INSTANT SNOW STORMS

by

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In northern latitudes there is a very strong need for a positive method of determining, quantitatively, the amount of snow accumulated on the roofs of buildings and on the ground around other structures. The largest possible load to which roofs are subjected is snow load and it becomes obvious that the magnitude and distribution of snow are important factors in design of the roof structure.

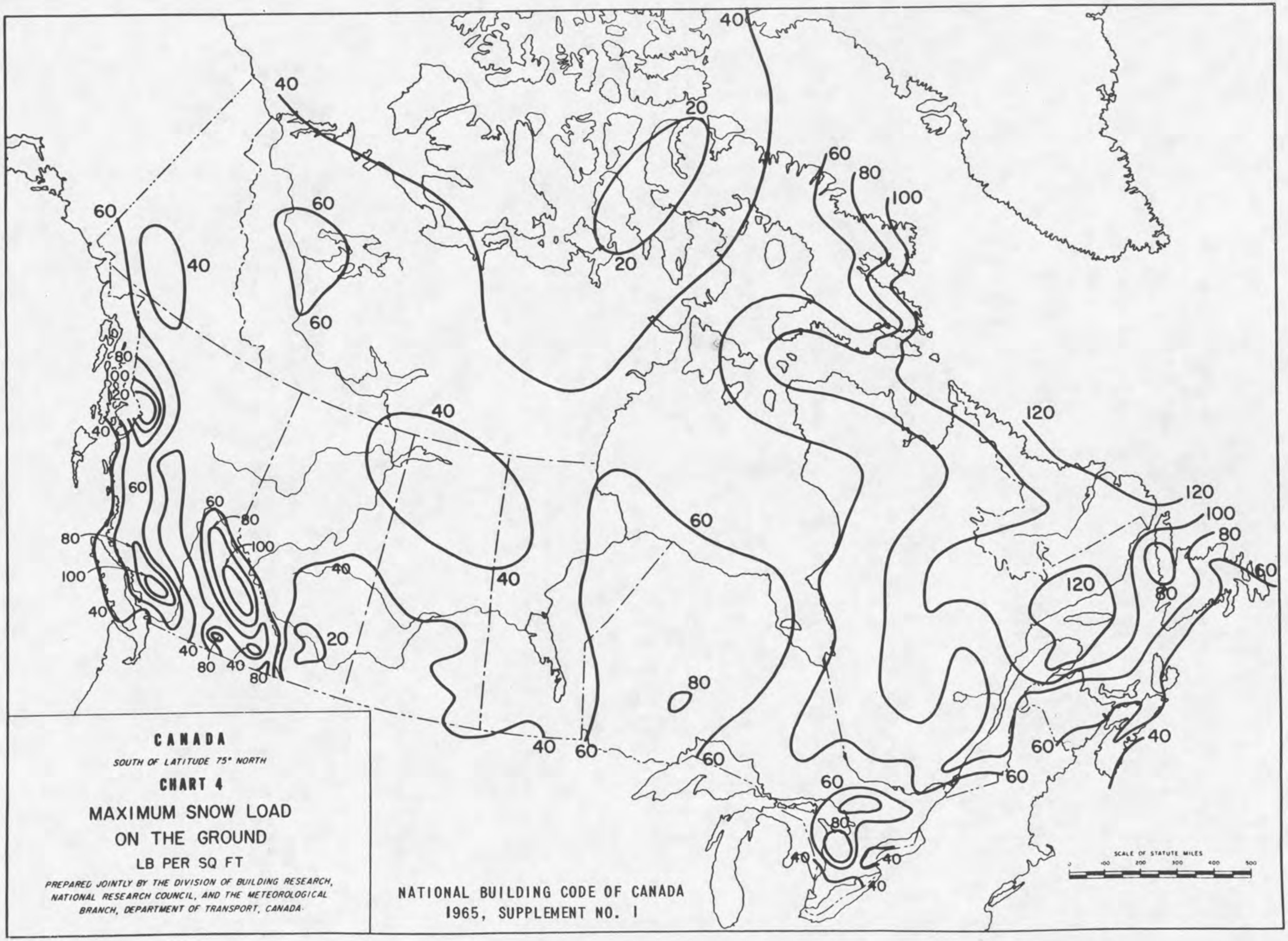
Prior to 1960, snow loads were specified by most building code analysts as a uniformly distributed load based directly on snow depth measurements at the ground level with modifications determined by the pitch of the roof. However, it has been observed that, in many instances, the average depth of snow on the roofs is appreciably less than that on the ground and in others, due to roof configuration, the depth of snow on the roof is much greater than that at the ground level.

