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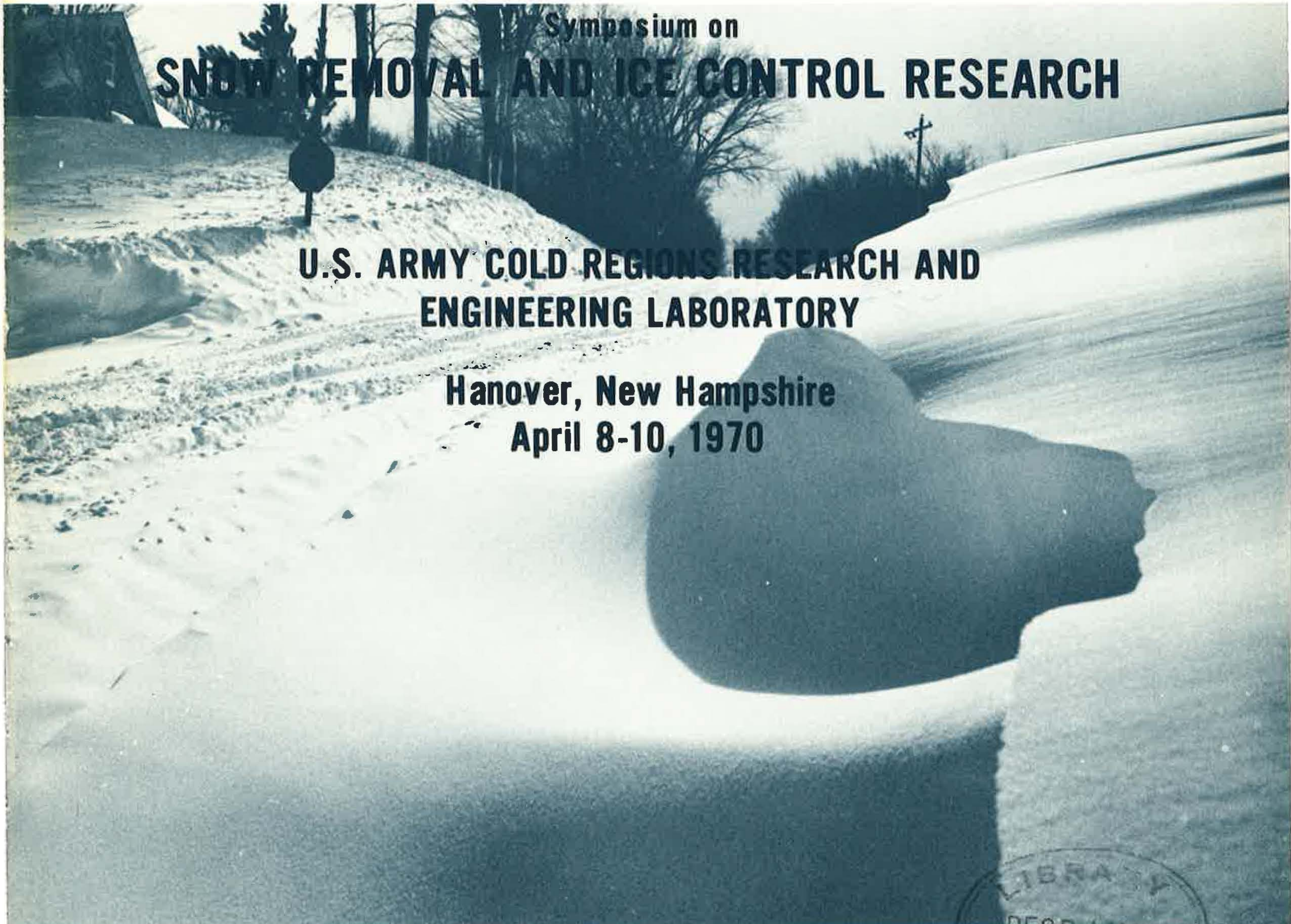

Symposium on

SNOW REMOVAL AND ICE CONTROL RESEARCH

U.S. ARMY COLD REGIONS RESEARCH AND ENGINEERING LABORATORY

Hanover, New Hampshire
April 8-10, 1970

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Symposium on

SNOW REMOVAL AND ICE CONTROL RESEARCH

THIS issue of Highway Research Circular contains information about a Symposium on Snow Removal and Ice Control Research, which will be held at Dartmouth College, Hanover, New Hampshire, April 8-10, 1970. Included are the program of all sessions and informative abstracts of the papers scheduled for presentation.

