Current Research on Ice Control

Gold, L. W.

Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/20378713
Technical Paper (National Research Council of Canada. Division of Building Research), 1965-07

NATIONAL RESEARCH COUNCIL
DIVISION OF BUILDING RESEARCH

CANADA

CURRENT RESEARCH ON ICE CONTROL

BY

L. W. GOLD

TECHNICAL PAPER NO. 202
OF THE
DIVISION OF BUILDING RESEARCH

OTTAWA

PRICE 25 CENTS

JULY 1965

NRC 8593

This publication is one of a series being produced by the Division of Building Research of the National Research Council as a contribution towards better building in Canada. It may therefore be reproduced, without amendment provided only that the Division is advised in advance and that full and due acknowledgment of this original publication is always made. No abridgment of this report may be published without the written authority of the Division. Extracts may be published for purposes of review only.

Publications of the Division of Building Research may be obtained by mailing the appropriate remittance, (a Bank, Express, or Post Office Money Order or a cheque made payable at par in Ottawa, to the Receiver General of Canada, credit National Research Council) to the Publications Section, Division of Building Research, National Research Council, Ottawa. Stamps are not acceptable.

A coupon system has been introduced to make payments for publications relatively simple. Coupons are available in denominations of 5, 25, and 50 cents and may be obtained by making a remittance as indicated above. These coupons may be used for the purchase of all National Research Council publications.

A list of all publications of the Division of Building Research is available and may be obtained from the Publications Section, Division of Building Research, National Research Council, Ottawa, Canada.

NATIONAL RESEARCH COUNCIL
CANADA
DIVISION OF BUILDING RESEARCH

CURRENT RESEARCH ON ICE CONTROL

by

L. W. Gold

(A talk presented to the Annual Meeting of the Saskatchewan Safety Council in April 1965, and reproduced in this form with their permission)

Technical Paper No. 202
of the
Division of Building Research

OTTAWA
July 1965

CURRENT RESEARCH ON ICE CONTROL

by

L. W. Gold*

I wish to express to you my appreciation for this opportunity to speak to you on a subject of real concern to all motorists. Before beginning on the subject of my talk, however, I would like to tell you about some of the activities of the National Research Council, so that the contribution these activities can make to the solution of problems of snow removal and ice control will be quite clear to you. The NRC is only one of a number of institutes and departments that is investigating or can investigate the problems of control of ice on roadways. But it is probably the organization most actively engaged in studies of this problem at present, and because of its position within the framework of science in Canada, the Council is the organization best able to provide the means by which studies on ice control throughout the country can be coordinated.

Late in 1916, the Government of Canada established an Honorary Advisory Council for Scientific and Industrial Research, now known by the short title "National Research Council". The Council is at present composed of twenty-one Canadians, including the President and three Vice-Presidents as full-time officials, and reports directly to the Privy Council of Canada.

The first activity of the National Research Council was to undertake a survey of Canada's scientific resources. This inventory showed that industrial research, at that time, was practically non-existent, and the national supply of research men entirely inadequate. To help remedy this situation, a system of scholarships and research grants was established in 1917. This program, which has been continued and expanded over the years, is one of the major activities of the National Research Council. Today, over 18 million dollars per year is directed toward the support of research at Canadian universities in this way, or

* Head, Snow and Ice Section, Division of Building Research, National Research Council, Ottawa, Canada.

about one-third of the Council's budget. The system of scholarships and research grants is one method by which money can be made available for research on ice control, but only to universities.

In 1917 the National Research Council began to coordinate research programs of a national character by means of Associate Committees. These Committees are national in scope, each acting as an autonomous unit; their membership is drawn from federal, provincial, university, and industrial organizations. When a major problem arises, the National Research Council forms a Committee composed of leading workers in the area of the problem who are particularly qualified to give guidance and advice. These men contribute their time without salary, and by exchanging information and views, work out a coordinated approach to the problem. At present there are some 40 Committees, operating in diverse fields, such as, Aerodynamics, Space Research, Paint Research, and Plant Breeding. One Committee in particular, the Associate Committee on Soil and Snow Mechanics, has a Subcommittee on Snow and Ice that gives attention to problems created by these materials. This Subcommittee is currently studying the problem of snow removal and ice control.

