DETERMINATION OF ROOF SLOPES AND ROOFING

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DETERMINATION OF ROOF SLOPES AND ROOFING

MATERIAL RE SNOW RETENTION

A Report

by

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Guelph, Ontario

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SUMMARY

This project was initiated to determine the effect of roof slopes and roofing materials on the retention or release of snow.

A Snow Simulator or laboratory technique was used for the major part of the research and proved to be effective in analysis of models scaled to prototype roofs.

Static tests were used to determine the effect of roofing materials as well as degree of slope on sliding snow. Some field studies were carried out to confirm laboratory results.

OBJECTIVES OF RESEARCH

1. To determine critical slopes of roofs of houses and buildings, in general, which retain or disperse snow by gravity.

2. To determine the effect of common roofing materials on retention or dispersal of snow on roofs of various slopes by gravity.

Introduction

F.H. Theakston and Associates, Consulting Engineers, Guelph, Ontario, were commissioned by Canada Mortgage and Housing Corporation to conduct research in determining roof slopes and types of roofing material with respect to sliding or retention of snow on buildings in Canada.

There is a widespread variation of snow accumulation on the roofs of houses and other buildings in Canada throughout the winter months. There are many factors related to this occurrence such as the geographical location of the house or building, the snow belt location in which the house or building is sited, orientation, the prevailing wind, effect of other structures, type of terrain, trees and other objects. However, the retention of snow on roofs is mostly due to the slope of the roofs and the material used for the roof surface. Other factors will certainly add to the cause of retention such as sudden changes in the roof slope, dormer windows, overhangs, canopies and building appurtenances and the longer snow remains in situ the greater the density of the snow.

Most snow loads can be calculated from National Building Code criteria and by using a practical snow density value. However, snow which tends to slide makes it difficult to assess since the duration of the loading is difficult to compute.

In some parts of Canada house and other building owners wish to retain snow on the roof for insulation purposes and in some instances the owners have added devices to the roof to assist in retention of snow. Still others wish to remove snow as quickly as possible to decrease snow load on the roof either by gravity or other means. Owners of ski resorts, cottages and hotels sometime desire snow accumulation on the roofs for aesthetic reasons and conversely, others wish to have the snow removed as quickly as possible for structural safety reasons. It has been observed that overhanging snow or cornices at resort areas, dwellings, hotels, airport buildings such as terminals, hangars, etc., schools, churches and public buildings often create human hazards.

Generally, snow will remain on the roofs of buildings for a time the duration of which is dependent upon the slope and the roofing material. The snow accumulation will occur, to the greatest depth, on the leeside, which is due to wind currents. In protected areas snow will accumulate in depth on both sides and may release simultaneously. There is a striking similarity between the release of snow from a roof and the occurrence of avalanches though, of course, the latter is of greater extent. Some of the information related to the release of avalanche snow has been useful in this study.

In certain buildings where metal cladding on the roofs has been used and where heat is transferred through the material from within it is expected that freezing and thawing through the night and day, respectively, creates globules of ice which accelerates the avalanche effect. However, even with this possibility the slope of the roof and the roofing material will be most dominant in the release or retention of the snow.