Authors who will present formal papers have been requested to furnish a limited supply of preprints of their papers. Because of the limited supply, preprints will be available during the symposium only to persons who desire to discuss specific papers. The Symposium Proceedings will be published later and will contain the papers and written discussions received not later than June 15. A copy of the Proceedings will be provided to each registrant, and the cost is included in the registration fee of $25, which will be charged all registrants.

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Addendum

SESSION 2

SURVEY OF ICE ADHESION

H. H. G. Jellinek, Department of Chemistry, Clarkson College of Technology, Potsdam, New York

Understanding adhesion is essential for solving problems of ice adhering to aircraft, runways, ships, and all kinds of solid surfaces. These problems have not been solved satisfactorily in many cases; frequently mechanical devices rather than principles of interfacial physical chemistry have to be used for minimizing ice adhesion. This paper discusses some of the fundamental parameters in adhesion, recent work on ice adhesion, application of fundamental principles of interfacial physical chemistry, effects of mechanical, rheological, and morphological properties of ice and its substrates, transition layer in the ice-air or ice-solid interfaces, and significance of some recent developments in interfacial physical chemistry for the problem of ice adhesion.

SESSION 3, PART 1

CALIFORNIA'S EXPERIENCE WITH ALL-WEATHER ROADS

C. E. Forbes, C. F. Stewart, and D. L. Spellman, California Division of Highways, Sacramento

This paper describes the present operations involved in snow removal and ice control in California where problems result from a variety of factors such as complex weather conditions, vast differences in elevation, wide temperature ranges, and changing traffic patterns. The paper includes a discussion of a research project initiated to study deck heating and motorist and maintenance warning systems to minimize the hazards of frosting. Also discussed is a study to find a de-icing chemical for use as an alternative to the chloride salts. A comparative test was established to measure the rate as well as the quantity of ice that could be melted at various temperatures. Also considered was the effect of the chemicals on the friction factor of concrete; the corrosivity to steel, concrete, and other materials; the environment, including streams, domestic water supplies, fish, and plant and animal life; and maintenance personnel who will distribute the chemicals on the roadway.

SESSION 3, PART 2

REVIEW OF SNOWDRIFT RESEARCH

Malcolm Mellor,
U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire

The blowing-snow phenomenon is described, and practical procedures for controlling deposition of wind-blown snow are reviewed. Field methods are given for measuring velocity, particle concentration, mass flux, particle size, and their distributions with respect to height. The analysis of steady-state wind transport over a plane surface is outlined, and difficulties in extending the treatment to cover complex flow perturbations are stressed. Wind tunnel studies are reviewed, and modeling criteria for snowdrift simulation are given. Suggestions for future work include semi-empirical model and prototype studies for short-term benefits, and extension of fundamental analyses and field observations for progress over the long term.

The Symposium is sponsored by the Committee on Snow and Ice Control of the Highway Research Board with the cooperation of the U.S. Army Cold Regions Research and Engineering Laboratory and Dartmouth College. The program was developed by a special steering committee under the chairmanship of L. D. Minsk, Research Physical Scientist, U.S. Army Cold Regions Research and Engineering Laboratory. Other members are G. M. Briggs, Assistant General Supervisor of Highway Maintenance, New York Department of Transportation; L. G. Byrd, Partner, Bertram D. Tallamy Associates; W. E. Dickinson, President, The Salt Institute; A. F. Ghiglione, Deputy Director for Operations, U.S. Bureau of Public Roads; L. W. Gold, Head, Building Research Division, National Research Council of Canada; J. F. Kelley, Maintenance Engineer, Massachusetts Department of Public Works; R. W. Korzilius, Division Sales Manager, Meyer Products, Inc.; James McDonough, Commissioner of Streets and Sanitation, City of Chicago, Illinois; Professor W. E. Meyer, Professor of Mechanical Engineering, Pennsylvania State University; D. L. Richardson, Arthur D. Little, Inc.; and C. L. Schulten, Federal Aviation Administration. The Committee on Snow and Ice Control is a committee of the Maintenance Department of the Highway Research Board under the chairmanship of J. F. Andrews, Director, Division of Maintenance and Equipment, New Jersey Department of Transportation.

The Symposium will provide a forum for discussions of the technical aspects of snow and ice control on roads and runways and for suggestions for the course of future work in the field.

