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(Progress Report)

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EVALUATION OF LIQUID CHEMICALS FOR PREVENTING ICE FORMATION ON HIGHWAY BRIDGE DECKS
(Progress Report)

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INTRODUCTION

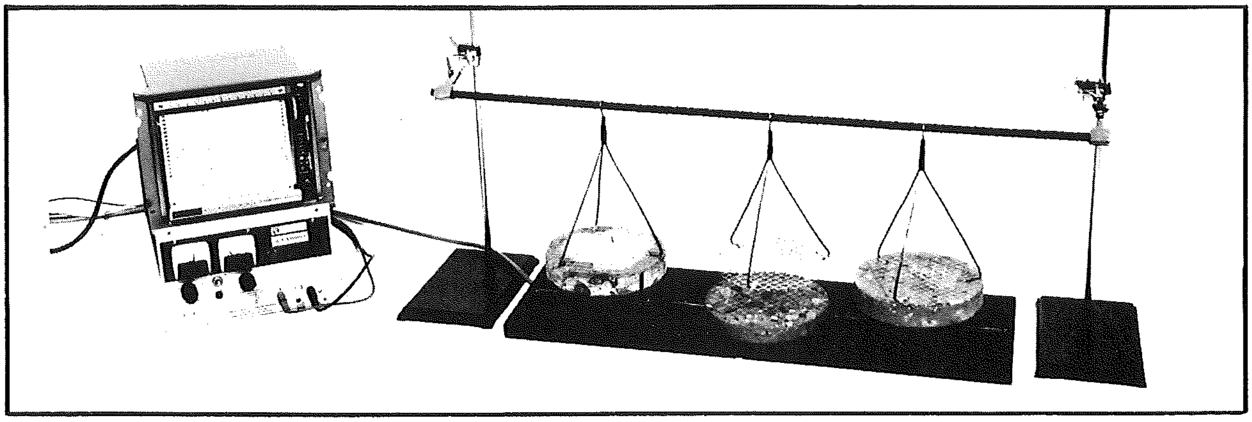
Prompt removal of ice and snow and the prevention of ice formation on highway surfaces is a vital aspect of highway maintenance. In order to accomplish this task, ice melting chemicals are applied in conjunction with scraping and plowing operations. Calcium chloride and sodium chloride materials, which are relatively inexpensive and readily available, are most often used for this purpose. These chlorides, however, are corrosive and accelerate deterioration of the steel and concrete used in highway structures. Damage to bridges is of special concern because repairs are costly, hazardous, inconvenient to the motorist, and must be made quickly before further serious structural damage takes place.

To alleviate this situation, J. F. Oravec in a memorandum to M. N. Clyde (August 28, 1972) requested that the Research Laboratory undertake a study to determine the effectiveness of four products, then on the market, which were claimed by their producers to be non-damaging deicing chemicals. As a result of this memorandum, a research project was established and assigned to the Soils and Aggregates Unit in December 1972, the purpose of which was to evaluate the ice melting effectiveness of four liquid solutions submitted by four different suppliers: Kaiser Agricultural Chemicals (ISOLV); Dow Chemical (propylene glycol); Union Carbide (UCAR); and Allied Chemical (ARD-45). Shortly after the start of this project, the Allied product (ARD-45) was removed from the market and was not included in this study.

All of the materials supplied are basically glycol solutions (some containing a dissolved urea compound). Each liquid, according to the suppliers literature, is effective at rates varying from 1 gal/500 sq ft to 1 gal/2,000 sq ft, depending upon storm and temperature conditions at the time of application. Prices of the solutions are about $1.00/gal.

Some of these, or similar chemicals, have been in use for several years at major airports to remove ice from aircraft and, to some extent, from paved runway surfaces. Highway application is more recent and has been on an experimental basis, primarily on bridge decks.

During 1971-72, the Indiana State Highway Commission made 15 applications of one chemical (ISOLV) to 150 Interstate freeway bridges near Indianapolis. Results indicated the chemical was ineffective when used on packed snow, and ice already formed, but it was effective as a frost deterrent when applied prior to storms. In the latter cases, it appeared to be effective in preventing ice formation for periods of as long as six or seven days.



Measurement of melting rate. Elapsed time recorded at left with samples suspended over timing contacts at right. Center sample has dropped and the time recorded.