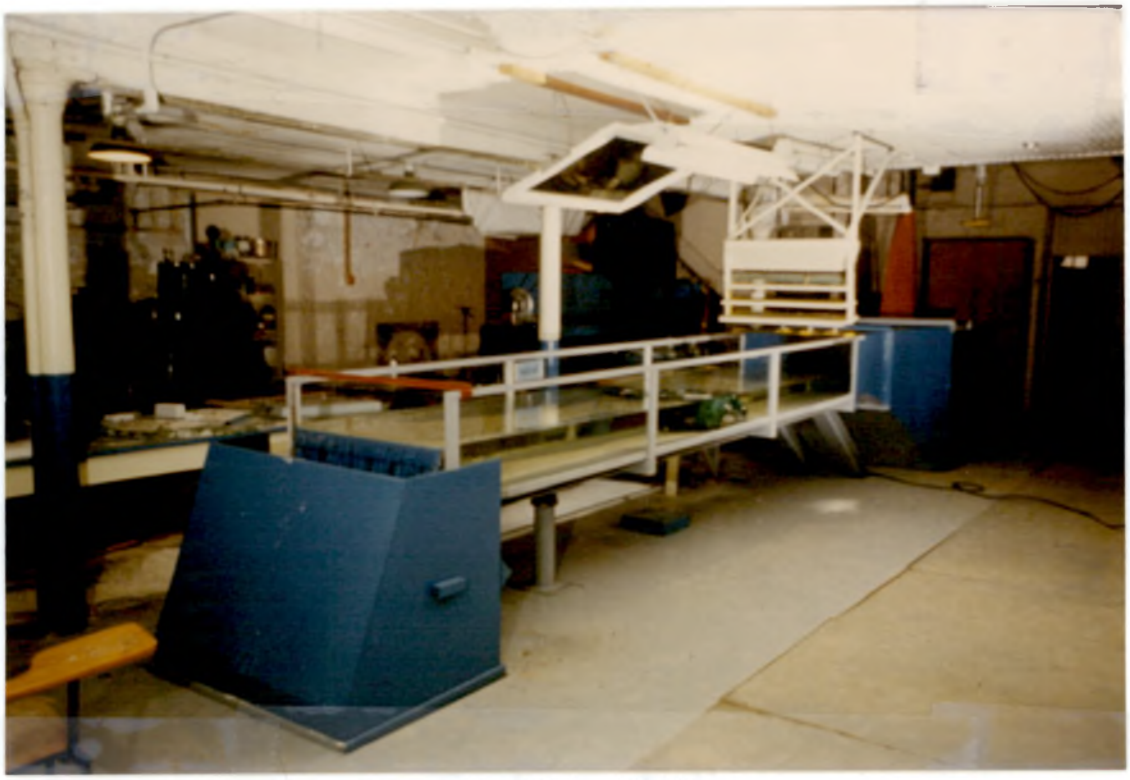
Some buildings, particularly Agricultural buildings, have a "racking" effect as wind pressure is applied to the building. This has a tendency to "spring" snow free of the roof especially if the roofing material is metallic.

While design information is available to architects and engineers through several sources it is not sufficient to provide builders with sound information regarding proper slopes of roofs for prescribed situations and, indeed, some of the slopes commonly used on houses encourage accumulation and subsequent retention which, of course, increases the snow load.

A Laboratory Procedure for Analysis

A laboratory procedure which utilizes "The Snow Simulator", (Figure 1) has has been most useful in studying slopes and accumulated snow. This device has been used for many years and was pioneered by the principal researcher in this study. The apparatus uses flowing water to simulate wind and silica sand to simulate snow. Models were used in studying various slopes of roofs and resulting accumulated snow and point of release of snow. It has proved to be effective in this study since a large number of units were tested in a relatively short period and without the necessity for winter conditions, (Figure 2).

The "Snow Simulator" is basically an open channel with glass sides for observation and measurement purposes. It is 9.2 m. long, 1.0 m. wide and 0.5 m. high. A wide range of simulated wind



OVERALL VIEW

END GATE-VELOCITY CONTROL

FIGURE I
SNOW SIMULATOR

velocities can be used by raising or lowering an end gate.

The models are made of plexiglass and are scaled to give comparative results with that of prototypes. The models are easily rotated to enable the researcher to study the effect of snow accumulation from varying wind directions. Silica sand is injected into the flowing water at the flume entrance and falls out at the model in the same manner as in a prototype situation. Maximum snow accumulation is identical to that obtained in prototype conditions. Because the model analysis is quite exacting in comparison with prototypes it is possible to study various roof pitches to determine critical slopes at which snow is retained or released. Field studies were made of several roofs and valuable information was obtained, (Figures 3 & 4). However, due to the period in which the study was made (April to August) it was not possible to obtain data for maximum snow conditions. It is recommended that follow-up field studies be made in the winter of 1984.