Program

WEDNESDAY, APRIL 8

9:00 a.m. INTRODUCTION

Welcome—John E. Wagner, U.S. Army Cold Regions Research and Engineering Laboratory, Hanover

Welcome—W. N. Carey, Jr., Highway Research Board, Washington, D.C.

A Short History of Man's Attempts To Move Through Snow—L. D. Minsk, U.S. Army Cold Regions Research and Engineering Laboratory, Hanover

SESSION 1

CLASSIFICATION, MEASUREMENT, AND DETECTION OF SNOW AND ICE

Classification of Snow and Ice on Roads—Seiiti Kinosita and Eiju Akitaya, Institute of Low Temperature Science, Hokkaido University, Japan

A Study of Ice Detection, Prediction, and Warning Systems on Highways—Motoya Inoue, Japan Highway Public Corporation, and Kozaburo Baba, Hayakawa Electric Company, Ltd., Tokoyo

Prediction of Preferential Icing Conditions on Highway Bridges—C. Birnie, Jr., and W. E. Meyer, Transportation and Traffic Safety Center, Pennsylvania State University, University Park

The Profiling Radioactive Snow Gage—J. L. Smith, H. G. Halverson, and R. A. Jones, U.S. Pacific Southwest Forest and Range Experiment Station, Berkeley, California

SESSION 2

1:00 p.m. ICING ON PAVEMENTS AND ITS CONTROL

Survey of Ice Adhesion—H. H. G. Jellinek, Clarkson College of Technology, Potsdam, New York

Ionic Diffusion at the Ice-Solid Interface—R. P. Murrmann and J. W. Peek, U. S. Army Cold Regions Research and Engineering Laboratory, Hanover

Ice Adhesion Studies: Properties of Defects in the Interfacial Region—K. Itagaki and S. F. Ackley, U.S. Army Cold Regions Research and Engineering Laboratory, Hanover

Compaction or Removal of Wet Snow by Traffic—P. A. Schaerer, National Research Council of Canada, Ottawa

Skid Resistance Coefficient on Snow or Ice Roads—K. Ichihara, Japan Public Works Research Institute

Effect of Salt on Steel in Roadway and Bridge Concrete—P. E. Cunningham, U.S. Bureau of Public Roads

Pavement Heating—Keith Rosser, New Jersey Department of Transportation, Trenton

Wednesday evening. Banquet. Films of the European snow removal competition will be shown by John Wilmot.

THURSDAY, APRIL 9

SESSION 3

9:00 a.m. PART 1—ICING ON PAVEMENTS AND ITS CONTROL

Control of Road Snow and Ice by Salt and Electrical Heating—L. H. Watkins, Road Research Laboratory, Crowthorne, Berkshire, England

Chemical Melting of Ice and Snow on Paved Surfaces—D. A. Dunnery, Union Carbide Corporation, Tarrytown, New York

California's Experience With All-Weather Roads—R. Stratfull, California Division of Highways, Sacramento

PART 2—SNOW DRIFTING AND SNOW DRIFT CONTROL

Review of Snow Drifting Principles and Research—M. Mellor, U.S. Army Cold Regions Research and Engineering Laboratory, Hanover

Aerodynamic Snow Fences To Control Snow Drifting on Roads—A. R. Jumikis, Rutgers, The State University, New Brunswick, New Jersey

Snow-Drift Control in Mountainous Terrain—R. A. Schmidt, U.S. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado

Model Technique for Controlling Snow on Roads and Runways—F. H. Theakston, University of Guelph, Ontario

SESSION 4

1:00 p.m. EQUIPMENT FOR SNOW AND ICE CONTROL

Principles of Snow Removal and Snow-Removal Machines—I. K. Croce, Inzell, Germany

Snow-Removing Performance of Snowplow Trucks—Y. Tanaka, Japan Public Works Research Institute

Plow Clean Without Scraping—C. J. Posey, University of Connecticut, Storrs

Engineering Studies for Snow Removal—E. C. Bain, Dungarvon Company, Ltd., Almonte, Ontario

Current Research on Snow Removal and Ice Control on Roads in Japan—Raizo Tsuchiya, Japan Public Works Research Institute, and Motoya Inoue, Japan Highway Public Corporation

Panel discussion on experiences with snow-removal and ice-control tests during the 1969 and 1970 winter

FRIDAY, APRIL 10

SESSION 5

9:00 a.m. ECONOMICS OF SNOW AND ICE CONTROL

Models for Predicting Snow-Removal Costs and Chemical Usage—E. L. Miller, Ohio Department of Highways, Columbus

Tour of U.S. Army Cold Regions Research and Engineering Laboratory

GENERAL INFORMATION

Location

The Symposium will be held in the U.S. Army Cold Regions Research and Engineering Laboratory Building unless the number of preregistrations indicates attendance will exceed the capacity of this building. If so, the Symposium will be held in an appropriate Dartmouth College facility.