In 1960, a revision of the National Building Code of Canada was made to arrive at a more realistic prediction of snow loads for various roof shapes. In spite of the revision more detailed prediction methods appear to be necessary to encompass the effect by factors hitherto unexplored.

Qualitative analyses in the field and in the laboratory have indicated definite repeating patterns created by snow deposition which can be predicted for certain conformation of roof structures. The accumulation of snow is initiated wherever wind, strong enough to transport snow particles horizontally, encounters an obstacle in the air-stream. This is the result of turbulence created by the obstruction and if all factors are considered such as, the shape of the roof, roughness of the surface, speed and direction of the wind, temperature, shelter conditions due to adjacent structures, heat loss, solar radiation and the physical properties of the snowflakes, the problem of prediction becomes complex indeed. Firstly, it would be desirable to study movement of a single particle but due to the physical characteristics of the flake, snow must necessarily be studied as a mass. Meteorological parameters compound the problem of prediction since the quality of flakes vary widely from light to fluffy to heavy and wet condition. If snowfall occurs with relatively calm conditions prevailing it is quite easy to measure the amount of snow accumulation by taking sample probes and averaging the results. The condition described rarely occurs since there is usually blowing and drifting accompanying the snowfall or following the storm. With granular flakes additional rolling situations occur which may make positive prediction impossible by normal methods of assessment.

It is a most time consuming and indefinite effort to study snow accumulation in the field due to constant changing weather conditions, length of storms and difficult wind attitudes. Therefore, a more satisfactory approach is by laboratory study if laboratory techniques can be developed to complement prototype conditions. Each study by itself cannot supply complete solutions tc a problem but a combination of a theoretical approach and an experimental study will yield success.

Researchers at the University of Guelph, Canada, have been able to establish a laboratory method to study snow deposition qualitatively by the use of an open channel water flume to create a fluid flow similar to that of wind but slowed to a degree which makes observation studies possible. By injecting light, white sand (density 2.675 g/cm^3) in the fluid simulated snow