Sample suspension method and timing contacts.

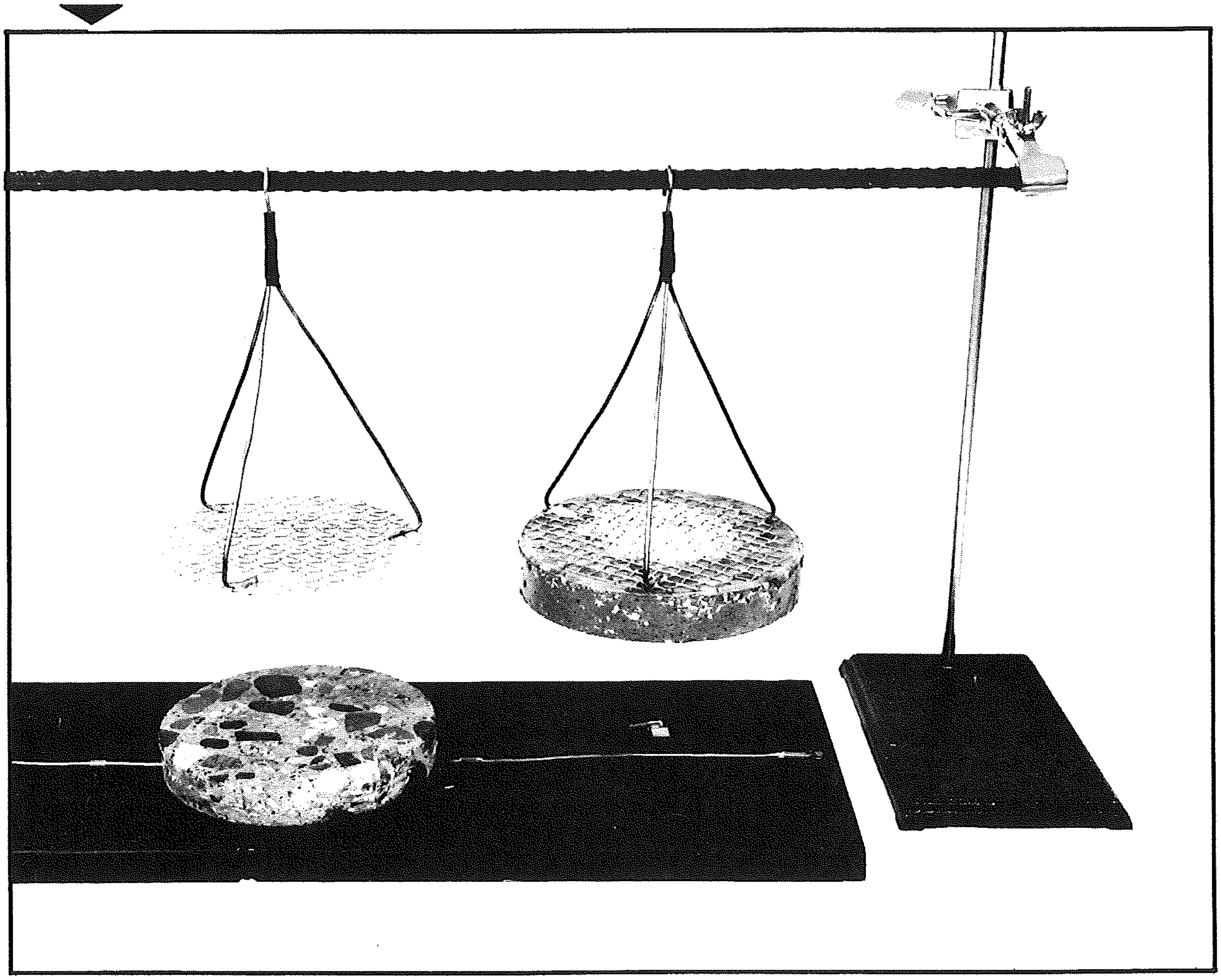


Figure 1. Drop test equipment for evaluating ice melting rate.

During the 1971-72 winter season, 10,000 gal of a propylene glycol-water solution were applied at the Tri-Cities Airport, Freeland, Michigan with satisfactory results. The International Bridge Authority used one chemical experimentally for the past two winter seasons with favorable results. In their experience, the chemical worked well on ice or packed snow (less than 1-in. thick) with effectiveness lasting up to three days. No problems due to slipperiness were noted.