Fee

The registration fee for the Symposium is $25.00. This includes the Wednesday evening banquet and a copy of the Symposium Proceedings. Other meals and personal accommodations are not included.

Accommodations

A block of rooms has been reserved in the Hanover Inn, Hanover, New Hampshire, U.S.A. The rate for single-room lodging and breakfast is $14.00 per day and for double-room $10.00 per person per day. (These special rates apply only to persons staying for the duration of the Conference. Persons staying for less than the period April 8-10, will be charged higher rates.) Single accommodations will be limited, and accepted in order of receipt to capacity. A few additional units are available in two nearby motels if advance reservations are made.

Accommodations must be reserved in advance by individual conferees.

Accommodations in Hanover are limited although additional space is available in other nearby towns for persons driving to the Symposium.

Transportation

Hanover is served by the Lebanon Airport approximately 6 miles south. Taxi service is available from the airport to Hanover. Fare is approximately $2.00.

Bus service will be provided between the Cold Regions Research and Engineering Laboratory and the Hanover Inn and motels in Hanover.

Banquet

A banquet will be held at the Hanover Inn on Wednesday evening, April 8, at 7:30. The banquet will be preceded by a no-host social hour beginning at 6:30 p.m. The cost of the banquet is included in the registration fee. Wives are welcome to attend the social hour and banquet. However, an additional charge of $8.00 will be necessary.

No-Host Dinner

A dining room has been reserved at the Hanover Inn for conferees for Thursday evening, April 9, at 7:00. Refreshments will be available for purchase beginning at 6:30 p.m. The cost of this dinner is not included in the registration fee.

Registration

Hotel space is limited. Meeting space may be limited. Therefore, preregistration is requested, and it is suggested that the form on the last page of this Circular be used for preregistration. Requests for information on meetings and hotel accommodations should be mailed to

L. David Minsk
Applied Research Branch
U.S. Army Cold Regions Research and Engineering Laboratory
Hanover, New Hampshire 03755, U.S.A.

Registrants may mail payment for the conference with the preregistration form or pay upon arrival. All checks or money orders should be made payable to the Highway Research Board. Final registration arrangements will be completed on Wednesday morning, April 8, from 8:00 until 9:00.

Informative Abstracts of Papers To Be Presented at Symposium

SESSION 1

CLASSIFICATION OF SNOW AND ICE ON ROADS

Seiiti Kinosita and Eiji Akitaya,
Institute of Low Temperature Science, Hokkaido University, Japan

Snow on roads appears in many different types and changes ceaselessly by the action of traffic, snow removal work, and weather. Attention must be given to these changes in the study of snow removal and ice control operations and winter driving. Measurements were taken of density, hardness, temperature, and soil content, and micrographical observations were carried out in the winter of 1968-1969 on thin snow layers covering urban arterial roads in Hokkaido, Japan. Based on these data, the following classifications are proposed: new snow, composed of snow flakes; powdery snow, composed of loose grains 0.05 to 0.3 mm in diameter and blown up by a passing car; grainy snow, composed of loose grains 0.3 mm or larger in diameter, never blown up, and formed by mechanical mixing or chemical treatment; packed snow, composed of a network texture of grains of 0.05 to 0.3 mm in diameter; ice crust, formed by freezing of wet packed snow; ice film, formed by freezing of melt-water film; and slush, formed by melting of snow.