For the first eight years of its existence the Council employed a small administrative staff but no working scientific staff. It gradually became clear that in order to fulfil its responsibilities to Canadian industry, the Council would require its own laboratories. These facilities were initiated in 1925 and have increased through the years, and particularly during the war years, so that they now include eleven Divisions and two Regional Laboratories, providing a capability over a broad range of science and engineering.

In 1947, the Division of Building Research was formed to provide a research service for the construction industry and technical assistance to the newly established Central Mortgage and Housing Corporation. Within this Division there was established a Section that was to give attention to problems created by snow and ice.

The activities of the Snow and Ice Section are broad indeed, ranging from fundamental research to engineering, and include providing technical information. This Section considers problems such as establishing the thickness of ice on lakes and rivers required to carry a given load; determining the forces that ice can exert against structures, such as dams, wharfs, bridge piers; obtaining information on how ice deforms and fails under load; avalanche defence, and snow removal and ice control. In short, it attempts to provide to the engineer knowledge necessary for the solution of problems, and to obtain needed knowledge, when it is not already available, through the application of science. To place the activities of the Section in the right perspective, however, it should be pointed out that it is a small group, composed at present of four people trained in the sciences and engineering and two technicians, with the part-time assistance of a climatologist seconded from the Meteorological Service.

Other groups within the NRC consider problems caused by snow and ice, or study the properties of these materials. For example, the Division of Mechanical Engineering has developed a special gate attachment for ploughs that can be used to prevent ploughed snow from blocking driveways; the Division of Applied Chemistry is conducting fundamental studies on the optical and thermal properties of ice.

It is useful to emphasize that the three activities of the National Research Council, namely, administering University scholarships and research grants, Associate Committees, and running the laboratories, are quite independent. All three activities contribute in their own way toward the solution of problems of ice control.

In February of 1964, the Subcommittee on Snow and Ice sponsored a Conference on Snow Removal and Ice Control (1). This Conference had three principal objectives: to begin to define those factors primarily responsible for the cost of snow removal and ice control; to begin to record in one place easily accessible to all the considerable experience available on the problem; and to begin to define areas where research and development should be encouraged. One of the results of that Conference was the establishment of a Working Group under the chairmanship of Mr. W.D. Hurst, City Engineer for Winnipeg, which will consider the problem of Snow Removal and Ice Control in Urban Areas.

The papers presented at this Conference pointed out quite clearly that one of the more serious problems of winter maintenance is that of the control of ice on roadways. About 50 per cent of the winter maintenance budget for the Highway Departments of the Provinces of Ontario and Quebec is spent on the purchase and application of chemicals and abrasives for ice control. For example, the annual highway winter maintenance cost for the province of Ontario is now about $15.5 million, with about $5 million spent on ploughing snow, $5 million for sanding highways, $3 million for salting, and the remainder for road patrols, erection of snow fences, and other special tasks (2). Discussions with the staff of the Road Research Institutes in Norway, Sweden, and England, and with others in Switzerland, showed that the formation of ice on roads is also a major problem in these countries.

For the purpose of the present discussion, the ice control problem can be divided in the following way:

1) Ice formation and detection,

2) Prevention of the formation of ice,

3) Removal of ice,

4) The interaction between ice and traffic,

5) Ice control measures for vehicles.

In the following, information is presented on the research being conducted on these aspects of the ice control problem, and an indication of some of the problems that still require study. It is very probable that some current research projects have been omitted, and if so, we would be grateful if these omissions could be brought to our attention.

ICE FORMATION AND DETECTION

With the traffic conditions that exist on many of our modern highways, it would be useful if those responsible for winter maintenance had some method of predicting when the formation of ice on a road surface could be expected. This ability would have two practical applications: providing adequate warning so that preventive action could be taken, and providing motorists with a warning of dangerous highway conditions.

Ice forms on roadways as a consequence of weather conditions alone, or through the right combination of weather and traffic. In any program to combat ice, in particular to predict when and where it will form, it is necessary to have a good understanding of how the occurrence of ice depends on weather and on traffic. This information can be obtained only through a study of the micrometeorological conditions at road surfaces prior to and during periods of ice formation, and the characteristics of the traffic. Such studies are not being conducted in Canada, as far as we are aware, but they are being actively pursued in Sweden, Switzerland, and England. A difference between the average icing conditions that occur in these three countries, and the conditions generally encountered in Canada, should be noted. In Sweden, Switzerland, and England, ice formation usually results from the freezing of water on the roadway, or by the deposition and subsequent freezing of moisture on the road surface. In Canada, the serious ice problems usually result from either freezing rain or by packing of the snow by traffic.