The original scope of this study included evaluation of the deicing chemicals for ice melting ability, friction characteristics on the road, and for effectiveness in snow and ice removal when used in conjunction with scraping operations. However, evaluation of effectiveness under traffic conditions has not been attempted yet because of delays due to equipment preparation and an extended period of mild weather, which curtailed the project. It is planned to continue this work during the 1973-74 winter season.

This report describes the laboratory studies and initial field tests made to determine friction characteristics of the treated roadways, and general ice melting properties of the chemicals. These portions of the project are substantially completed. During this work it has become apparent that further evaluation of the chemicals should concentrate on their potential as aids to mechanical removal operations rather than their ice melting ability alone.

TESTING

Laboratory Tests

Tests were performed in the laboratory to measure the effectiveness of the chemicals for melting ice and preventing the bonding of ice to concrete surfaces. Ice melting capacity was measured by a drop test procedure used during a previous study concerning ice control applications (Fig. 1)[1].

In this test, a layer of ice, in which is embedded a wire hanger arrangement, is frozen on the surface of a concrete disc. The ice and disc are suspended and the chemical applied to the surface of the ice. When the ice-concrete bond is broken by the melting of the ice, the disc drops and the length of time between application of the chemical and the disc drop is recorded as a measure of melting rate.

[1] Evaluation of Hardy salt for Ice Control Purposes. MDSH Research Report No. R-754. Lansing, Michigan. 1970.

Drop tests were conducted using each of the chemicals on equal amounts of ice under controlled temperature conditions. Results for various application rates are shown in Figure 2, where each point represents the average of three test replications. For comparison, melting or drop time is also shown for a typical range of application rates of rock salt as normally used for highway ice control. These results indicate that at least two gallons of liquid chemical per 1,000 sq ft are needed to obtain ice melting performance equal to that of a normal sodium chloride treatment, under these test conditions. Application rates recommended for the chemicals range from 1 gal/500 sq ft to 1 gal/2,000 sq ft.

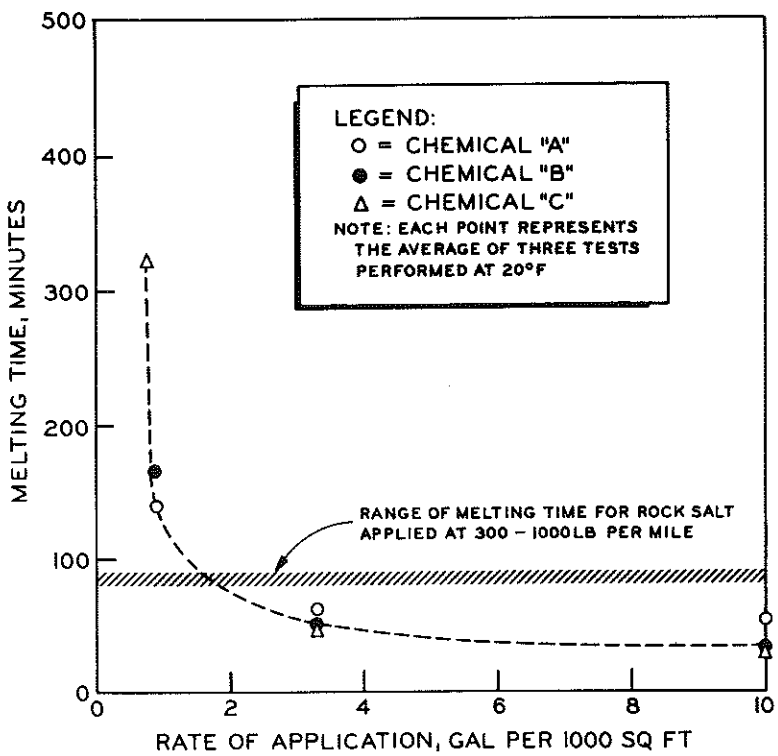


Figure 2. Ice melting ability of three liquid chemicals for different rates of application in the laboratory.