ICE DETECTION, PREDICTION, AND WARNING SYSTEM ON HIGHWAYS

Motoya Inoue, Japan Highway Public Corporation; and
Kozaburo Baba, Hayakawa Electric Company, Ltd., Tokyo

A system has been developed by which antifreezing action can be taken, e.g., spreading chemicals, and warnings can be provided to drivers to force slow driving. The system consists of the following five parts: (a) meteorological observation devices installed on roadway or roadside for measuring air, pavement, and underground temperature, wind direction, wind velocity, radiation, and humidity; (b) road surface moisture meter installed on roadside for measuring scattering of light and electric conductivity; (c) data processing equipment installed in the control center for use in predicting temperature transition and discriminating road surface moisture state; (d) data transmitter consisting of A-D converters and wireless or wire transmitters for transmitting data between observation sites and control center and between control center and warning signs; and (e) warning sign that has a changeable message and provides drivers with information on slippery conditions. With the use of this system we failed only once in 43 times (a skill score of 0.86) to predict at 5:00 p.m. that ice would form the following morning; we had a skill score of 0.96 in predicting 2 hours before hand that ice would be forming.

PREDICTION OF PREFERENTIAL ICING CONDITIONS ON HIGHWAY BRIDGES

C. Birnie, Jr., and W. E. Meyer,
Pennsylvania Transportation and Traffic Safety Center, Pennsylvania State University, University Park

Preferential icing of bridges, i.e., the freezing of bridges before the approaches do, involves the interaction of a number of variables such as location, weather conditions, thermal properties of the bridge structure, and traffic density. This paper reports on research undertaken to correlate these variables of weather, geographical location, and bridge deck thermal properties that lead to preferential icing. A bridge deck over a stream is instrumented to gather data on a continuous basis throughout the winter of 1969 and 1970. The field study is supplemented with a computer simulation of the heat flux in bridge decks and with measurements on a deck section in the cold room. With representative weather data and knowledge of the thermal characteristics of the bridge structure, it should be possible to construct a probabilistic model to predict the number of days per year that icing will occur. Such a model will be useful to the highway engineer in devising an economically justifiable countermeasure.

THE PROFILING RADIOACTIVE SNOW GAGE

J. L. Smith, H. G. Halverson, and R. A. Jones,
U.S. Pacific Southwest Forest and Range Experiment Station, Berkeley, California

Determination of snowfall amount or whether snow is actually falling is a major problem for agencies involved in snow removal or control on remote mountain roads or on remote, unattended airfields. A system has been developed by which snow density and depth may be measured in ½-in. increments by vertical profiling of a snowpack. The system is highly accurate and may be adapted for remote operation. With it one may determine whether snow is falling, the intensity of snow fall, the depth of the snowpack, and its density at all points in the pack. One may also determine whether rain is falling onto a pack, when the rain ceases, and when snow begins to fall again. Pack settlement, melt, or ice-crust formation may also be monitored. The gage consists of a small radioactive source and a detector that are drawn at a rate of one foot per minute through two access tubes extending from ground line to a point above the highest snow deposition. The signal can be sent by telephone line or radio to a base station where the signal is converted to depth and density and is recorded.

SESSION 2

IONIC DIFFUSION AT THE ICE-SOLID INTERFACE

R. P. Murrmann and J. W. Peek,
U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire

Diffusion of sodium chloride at the ice-aluminum interface was investigated at subzero temperatures in order to determine whether a liquid-like layer of water exists at this junction. The average value of the diffusion coefficient of sodium ions, determined at six different times ranging from 8 to 28 days after introduction of the ions to the interface, was $1.7 \pm 0.3 \times 10^{-7}$ and $0.72 \pm 0.32 \times 10^{-7}$ cm^2 sec^{-1} at -5 and -10 C spectively. Comparison of these values with the diffusion coefficient for ionic diffusion in bulk liquid water, $D \simeq 10^{-5}$ cm^2 sec^{-1}, and with that expected for ionic diffusion in cie, $D < 10^{-12}$ cm^2 sec⁻1, indicates that the net properties of the interface most closely resembled those of bulk liquid water. Lack of any consistent time dependence of the diffusion coefficient suggests that the nature of the interface was undisturbed on addition of sodium chloride. The decrease in diffusion coefficient with temperature was more than that which could be accounted for by assuming a constant activation energy of normal magnitude. These observations support the view that a transition zone with liquid-like properties and a temperature dependent thickness exists at ice-solid interfaces.

ICE ADHESION STUDIES: PROPERTIES OF DEFECTS IN THE INTERFACIAL REGION

K. Itagaki and S. F. Ackley,
U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire

Considerable work has been done on the surface chemical aspects of ice adhesion. Another point of view, however, is that ice adhesion may be primarily a function of the strength of ice in the interfacial region; i.e., ice sheared from a surface breaks away cohesively in the ice rather than adhesively at the substrate. The properties of ice in the interfacial region, especially those factors that influence the strength of ice (point and line defects), have been investigated this past year. Investigations, including Berg-Barrett and Lang X-ray topography, have revealed line defects in ice to be charged. The presence of this charge is considered in the devising of methods to weaken ice in this region. Other studies include surface self-diffusion, effects of ice-weakening impurities such as hydrofluoric acid, and microhardness investigations to determine the effects on ice dislocation mobility after the use of ice-release agents.