CANADA

SOUTH OF LATITUDE 75° NORTH

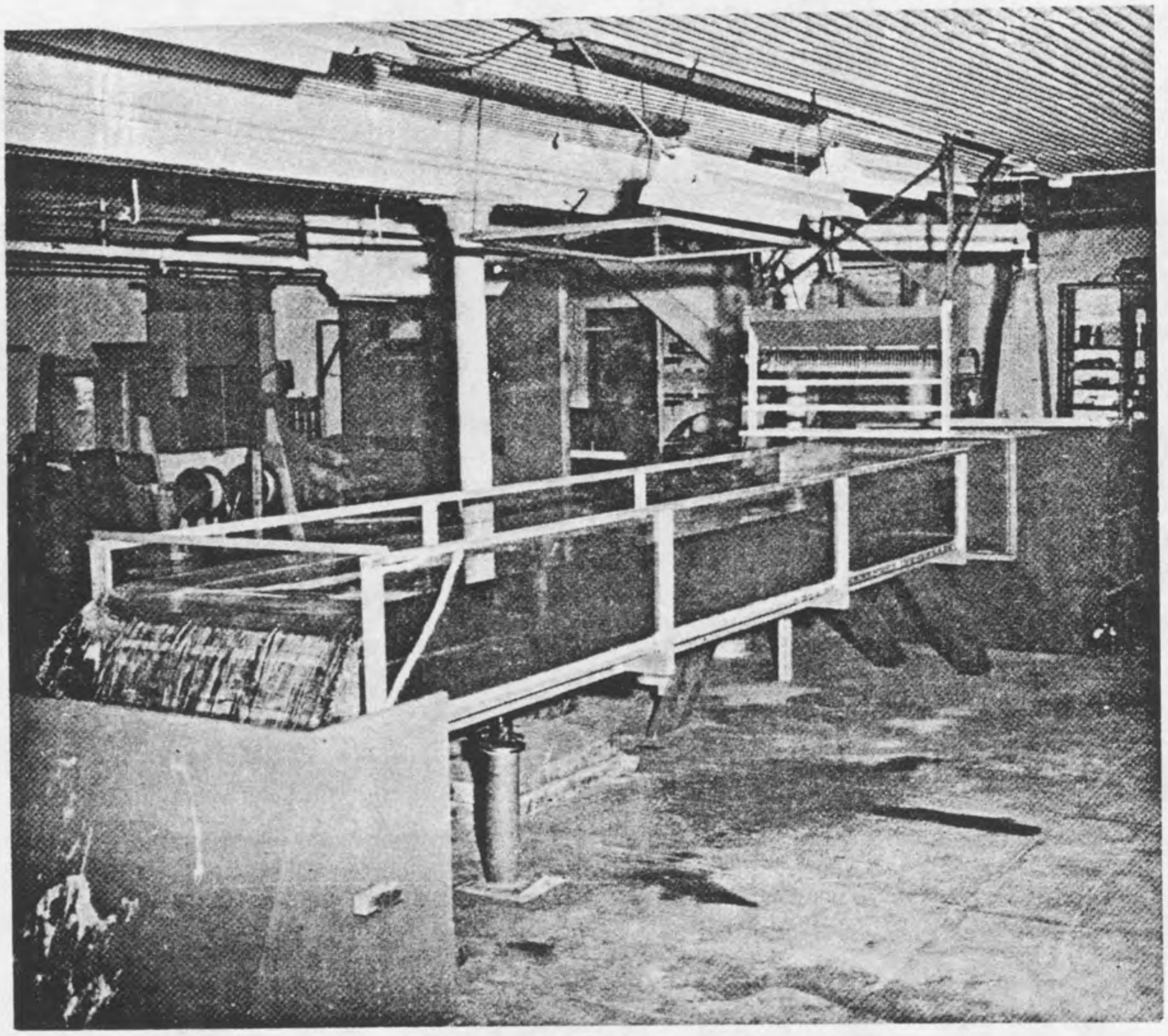
CHART 4

MAXIMUM SNOW LOAD ON THE GROUND

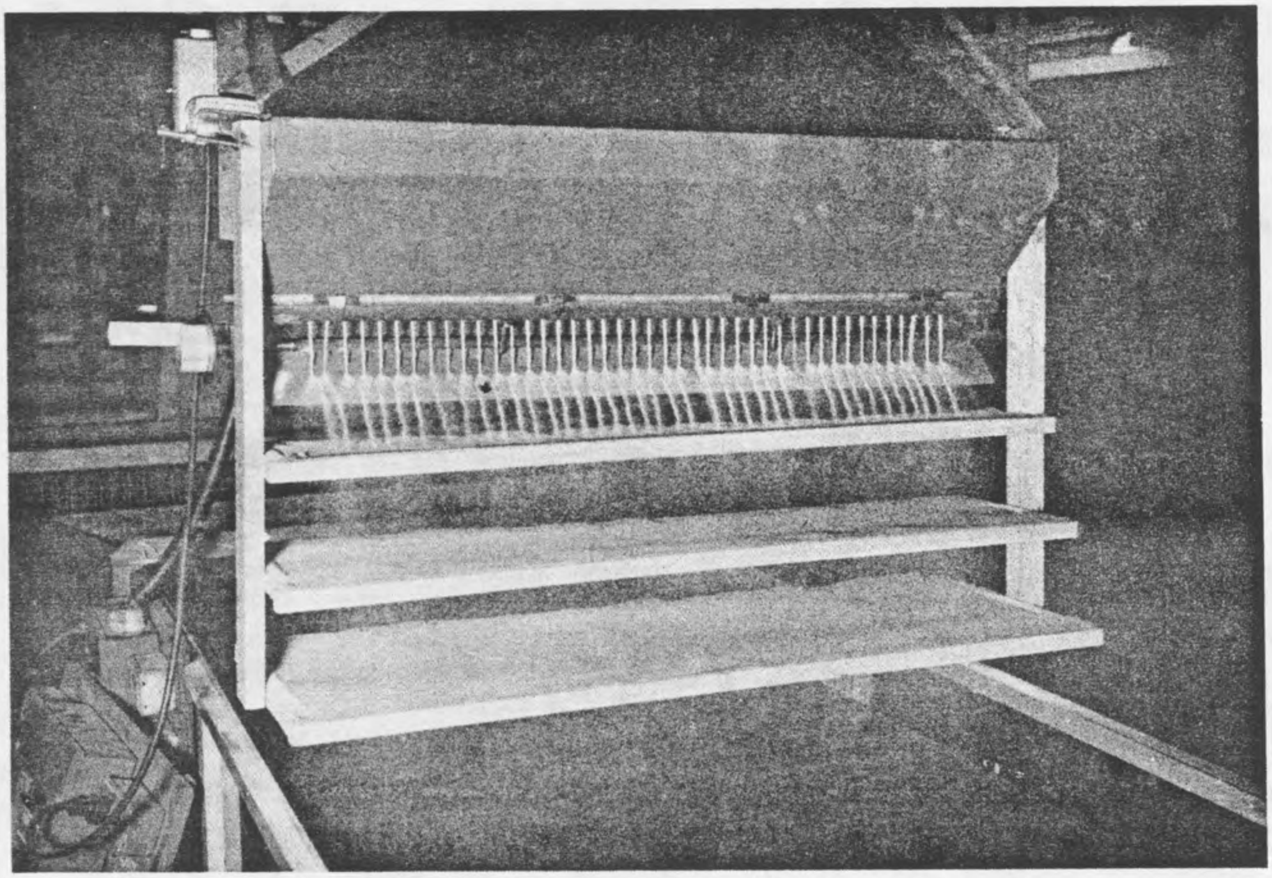
LB PER SQ FT

PREPARED JOINTLY BY THE DIVISION OF BUILDING RESEARCH, NATIONAL RESEARCH COUNCIL, AND THE METEOROLOGICAL BRANCH, DEPARTMENT OF TRANSPORT, CANADA.

NATIONAL BUILDING CODE OF CANADA
1965, SUPPLEMENT NO. 1



The water flume used for snow and wind model analysis.



The sieve used to distribute simulated snow in light, medium or heavy densities.

storms are created to pass over model buildings, fences, trees, undulating terrain depositing the sand at the base of turbulent areas in a manner identical to prototype conditions. No attempt is made to create similitude, indeed turbulent flow is desirable for ideal results.

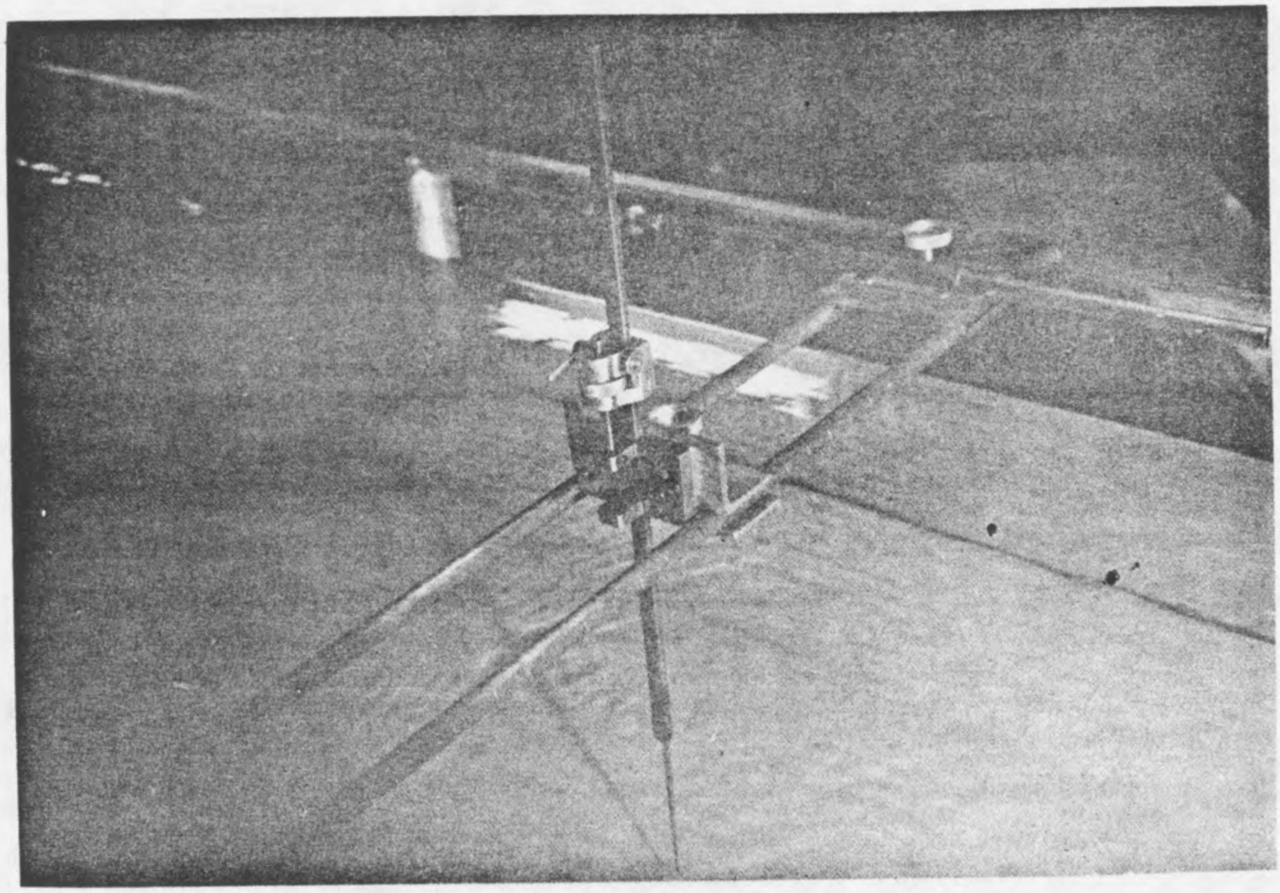
The water flume is 23 feet long, 3 feet wide and 18 inches deep with plexiglass sides to enable the researcher to observe and photograph resulting patterns. The flow of the snow carrying medium is approximately 3 cubic feet per second. The models are made from plexiglass at a scale of 1 inch equal to 16 feet and the terrain molded to compare with an actual site. Excellent results have been attained for qualitative analysis since the drifts around buildings and accumulation on the roofs of structures compare exactly with observations of prototypes. Comparative studies have been made time and time again by aerial photographs flown at 500 feet elevation and duplicated in a wind tunnel before submitting the model to a water flume analysis. Ground measurement of velocities are recorded at critical areas to ensure duplicity in the study. The sand used in the flume is carefully selected to compare with snow and is of a size that passes a 100 sieve.