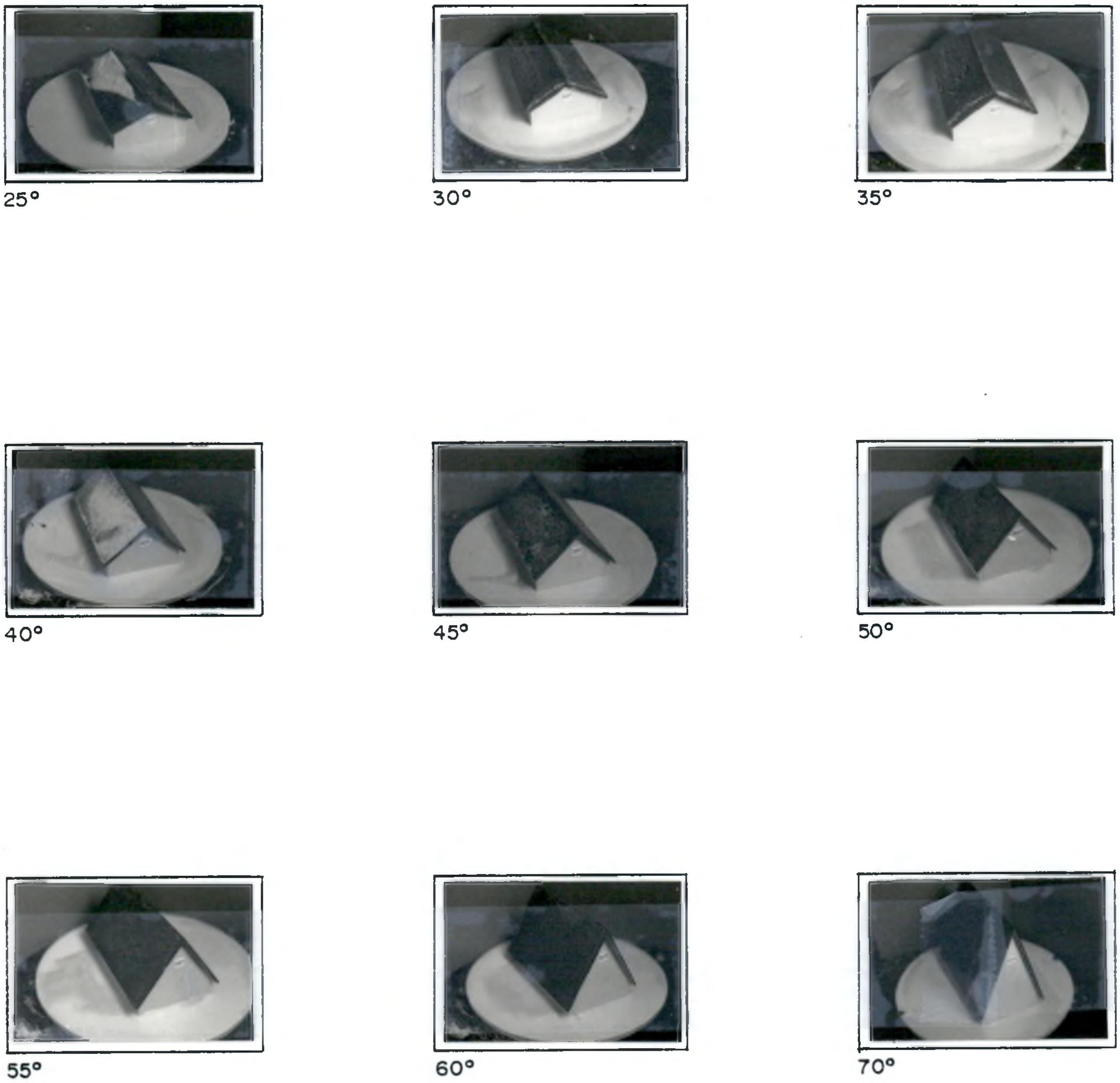


FIGURE 2

TYPICAL ROOF SLOPES

MODEL SIMULATION

FIGURE 3

SNOW ACCUMULATION ON ROOFS

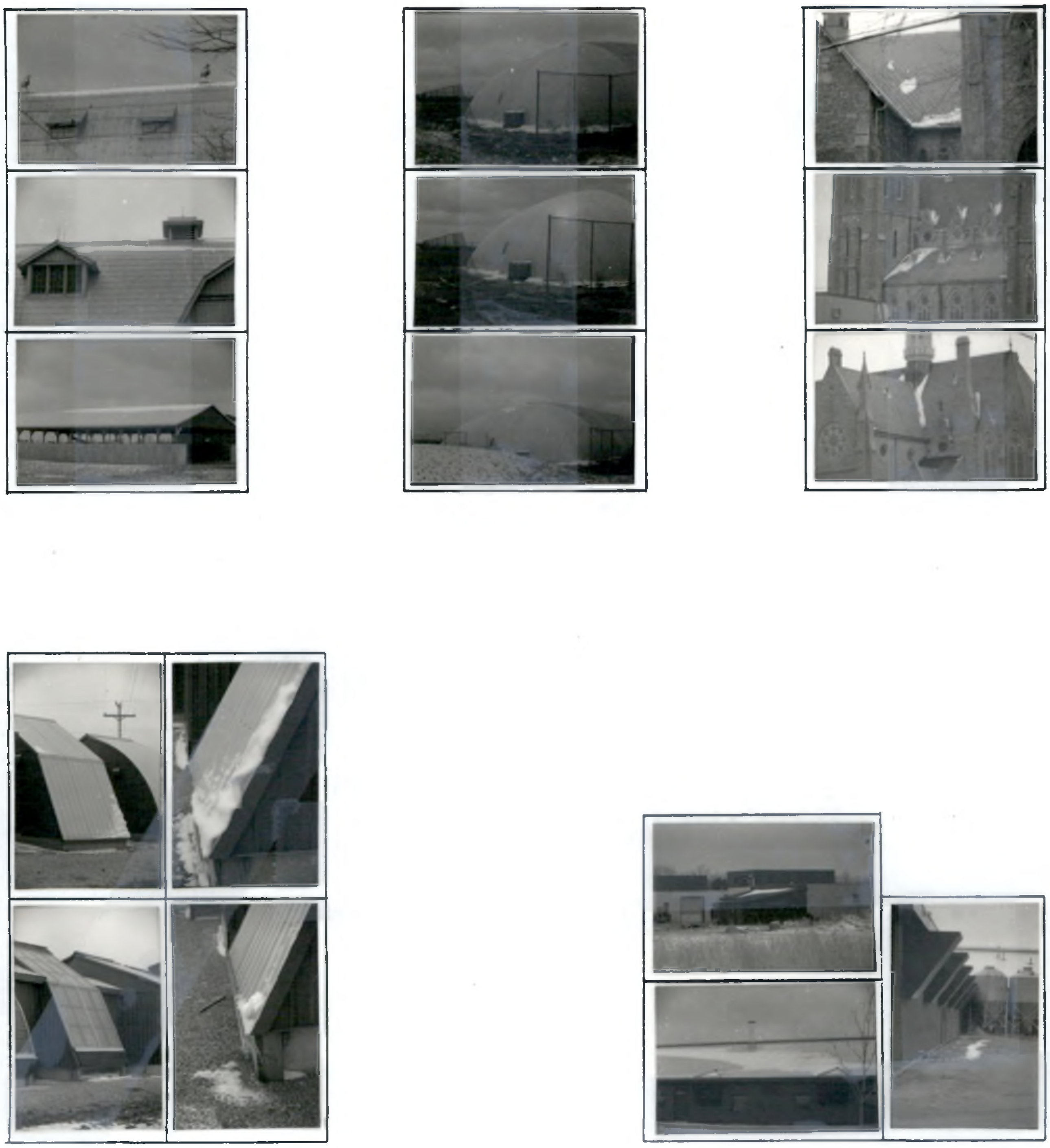


FIGURE 4

FIELD OBSERVATIONS OF SNOW ACCUMULATIONS ON VARIOUS ROOFS

Static Test of Roofing Materials

The study of roofing materials and their effect on retention or sliding of snow was most suitably carried out by using small scale roof shapes and actual roofing materials, (Figure 5). Snow, which had a density of 0.4 (the maximum density recommended by the National Building Code for design purposes) was used in the static tests. The roofing materials tested were those most commonly used in Canada and ranged from smooth to rough finishes. They were plywood, pre-painted sheet steel, pre-painted sheet aluminum, asphalt shingles, fibreglass, and cedar shingles. The angle of the slopes of the roofs varied from 25 degrees to 70 degrees at 5 degree intervals.

Observations were made of the reaction by the snow at each roof shape and roofing material. While this was being carreid out in the laboratory field studies were being made of prototype roofs of similar slopes and materials, (Figure 4). Although snow deposition in 1983 was minimal it was possible to do some field analysis and the comparison between field results and laboratory results was very favourable. Photographs were taken and some are included in the report. Tables showing the results of both Snow Simulation studies and Static Tests are included in the report, (Figures 6 to 11).