COMPACTION OR REMOVAL OF WET SNOW BY TRAFFIC

P. A. Schaerer, National Research Council of Canada, Ottawa

Observations were made of the free-water content of snow on roads and its behavior under traffic. A Tapley decelerometer was used to measure the skid resistance of the snow-covered roads. It was found that snow having a free-water content of less than 15 percent was compacted by traffic and formed a slippery surface on which a deceleration value of 0.30 was measured. Snow with a free-water content between 15 and 30 percent was usually not compacted but remained on the road in a soft, loose state and gave deceleration values of 0.35 to 0.42. The exact behavior depended on other variables such as depth, shape, and size of the grains. Snow with a free-water content of 30 percent was removed by traffic. Deceleration values between 0.40 and 0.50 were measured on this surface, and a value of 0.60 was measured on the bare, wet pavement. The observations confirm that chemicals need to be applied only in an amount sufficient to produce 30 percent melting if a decrease of the skid resistance can be tolerated. A melting of 15 percent would prevent the snow from being compacted into an ice crust but usually would not cause it to be removed by traffic, and thus plowing would be required.

SKID RESISTANCE COEFFICIENT ON SNOW OR ICE ROADS

K. Ichihara, Japan Public Works Research Institute

This paper reports skid-resistance coefficients obtained on snow or ice roads. Skid resistance changes according to snow conditions, temperature, kinds of vehicle tires, and chemicals used.

Three classifications of skid resistance used are skid resistance in braking condition, skid resistance in driving condition when the tire does not slip and just before it begins to spin, and skid resistance in driving conditions when the tire is spinning. These data are used in the discussion of stopping distance, longitudinal gradient, and cross fall of the road.

PAVEMENT HEATING

Keith Rosser, New Jersey Department of Transportation, Trenton

An experimental, heated pavement has been constructed in Trenton, New Jersey, by the New Jersey Department of Transportation in order to develop improved methods for snow and ice control. The experimental pavement serves the dual purposes of (a) providing design data for snow-melting systems of embedded pipe, and (b) utilizing the earth both as a source of heat and as a means of storing solar energy.

Wrought iron pipes of various diameters are embedded in portland cement concrete and bituminous concrete at a depth of 2 in. and 4 in. and at various spacings. During snow and ice conditions an ethylene glycol solution is circulated through these pipes, and a record is kept of the flow rate and temperature drop of the heating fluid. The effectiveness of any particular combination of pipe diameter and spacing and depth of embedment may be evaluated by observing the rate at which the snow melts and by calculating the amount of heat supplied to the pavement by the embedded pipes. Heat is extracted from the earth by means of a buried heat exchanger consisting of 6,000 ft of $1\frac{1}{4}$ in. wrought iron pipe. The earth beneath the pavement was excavated to a depth of 13 ft, and 5 layers of pipe were laid with a horizontal and vertical spacing of 2 ft as the pit was backfilled.

Operation of the system during the summer months, when the pavement temperature is greater than the earth temperature, reverses the heat transfer cycle, thereby transferring solar heat to the earth for storage. Heat losses from the earth to the air are minimized by an 8-in. layer of rigid polystyrene insulation installed beneath part of the pavement subbase directly above the heat exchanger. In addition, a 6-in. layer of polystyrene insulation completely encloses one section of the buried heat exchanger in order to reduce heat losses from the storage volume to the surrounding earth. The temperatures of the pavement, subbase, and earth are monitored by means of 100 temperature-sensitive thermistors located throughout the area.

EFFECT OF SALT ON STEEL IN ROADWAY AND BRIDGE CONCRETE

Sanford LaHue and J. N. Hall, U.S. Bureau of Public Roads
(to be presented by P. E. Cunningham)

The deterioration of bridge deck concrete has caused serious concern among highway engineers for several years. Considerable research has been undertaken to determine the causes for this deterioration. It is generally agreed that surface spalling is the most serious and annoying type of distress found in bridge decks. Several recent research reports indicate that corrosion of reinforcing steel is often a factor in the occurrence of surface spalls. This paper focuses on this relationship and discusses the various factors that may contribute to corrosion of reinforcement.