Hundreds of situations have been duplicated in the flume by this method and solutions reached by installation of snowbarriers and wind breaks and often by removal of an obstruction causing turbulence at critical points. Every cardinal direction is observed by rotation of the model with very quick analysis. Since certain snow belts have repeated accumulation from prevailing wind directions, this is the usual direction studied for most cases though prevailing winds may often change due to effects by large bodies of water or other geographical features. Complete mining town areas have been studied in the Hudson Bay area prior to construction eliminating many difficult areas in the planning stages.

While qualitative assessment is of immense value to the design engineer, the landscape architect and site planner, it is of equal importance to be able to predict depth of accumulation. This is a most difficult assignment because of the inherent qualities of the snow particles. However, some progress has been made through the laboratory studies since fast simulated effects can be established for close study by the observer.

Pioneer work in drifting problems has been carried out by Bagnold who has provided basic descriptions of the various significant phenomena. Schneider(2) has indicated that the application of Bagnold's investigations with sand in relation to snow drifts requires close examination since the specific weight, (sand; approximately 2.5 g/cm^3; ice, 1.0 g/cm^3), the grain shape and size, and the general physical behaviour of the snow cover show substantial differences compared to sand. Bates(3) has also recognized these differences but points out that despite the physical differences there is similarity in the movement of snow and sand. Almost every type of sand formation, ripples, ridges, dunes and "shadows" has its similarity to snow. In all cases dryness is essential to movement and the transport of small particles over a surface has been shown to consist of suspension, saltation and surface "creep" of the material involved. In the application of drifting problems characteristic of snow, particle-surface interactions are of primary interest(4).

In this study three densities of snow storm, dense, medium and light have been created in the laboratory by careful control of the sand quantity injected into the water flume. A depth gauge is used to measure the depth



Measuring device used to scale depths of snow in and around models.

of snow accumulation. The development of the tests began with an accumulation measurement without any obstruction, then using model fences of varying heights and finally buildings arranged to create turbulence at critical points. When measurements were made in the flume comparative measurements were made in the field with timed intervals of snow fall in the flume and comparative timed intervals in the field. Through many analyses by this means there appears to be a linear relationship between the depth of snow and the time interval at the site of the model and the prototype. It is significant to note that characteristic "cupping" on the windward side of an obstruction and the characteristic sloping build-up on the leeward side of the obstruction shows linear relationship as well.

Certainly densities of wind-breaks and snow-barriers play an important part in snow distribution and this factor has been exploited by using louvered fences on wide roofs to spread the snow load uniformly to be consistent with design criteria rather than concentrate large drifts at critical roof areas such as roof valleys, low secondary roof lines and areas behind vertical objects such as chimneys or towers. In a recent publication by Schriever, Faucher and Lutes(5) confirmation of critical areas has been established by case histories of snow accumulation in Canada. The results from actual field measurements have corroborated findings in the laboratory to give further credence to prediction by model techniques.

In studies of this kind there is a relationship between the pressure-velocity pattern established in wind tunnel experiments with snow accumulation patterns on the roof of an actual building. As the pressure velocity pattern decreases snow accumulation increases. For example, when the pressure coefficient on the roof is -0.8 p.s.f. the depth of snow in the model is 0.75 inches, whereas, when the pressure coefficient is -0.1 p.s.f. the depth of snow is 0.5 inches and the length of snow accumulation is established by qualitative analysis.

Several conclusions may be drawn from the model technique used in this study.

1. Density distribution of the simulated snow depends upon the velocity of flow of the transporting medium. An increase in flow increases the carrying capacity.