In Sweden, an instrument is being tested that gives a signal indicating a risk of slipperiness when the temperature of the air or ground surface is lower than 30°F (-1°C) and at the same time the relative humidity is higher than 95 per cent. An apparatus has been developed to measure at intervals of five minutes the coefficient of friction between a slide with rubber runners and a dummy road surface (3). This apparatus has not given satisfactory correlation between the signal indicating a risk of slipperiness and the road conditions that did occur. Development work is continuing.

In Switzerland, equipment has been developed to measure temperature at various depths in the ground and at various heights above the ground surface. The humidity of the air is measured at various levels as well. The temperature and humidity, and their change with time, are used to predict when ice can be expected to form on the road surface. In England, a device has been developed that gives a signal when the temperature of the road surface is 37°F (3°C) and moisture conditions are suitable for ice formation. For only about 50 per cent of the cases when this device gave a warning, however, did icing occur. The results of these studies have been encouraging. In both England and Switzerland it is hoped that ability to predict the formation of ice can be improved by further research and development.

The present cost of installations for predicting when ice may form is about 3 to 5 thousand dollars per site, and so they cannot be used in great quantity. The general thinking at present is that such instruments could be usefully located at sites where ice usually forms first, and that the warning they provide must then be interpreted by the individual responsible for the maintenance of the roadway.

These devices are primarily for predicting ice formation on roadways due to freezing rain or deposition and subsequent freezing of water vapour as ice or frost. They would not be suitable for predicting the formation of ice due to the packing of snow by traffic. It is possible that adequate warning of all types of ice conditions can be obtained from special weather observations once the inter-relationship between ice formation, weather and traffic is well understood. This knowledge would be very useful background information for the problem of ice control in Canada, and so the necessary observations should be encouraged at universities and in those departments and institutes that have a direct interest in winter maintenance of roads.

THE PREVENTION OF ICE FORMATION

Once it is known that ice may form on a road surface, what steps can be taken to prevent its formation? At present, there is only one economical method - by the application of chemicals such as sodium or calcium chloride. The application of a chemical to the road surface prior to the formation of ice ensures that the water will remain liquid even while the air and road surface temperatures are below freezing. Considerable knowledge is now available on the action of chemicals in preventing the formation of ice, but good practical guide lines have yet to appear on how chemicals should be applied, and at what rate, for given weather, road and traffic conditions. Some work has been done on this problem in Canada, notably by the Ontario Department of Highways, and investigations are currently being conducted in Switzerland at the Swiss Federal Institute for Snow and Avalanche Research. There is considerable practical experience on the use of chemicals, but this experience is largely unrecorded and not thoroughly checked by controlled field studies. Spreading equipment has yet to be developed that will provide to the operator adequate control of the application of chemicals. It is useful to emphasize these facts since the current consumption of salt for ice control purposes in Canada is now about 1 million tons annually with the cost between $15 to $40 per ton, depending on the distance and method of transportation. Because of the amount of money now being spent on chemicals for ice control, and the present concern over their side effects, investigations should be encouraged that will provide the needed information about the application of chemicals under given conditions.

The contribution of sodium or calcium chloride to corrosion cannot be tolerated by aircraft, and is of considerable concern with respect to structures such as bridges, particularly if they have steel decks. The Central Experimental Establishment of the RCAF has conducted field trials of some non-corrosive chemicals for use on aircraft runways. These chemicals are, however, considerably more expensive than sodium chloride. The RCAF, City of Winnipeg, and the Ministry of Transport in England have conducted trials with urea, but, in addition to being quite expensive, it was found to be slower acting and had to be used in larger quantities than sodium chloride in order to obtain the same effectiveness. Studies have been made in Canada (by the RCAF) and in England on the use of glycol solutions but these were found to make the surface quite slippery and to leave a residue that was difficult to remove.

The RCAF has evolved a useful technique for preventing ice formation by the packing of snow by aircraft. A rotary broom was developed which, when used either alone or in conjunction with ploughs, depending on the snow conditions, will produce a snow-free runway.