SESSION 3—PART 1

CONTROL OF ROAD SNOW AND ICE BY SALT AND ELECTRICAL ROAD HEATING

L. H. Watkins, Road Research Laboratory, Ministry of Transport, Crowthorne, Berkshire, England

The normal treatment for control and removal of snow and ice from roads in the United Kingdom is the application of sodium chloride, usually in the form of rock salt. The efficiency of this method depends on whether salting-lorry crews get into action at the correct moment; therefore, reliable ice-warning devices are needed. This paper briefly reviews present salting practice and work being done to develop suitable ice-warning equipment. It also gives an account of the development of an inhibitor to the corrosion of steel in automobile bodies caused by sodium chloride. The cost of this corrosion in the United Kingdom is many times greater than the cost of adding a corrosion inhibitor, if a suitable one can be found. A feasible, although expensive, alternative to using salt is to employ electrical road heating. This paper discusses work done at the Road Research Laboratory on the design and specification of these systems and gives some practical experience with their use in the United Kingdom.

CHEMICAL MELTING OF ICE AND SNOW ON PAVED SURFACES

D. A. Dunnery, Union Carbide Corporation, Tarrytown, New York

When it is impossible to remove ice from paved surfaces by mechanical means, chemical agents are employed either to completely melt the ice or to partially melt it so that it can be broken up and removed by brooming or scraping. Chlorides, which have long been used for this purpose, are objectionably corrosive. Urea, which is also widely used, is ineffective below the eutectic temperature of 11 F and is marginally effective below $\sim$ 15 F. A noncorrosive liquid agent has been formulated for use at temperatures down to 0 F. During the winter of 1969 and 1970 the agent will be tested in two applications at LaGuardia Airport in New York. In one area the agent will be tested for anti-icing, the object being to keep the test area completely free of ice throughout the winter. The agent will be applied weekly on a routine basis; additional applications will be made when icing conditions are imminent or as needed while icing conditions persist. In another area the agent will be used to facilitate the removal of accumulated ice and the residual compacted snow after snowplowing.

SESSION 3—PART 2

AERODYNAMIC SNOW FENCES TO CONTROL SNOW DRIFTING ON ROADS

A. R. Jumikis, Rutgers, The State University, New Brunswick, New Jersey

This paper describes some problems of snow-drifting control on roads in open terrain. Some of the relationships between geomorphological-climatic factors and snow fences as snow-drifting control devices are discussed. The aerodynamic-snow mechanics aspects of snow fences and flow processes of air-snow currents across dense and permeable snow fences are described, rough calculations are made for spacing of snow fences, and difficulties in theoretical analyses of aerodynamic snow fences are discussed. The paper also suggests additional studies that are needed to improve the effectiveness of snow fences. These include studies of geomorphology and climate of regions prone to snow drifting, aerodynamics of snow drifting, and aerodynamic-snow mechanics of various kinds of snow fences and their components.

SNOW-DRIFT CONTROL IN MOUNTAINOUS TERRAIN

R. A. Schmidt, U.S. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado

A series of tests using large snow fences to control snow accumulation in alpine areas of central Colorado has provided greater understanding of the effects of surrounding terrain on snow-drift control with fences. Cross-sectional profiles of the resulting snow drifts show that an upslope approach to the fence causes a short, high drift to form, and that a downslope approach causes a long, shallow drift to form. With the downslope approach, however, the total volume of snow trapped by the fence may equal or exceed the volume in the drift behind a fence with an upslope approach. Problems of locating fences for maximum effectiveness in irregular terrain are complicated by the need to maintain a gap between the fence and ground throughout the snow season. Placing fences in the lee of a ridge crest or other natural break in the terrain often increases the adverse pressure gradient and results in snow deposition upwind of the fence. The paper discusses how these situation can be avoided.

MODEL TECHNIQUE FOR CONTROLLING SNOW ON ROADS AND RUNWAYS

F. H. Theakston, University of Guelph, Ontario

Snow has always been a most difficult element to predict and also to control in areas where there is heavy accumulation. An open channel water flume and models have been used to predict consistently the patterns developed by falling snow. Light, white sand is used to simulate snow. Various densities of snow storms are created within minutes, and qualitative analyses are made for remedial measures. A wind tunnel study is carried out to ensure positive results.