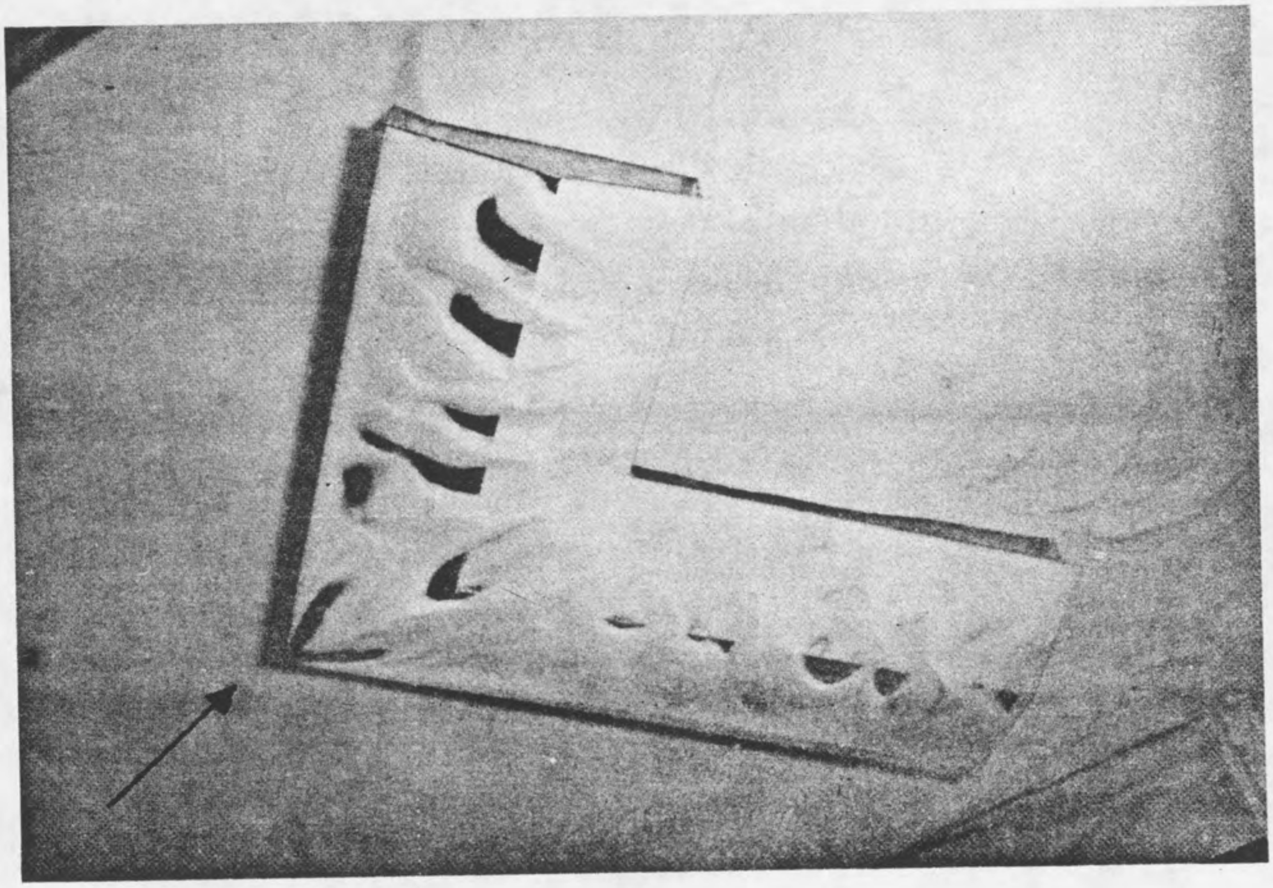
2. Gravity effects deposition with coarser particles settling out first and the lighter particles creating the patterns immediately downstream from the obstruction as is the case in the prototype field studies.

3. The "cupping" effect with light density snowfall is twice the width formed under medium and heavy snow storms of the same duration. This is due to the violent turbulence with the less dense material.