FIBREGLASS, ASPHALT SHINGLE AND PAINTED STEEL MODELS

CEDAR SHINGLE, PAINTED PLYWOOD AND PAINTED ALUMINUM MODELS

FIGURE 5

STATIC MODELS OF VARIOUS ROOFING MATERIALS

Conclusions and Discussion of Results

This study has enabled the researchers to analyse quickly and efficiently the effect of slopes of roofs and the roofing material on sliding snow. This has been possible, primarily, by the use of the "Snow Simulator" which has been developed by the principal researcher in this project.

In preparation of standards for snow loads on roofs in various countries with particular reference to the U.S.S.R. and Canada, Schriever and Ostavnov state "More research on the relationship between inclination and snow load for various conditions is required before much refinement can be developed." The results of the project indicate there is an opportunity for further investigation, primarily in the area of field studies, to support the results of the model analysis. The results of the project indicate that architects, engineers, designers and builders can put confidence in the model technique in planning roofs of usual or unusual slopes.

The static test of roofing materials indicates that all roofs, with either smooth or rough surfaces, will accumulate snow on both slopes if the building is enclosed by trees or other buildings. However, the snow will slide slowly under increases of accumulation up to an angle of slope of 30 degrees. From 30 degrees of slope to 50 degrees of slope the snow will accumulate to a maximum depth and as the density increases it will suddenly release similar to an avalanche. Further work should be carried out to determine the precise density at various slopes though in this study the recommended density of 0.4 by the N.B.C. was used in all cases. From an angle of slope of 55 degrees and greater there was little, if any, retention as the snow immediately slid from the roof, (Figures 6 & 7).

The model studies in the "Snow Simulator" permitted the researcher to study the effect of various wind directions relative to accumulation areas and retention. Cornering winds result in the greatest concentration of snow in one location of the roof (on the leeside) but no matter which orientation of wind used a maximum accumulation occurred. This was either retained or released on the same basis as the static test and was dependent on the degree of slope and texture of the surface, (Figures 8 to 10).

Six roofing materials were used in the study and, as may be expected, the rough textured surfaces retained snow for longer periods up to 50 degrees of slope but in every case there was a similarity of retention or release depending on the surface and slope, (Figure 11).

Recommendations

It is recommended that this project be a guide for future investigations of roof snow slide since it can be carried out in the laboratory.

However, corroboration should be obtained by field analysis under winter conditions. The researchers have already established a base for field analysis.

Some closer measurements of density should be made in the field and comparison made with initiation of sliding or avalanche flow.

Respectfully submitted,

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ROOF SLOPE (PITCH)	SMOOTH FINISH	ROUGH FINISH
25° (1/4)	NS	NS
30° (1/3)	SS	SS
35° (1/3)	A	A
40° (5/12)	A	A
45° (1/2)	A	A
50° (3/5)	A	A
55° (3/4)	SI	SI
60° (3/4)	SI	SI
70° (1 1/2)	SI	SI

KEY:

A — AVALANCHES
NS — DOES NOT SLIDE
SI — SLIDES IMMEDIATELY
SS — SLIDES SLOWLY

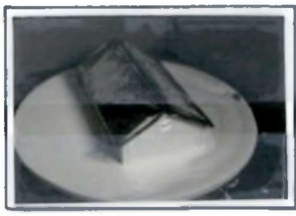
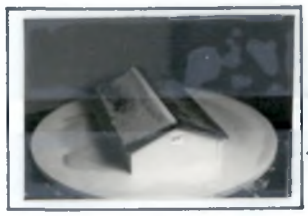
FIGURE 6
RESULTS OF STATIC TESTS
COMPARISON OF ROOF SLOPE, ROOF FINISH AND SLIDING OF SNOW

ROOF SLOPE (PITCH)	SMOOTH FINISH	ROUGH FINISH
25° (1/4)	A	A
30° (1/3)	A	A
35° (1/3)	A	A
40° (5/12)	MA	MA
45° (1/2)	MA	MA
50° (3/5)	MA	MA
55° (3/4)	NA	NA
60° (3/4)	NA	NA
70° (1 1/2)	NA	NA

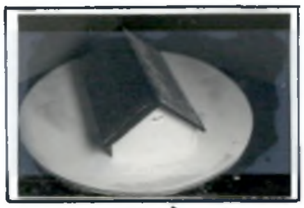
KEY:

A — ACCUMULATION
NA — NO ACCUMULATION
MA — MINIMAL ACCUMULATION

FIGURE 7
RESULTS OF STATIC TESTS
COMPARISON OF ROOF SLOPE, ROOF FINISH
AND ACCUMULATION OF SNOW

TYPICAL ACCUMULATION FOR 25°,30° & 35° SLOPES



TYPICAL ACCUMULATION FOR 40°,45° & 50° SLOPES

ALL WIND DIRECTIONS

* WIND DIRECTION

TYPICAL ACCUMULATION FOR 55°, 60° & 70° SLOPES

FIGURE 8

TYPICAL SNOW SIMULATOR TEST RESULTS

ROOF SLOPE (PITCH)	WIND DIRECTION *					
	SMOOTH FINISH			ROUGH FINISH		
	0°	45°	90°	0°	45°	90°
25° (1/4)	NS	NS	NS	NS	NS	NS
30° (1/3)	SS	NS	NS	SS	NS	NS
35° (1/3)	SS	SS	SS	SS	SS	SS
40° (5/12)	SS	SS	SS	SS	SS	A
45° (1/2)	SS	SS	SS	SS	A	A
50° (3/5)	SI	SS	SI	SI	SS	SS
55° (3/4)	SI	SS	SI	SI	SS	SS
60° (3/4)	SI	SI	SI	SI	SS	SS
70° (1 1/2)	SI	SI	SI	SI	SI	SI

KEY:

A — AVALANCHES
NS — DOES NOT SLIDE
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SS — SLIDES SLOWLY

* WIND DIRECTION

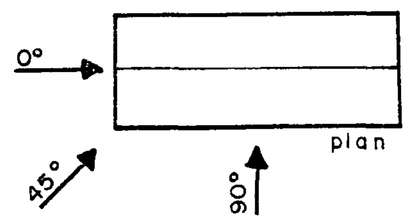

FIGURE 9

SNOW SIMULATOR TEST RESULTS

COMPARISON OF ROOF SLOPE, ROOF FINISH
SLIDING OF SNOW AND WIND DIRECTION

ROOF SLOPE (PITCH)	WIND DIRECTION *					
	SMOOTH FINISH			ROUGH FINISH		
	0°	45°	90°	0°	45°	90°
25° (1/4)	A	A	A	A	A	A
30° (1/3)	A	A	A	A	A	A
35° (1/3)	A	A	A	A	A	A
40° (5/12)	MA	MA	MA	A	A	A
45° (1/2)	MA	MA	MA	A	A	A
50° (3/5)	MA	MA	MA	A	MA	MA
55° (3/4)	MA	MA	MA	MA	MA	MA
60° (3/4)	NA	NA	NA	MA	MA	MA
70° (1 1/2)	NA	NA	NA	NA	NA	NA

KEY:

A — ACCUMULATION
NA — NO ACCUMULATION
MA — MINIMAL ACCUMULATION

* WIND DIRECTION

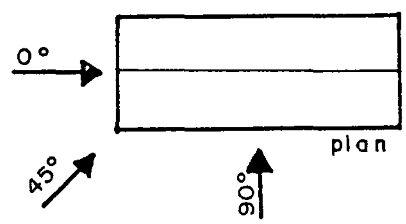

FIGURE 10

SNOW SIMULATOR TEST RESULTS

COMPARISON OF ROOF SLOPE, ROOF FINISH

ACCUMULATION OF SNOW AND WIND DIRECTION

ROOF SLOPE (PITCH)	FIBREGLASS	ASPHALT SHINGLES	PAINTED STEEL	CEDAR SHINGLES	PAINTED PLYWOOD	PAINTED ALUMINUM
25° (1/4)	SS	NS	SS	NS	NS	SS
30° (1/3)	SS	NS	SS	NS	SS	SS
35° (1/3)	SS	NS	SS	NS	SS	SS
40° (5/12)	SI	NS	SS	NS	SS	SS
45° (1/2)	SI	NS	SS	NS	SS	SS
50° (3/5)	SI	NS	SS	NS	SI	SI
55° (3/4)	SI	SS	SI	SS	SI	SI
60° (3/4)	SI	SS	SI	SI	SI	SI
70° (1 1/2)	SI	SI	SI	SI	SI	SI

KEY:

NS — DOES NOT SLIDE

SI — SLIDES IMMEDIATELY

SS — SLIDES SLOWLY

FIGURE 11

TEST RESULTS COMPARING VARIOUS ROOFING MATERIALS

ROOF SLOPE AND SLIDING OF SNOW