SESSION 4

PRINCIPLES FOR SNOW REMOVAL AND SNOW-REMOVAL MACHINES

I. K. Croce, Inzell, Germany

This paper discusses the principles for snow removal and describes a snow-removal machine whose design is based on these principles. The machine can remove snow 3.5 meters deep in one operation. For many years it has proved to be very useful on roads and airports.

SNOW-REMOVING PERFORMANCE OF SNOWPLOW TRUCK

Y. Tanaka, Japan Public Works Research Institute

Field studies of the performance of a four-wheel-drive truck with snowplow produced the following results: (a) working resistance of the truck consists of the truck's rolling resistance that varies with its speed, sliding resistance of the snowplow, and snow accelerating resistance expressed as a quadratic of the truck speed; (b) at a truck speed of less than 7.5 mph, snow-removing performance of the one-way plow is not effective because the plow pushes snow without throwing; (c) snow-removing efficiency of the plow falls quadratically in accordance with the truck speed; (d) the distance removed snow is thrown increases quadratically depending on the plow speed; and (e) the plow with a conical surface has a better snow-removing performance than that with a cylindrical surface.

PLOW CLEAN WITHOUT SCRAPING

C. J. Posey, University of Connecticut, Storrs

In the method of highway snow removal most commonly used at present, a heavy steel blade or plow is mounted at an angle on the front of a heavy truck. If the truck is moving fast enough, the snow is thrown well to the side; otherwise it is pushed up into a ridge. At night a shower of sparks can often be seen where the blade is scraping the concrete. This wears the blade as well as the concrete and the reflective paint of traffic stripes. Where the blade does not contact the pavement, it may leave a hard-packed slippery skin of snow. This scraping can be avoided and at the same time snow can be removed completely by directing high-velocity air at the pavement. An air compressor is carried in the truck, and the compressed air is piped to a row of small orifices along the lower edge of the blade. Jet velocities in excess of 200 mph strip the pavement clean except where ice has frozen solidly to it. The air is intended not to blow the snow off the road but to lift it a few inches off the surface so that the plow can shove it off in the usual manner. Experimentation is under way to determine the best arrangement of jets to handle the many kinds of snow.

ENGINEERING STUDIES FOR SNOW REMOVAL

E. C. Bain, Dungarvon Company, Ltd., Almonte, Ontario

Changes in snow-removal methods will occur when snow removal is fully recognized as an engineering problem and sufficient engineering studies are made. Because adequate information and data are not available, the design and manufacture of snow-removal equipment has changed very little since the 1930's. Some of the needed engineering studies discussed in this paper are (a) advantages of snow throwing over snow plowing, especially in preventing snow banks or snow traps from accumulating along highways; (b) relationships among design of equipment, speed of vehicle, amount of snow, and distances snow can be thrown; and (c) safety features required on snow-throwing equipment operated in the 20 to 30 mph range.

CURRENT RESEARCH ON SNOW REMOVAL AND ICE CONTROL ON ROADS IN JAPAN

Raizo Tsuchiya, Japan Public Works Research Institute; and
Motoya Inoue, Japan Highway Public Corporation

This report describes various research studies relating to snow and ice on roads in Japan. Some of the results have already been applied in planning, design, maintenance, and operation of road projects. The studies deal with the following: the estimation of the effects of snow depth, topography, and vegetation on avalanche generation; the estimation of snow depth along planned routes, especially in mountainous areas where meteorological observations are not made; the classification of snow on road surfaces and the development of a highway ice information system; the space needed for roadside snow mounds and the design of that space; and the efficiency of different types of snow-removal equipment.

SESSION 5

MODELS FOR PREDICTING SNOW-REMOVAL COSTS AND CHEMICAL USAGE

E. L. Miller, Ohio Department of Highways, Columbus

One of the objectives of a maintenance cost study by the Ohio Department of Highways is the determination of the major factors that influence maintenance costs. This paper describes several models developed by multiple-regression analysis to predict both total cost and cost for material only for snow and ice removal on Ohio highways. The models indicate that the two most significant independent variables affecting cost per lane-mile for snow and ice removal are inches of snowfall and average daily traffic. The models have been used to budget snow- and ice-removal funds by applying 30-year weather data and current ADT to compute anticipated costs.

PREREGISTRATION FORM

Symposium on Snow Removal and Ice Control Research—April 8-10, 1970
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