1.0	0
○	0.33	0.32
□	0.5	0.32
△	1.0	0.32

Key to Figs. 3–5

In all cases, elevating the building caused an increase in snowdrift volume. This effect was less marked for Set 1. It can be seen from Tables I–III that in the elevated configuration, in most cases the drift was not attached to the buildings. This advantage can outweigh the increase in snowdrift volume in certain Antarctic building situations where the positioning of the snowdrift is more important than its size.

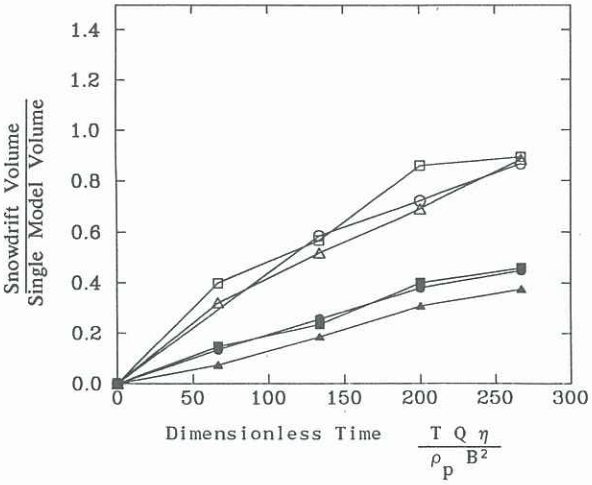


Fig. 4 Snowdrift growth rate: Model Set 2

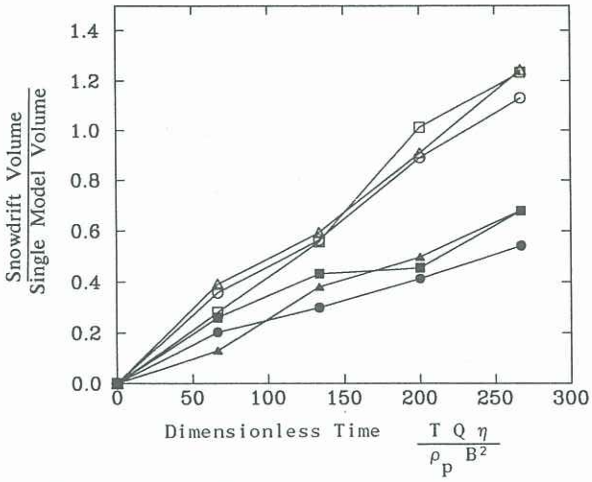


Fig. 5 Snowdrift growth rate: Model Set 3

For gap widths of b/B = 0.33 and 0.5, the elevated Set 1 models gave the maximum snowdrift volume, while for b/B = 1.0, the elevated Set 3 models gave the maximum snowdrift volume. For all gap widths, the on-ground Set 2 models gave the minimum snowdrift volume.

Fig. 6 shows the relationship of final snowdrift volume to gap width. For Set 1 models the smallest snowdrift volume occurred at b/B = 1.0. For Set 2, changing the gap width caused very little change in the final snowdrift volume. For Set 3, the smallest snowdrift occurred at b/B = 0.33. From these results it can be concluded that taller buildings form less snowdrift when the gap between them is reasonably small, while shorter buildings create less snowdrift when placed a building width apart. For buildings having the relative dimensions of Set 2, the snowdrift volume appears to be more or less independent of gap width (within the range of b/B = 0.33–1.0).

Fig. 7 shows the final snowdrift volume plotted against the relative height dimension of the building. In almost all cases, the building height dimension of $H/H_r = 1.5$ (i.e. Set 2) produced the smallest snowdrift volume. The one exception was that for elevated buildings with a gap width of b/B = 1.0, the height dimension of $H/H_r = 1$ (i.e. Set 1) produced less snowdrift.

Overall, the best performance with respect to minimisation of snowdrift formation was given by the buildings of Set 2 with a spacing of b/B = 1.0 in the on-ground configuration.

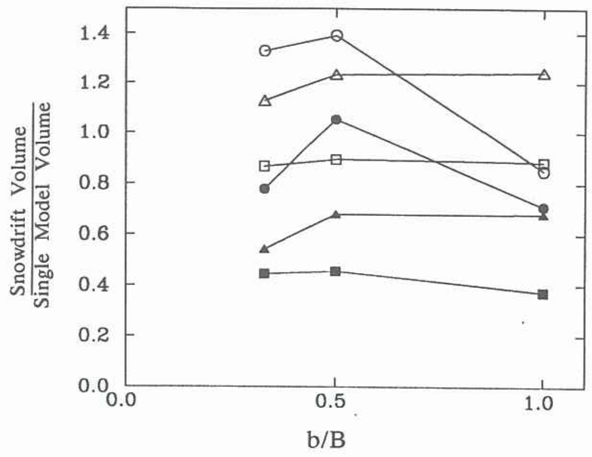


Fig. 6 Snowdrift volume at end of testing vs. gap width

Key to Fig. 6

Key	Model Set	h/H_r
●	1	0
■	2	0
▲	3	0
○	1	0.32
□	2	0.32
△	3	0.32

Key to Fig. 7

Key	b/B	h/H_r
●	0.33	0
■	0.5	0
▲	1.0	0
○	0.33	0.32
□	0.5	0.32
△	1.0	0.32

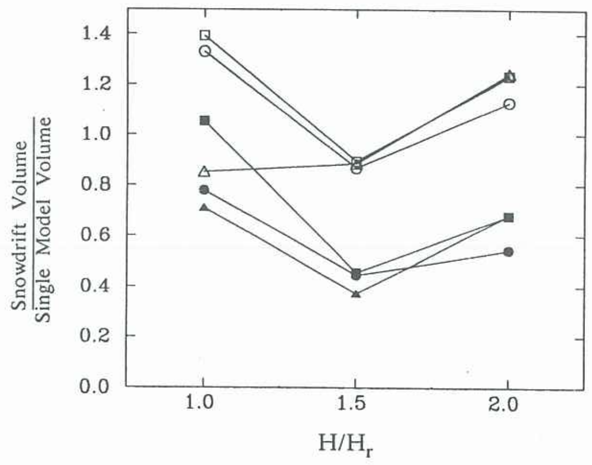


Fig. 7 Snowdrift volume at end of testing vs. building height dimension

CONCLUSIONS

The conclusions of this study can be expressed in the form of guidelines for the reduction of snowdrifting around groups of modular Antarctic buildings:

1. For groups of on-ground buildings, snowdrift accumulations in the gaps between the buildings can be minimised by spacing the buildings a building width apart.

2. Elevating the grouped buildings increases the volume of snowdrift, but the drift in most cases remains clear of the buildings.

3. Taller buildings (having the dimensions of Set 3) are likely to form less snowdrift when the gap between them is reasonably small. Shorter buildings (having the dimensions of Set 1) are likely to create less snowdrift when spaced a building width apart. For buildings of intermediate size (Set 2) the gap width appeared to have little effect on the snowdrift volume over the range tested.

4. The best performance with respect to reducing snowdrift accumulation was given by the Set 2 buildings placed on-ground and spaced one building width apart.

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