Heating systems buried in the road surface have been considered for preventing ice formation and for melting snow (4). The installation cost for such systems is quite high, however, and their operating cost is between 25 and 50¢ per square foot per year. Because of their high cost, they can be considered only for particularly critical sites, such as approaches to bridges and throughways. There is not available at this time in Canada all the information that is required for feasibility studies and design of heating systems. Considerable work has been done on these systems by the Road Research Laboratory in England (5), but the conditions in England are sufficiently different from those in Canada that it is not possible to apply this experience directly to the problems here. The investigations required to obtain the necessary background knowledge for the design of heating systems for ice control in Canada should be encouraged.

REMOVAL OF ICE

For consideration of possible, economical methods of preventing the formation of ice on roads, it would be useful to have a thorough understanding of the way ice adheres to road surfaces. Information is available on this subject but our knowledge is still incomplete. Some quite fundamental studies on adhesion of ice to solids have been carried out by Prof. H. Jellinek at Assumption University in Windsor, Ontario.

It is known that ice will adhere to materials, such as concrete and asphalt, with a strength that can exceed the strength of ice. Laboratory studies of the shear strength of the bond between ice and such materials have shown that the failure usually occurs in the ice rather than at the interface. Those responsible for winter maintenance know how difficult it is to remove ice mechanically, even with a grader--a machine with quite a good planing action. It is not unusual for machines to cause considerable damage to roads and curbs when attempting to remove ice.

If the air temperature is above about 10°F (-12°C), some success in removing ice can be achieved through the application of chemicals. This technique may be slow, however, because the chemical must melt through the ice before it can affect the bond between the ice and the road. In addition, the action of traffic does not provide the assistance it does when the chemical is applied directly to the road surface. Studies are being conducted currently on the action of chemicals on ice by the State Road Research Institute in Oslo, Norway.

If the air temperature is below about 10°F (-12°C), the only practical way at present to control ice is through the application of abrasives. Studies conducted in Sweden show that if sand only is applied, the coefficient of friction between the tire and the ice surface may be reasonably high initially, but the coefficient decreases with time due to the sand being removed by the action of the traffic. A technique of water sanding has been developed in Northern Sweden, where temperatures are low and snowfall quite light, in which sand is bonded to the road surface by applying a thin layer of water. This provides a surface with a coefficient of friction nearly as high as that for bare pavement, and the coefficient remains at a satisfactory value for a reasonable length of time depending on weather conditions. The water-sanding technique is also used under emergency conditions by the Royal Canadian Air Force (1). A standard street flusher vehicle has been modified successfully for this purpose, and is now also used for a variety of jobs about RCAF stations, such as weed control and as an auxiliary fire fighting unit.

INTERACTION BETWEEN ICE AND TRAFFIC

Canada now has at least 467,000 miles of road, of which about 65 per cent are surfaced. There are about 6,000,000 vehicles registered in the country; every year each vehicle travels an average of 8,250 miles and consumes 600 gallons of fuel. In terms of passenger miles, automobiles accounted for about 86 per cent of the total performed by all modes of transportation in 1962. The average family spends about 9 per cent of its income on this form of transportation. The idea that it should be possible to drive an automobile under all weather conditions is coming to be widely accepted.

In order to carry the large traffic flow rates that occur on modern highways, those responsible for the construction and maintenance of roads must provide a surface with an adequate coefficient of friction between the road surface and the tire. For bare pavement or asphalt, the coefficient of friction is about 0.60 to 0.65. For an ice surface, it is about 0.2 or lower. Extensive investigations on the coefficient of friction between a tire and road surfaces in various conditions have been made by the State Road Institute in Sweden (3). In one of their reports it is stated that the only way to reduce the risk of skid accidents in the winter is to adapt the speed and the manner of driving to road conditions (6).

One subject that should be given attention is the determination of the road surface condition required to allow traffic to flow safely at a given rate. In residential areas a well compacted snow surface may be quite adequate for the speeds and flow rates encountered there. Such conditions cannot be tolerated on throughways and similar high traffic density roads. Information on the condition of road surface required for given traffic flow rates would be useful for decisions concerning the location and design of roadways and for determining the extent of winter maintenance and the techniques that should be used.