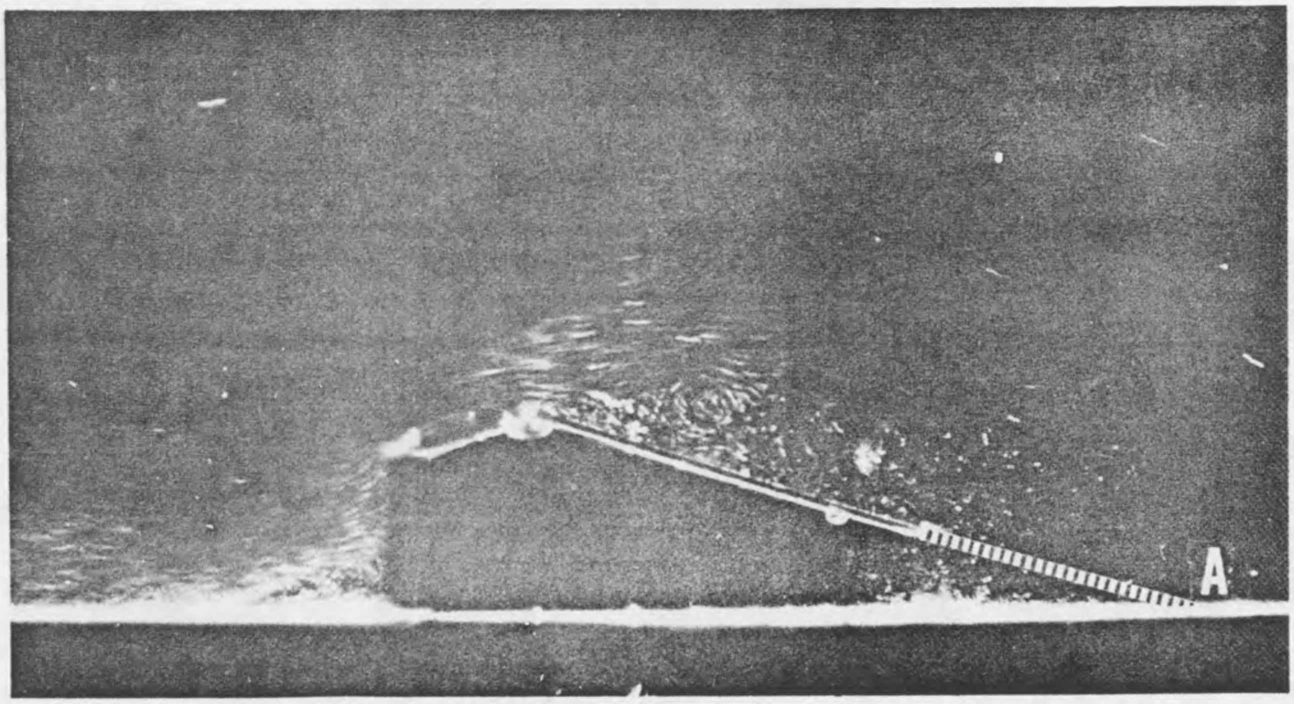
4. There is a proportional relationship between the height of the obstruction and the time interval of snow accumulation depending upon location and orientation of the obstruction.

5. A heavy density snowfall over a long period of time causes a "sliding off" action from a roof surface limiting depth of snow at any one location.

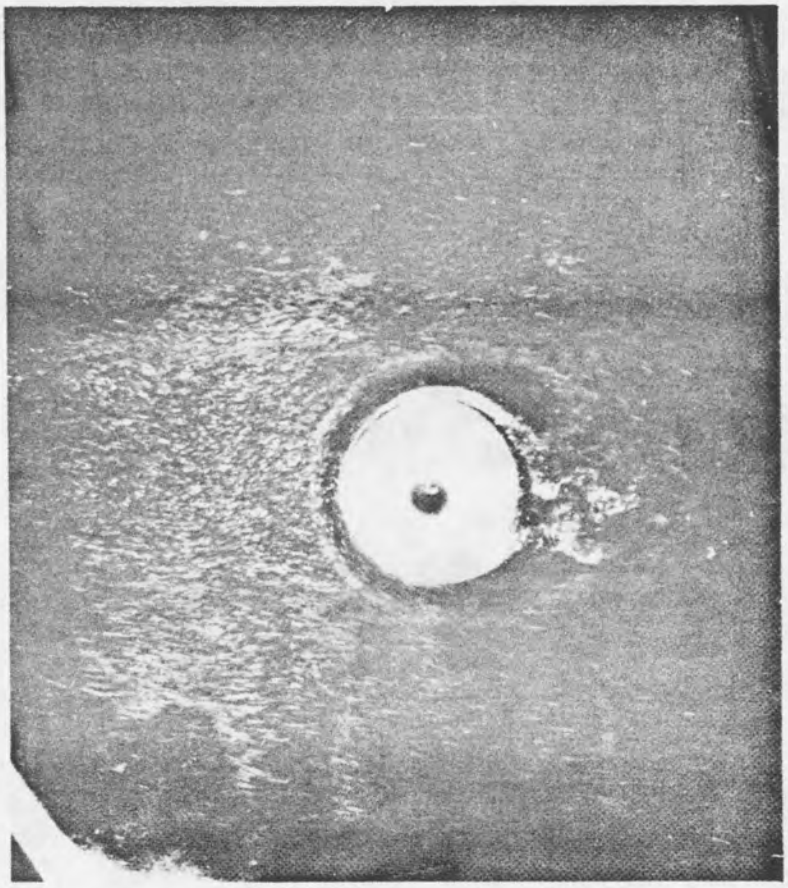
The laboratory method of analysis is conclusive for qualitative assessment of snow deposition and it is likely that further detailed research will result in positive prediction methods for design purposes which should be a valuable asset for establishment of improved building codes and provide a useful means of orientation of structures, highways, and landscaping features through a better knowledge of a most unpredictable natural element.