ICE CONTROL MEASURES FOR VEHICLES

Current research on the action that can be taken with respect to a vehicle in order to improve its ability to travel under icy conditions will be briefly considered. There is considerable interest currently in studded tires and the Highway Department of Ontario is conducting studies on their use. Extensive investigations are being conducted on studded tires by the State Road Research Institute of Sweden (3, 6). It is observed that studs increase the coefficient of friction between the tire and the surface by about 0.2 to 0.25 over that for a tire and ice alone. The value obtained is still far below that for a tire and road surface in summer. The friction appears to increase with the number of studs, and each tire would probably have to have about 200 studs in order to obtain an optimum effect. Studs decrease the coefficient of friction between a tire and bare pavement. Although studs do not cause a large increase in the skid resistance, they do improve steering ability. For maximum effectiveness, therefore, all four tires of an automobile should be equipped with studs. Observations indicate that studs are best for ice, chains are best for snow.

Studs do come out of tires, particularly at high speeds. This does not appear to be due to centrifugal force, but rather to forces associated with slip between the tire and the road. In Sweden there has been no evidence of studs causing damage after coming out of the tire. About 15 per cent of the automobiles in Sweden are equipped with studded tires. There is evidence that the studs do increase road wear. The main question concerning their use in Canada appears to be a legal one related to the possible damage that they might do to road surfaces. This aspect of their use requires further study.

The chemicals commonly used for ice control contribute to the deterioration of some components of automobiles. Consideration should be given to ways in which components that are directly involved with the safe operation of a vehicle, such as brake lines, brake cylinders, tie rods, and ball joints, can be adequately protected from the action of these chemicals. This problem does not appear to be receiving much attention in Canada. D. Craik, formerly at the University of Manitoba and now with the Manitoba Research Council, is conducting investigations on the effect of ice melting chemicals on metals.

CONCLUSION

From this brief review it is apparent that our ability to control icy conditions on roadways is very imperfect. It is true that maintenance organizations have made noteworthy advances over the past ten years in their ability to maintain roadways in a satisfactory condition, but it is just not possible at present to cope with all weather and traffic conditions that might occur. It may never be possible to guarantee an ice-free pavement at all times, but, until such time, drivers must realize that they are an important factor in maintaining safe conditions on icy roads. To keep this fact always before them will require active and continuing programs of education, such as those sponsored by the Saskatchewan Safety Council.

Considering the scale of the problem of ice control and its importance to the economic life of Canada, the amount of research being conducted on it in this country is certainly inadequate. Practically no attention is being given to collecting and organizing knowledge on the factors responsible for the formation of ice, on methods that could be used to prevent it from forming, on methods that could be used to remove it once it has formed, on the interaction between ice and traffic, and on the side effects caused by current ice control techniques. This is unfortunate not only because this knowledge would be very useful in the development of the techniques that are required for coping with present and future conditions, but also because other countries naturally turn to Canada for information when they are faced with similar problems.

There is available considerable practical experience in snow removal and ice control. Perhaps the most encouraging progress during the past four years has been in getting some of this experience properly recorded. Maintenance groups that have this experience however, are usually so involved with the task of removing snow and ice that they have neither the time nor the men to properly record experience or to carry out necessary research and development. These activities should be encouraged at universities and in appropriate institutes and Government departments. Because of the nature of the ice control problem, such studies should be conducted in close association with winter maintenance groups whenever possible. The Associate Committee on Soil and Snow Mechanics, through its Subcommittee on Snow and Ice, together with the Council's Division of Building Research, through its Snow and Ice Section, will continue to do what they can to assist in this advance.

REFERENCES

(1) Snow Removal and Ice Control. Proceedings, Tech. Mem. 83, Associate Committee on Soil and Snow Mechanics, Subcommittee on Snow and Ice, National Research Council, Ottawa, October 1964.

(2) Financial Post, Toronto, 27 March 1965.

(3) Annual Report of the National Swedish Road Research Institute, 1962 - 63, Stockholm, 1964.

(4) George, J. D., and C. S. Wiffen. Snow and Ice Removal From Road Surfaces by Electrical Heating. Presented to 44th Annual Meeting, Highway Research Board, National Academy of Sciences, Washington, January 1965.

(5) Whiffin, A. C., and P. J. Williamson. Electrical Heating of Roads to Prevent the Formation of Ice and Frost. Heating (Lond.), Vol. 25, No. 206, p. 41-47, Feb. 1963.

(6) Kullbey, G., and B. Kihlgren. Investigation of Friction Properties of Winter Tyres and Anti-Skid Devices. Statens Vaginstitut, Rept. 36, Stockholm, 1960 (in Swedish with English summary).