A model study of valley conditions with the wind from the bottom left. Maximum accumulation occurs level with highest obstruction.



Snow kicks into open-front buildings at point "A" in line with sloping roof. Turbulence occurs just over the ridge line. (Wind from the left).



Top view of circular structure showing turbulence on the lee side causing suction. (Wind from the left).

Date 25 February 1965
Location Sarnia, Ontario

Failure : Yes
Accumulation : Yes

No: 65-14

ROOF AND BUILDING DESCRIPTION

Type of structure and use : Large arched roofs. Warehouse.

Building Heated : No Roof Insulated: No

Shelter Conditions : Building exposed.

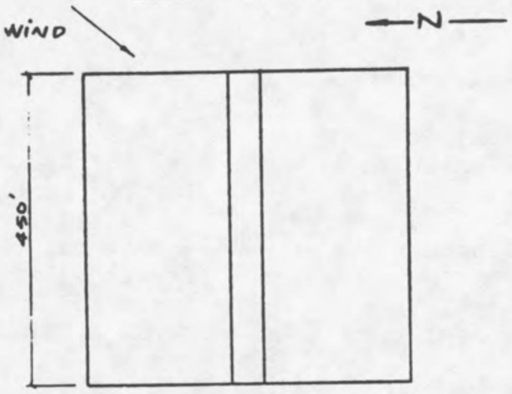
ROOF SNOW LOADS (psf)		GROUND SNOW LOADS (psf)	
NBC (1960):	24	NBC (1960):	30
Avg. Obsd.:	–	Avg. Obsd.:	13
Max. Obsd.: (estimated)	40 to 90		

SNOW LOAD DISTRIBUTION

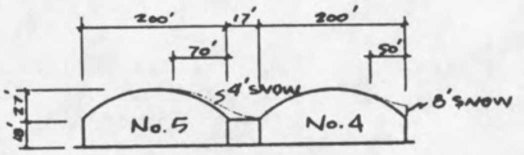
Snow accumulation on leeward side of building No. 5 caused collapse.

Collapse occurred after about 10 inches of snow had fallen in about 12 hours.

ROOF DESCRIPTION



PLAN



ELEVATION

Date 25 February 1965
Location Sarnia, Ontario

Failure : No
Accumulation : Yes

No: 65-15

ROOF AND BUILDING DESCRIPTION

Type of structure and use : Large arched roof. Warehouse.

Building Heated: No Roof Insulated : No

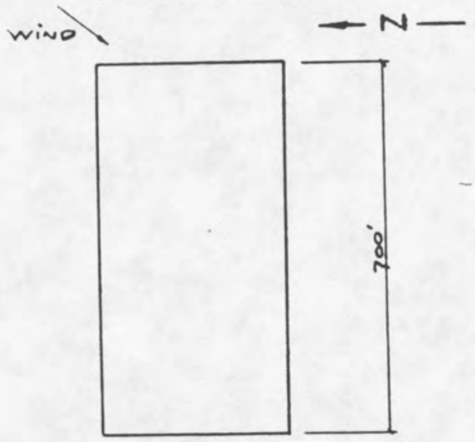
Shelter Conditions : No

ROOF SNOW LOADS (psf)		GROUND SNOW LOADS (psf)	
NBC (1960):	24	NBC (1960):	30
Avg. Obsd.:	12	Avg. Obsd.:	13
Max. Obsd.: (estimated)	50		

SNOW LOAD DISTRIBUTION

Drift up to 4 or 5 feet on leeward side of the warehouse. No failure occurred in this warehouse, but some bowing of the truss members was observed.

ROOF DESCRIPTION



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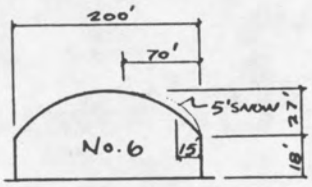

ELEVATION

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