To test the ability of the deicers to prevent formation of ice on a surface, they were each applied to the surface of concrete blocks at a rate of 1 gal/1,000 sq ft and air dried for varying time intervals. A layer of ice was then frozen on the treated surface and the shear force required to remove the layer measured. Control samples, in which ice was applied to untreated blocks and blocks treated with sodium chloride, were also tested as a basis for comparison. Figure 3 presents the results of this test showing the influence of drying time or the residual effectiveness of the several treatments. Although precise relationships are not evident, the treated samples were consistently somewhat lower in bond strength than the untreated control samples, indicating some residual effectiveness for reducing the adherence of ice to the tested surface.

In addition to these tests, which were performed at 14 F, an additional series was attempted at 20 F. At the higher temperatures the ice layer parted from the treated blocks before the shear test could be completed but the untreated control samples and blocks treated with sodium chloride did possess some bond strength (Fig. 3).

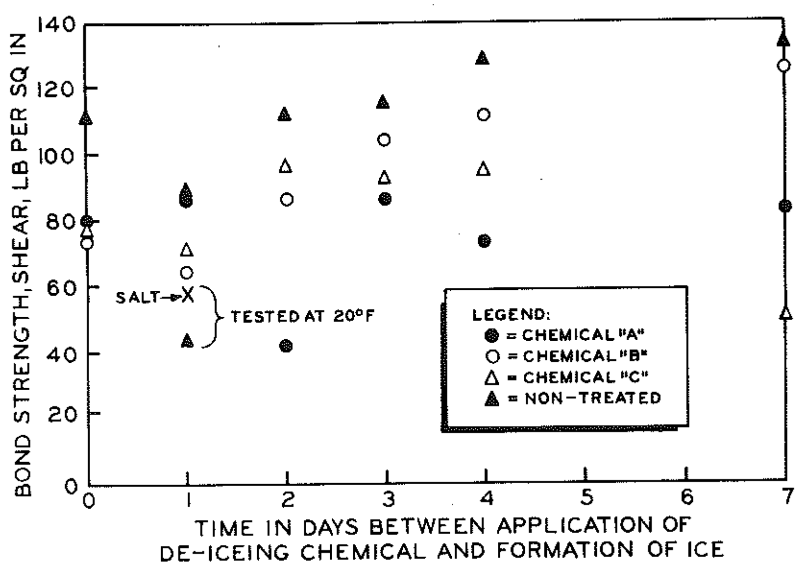
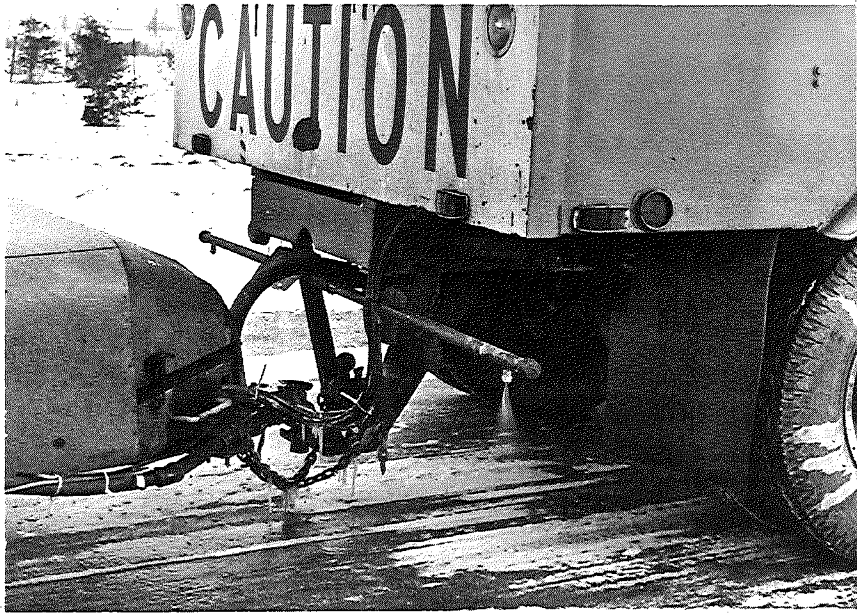


Figure 3. Residual effectiveness of chemicals for reducing ice-to-concrete bond as shown in the laboratory tests (tested at 14 F except as noted).

Field Testing

Although extensive field evaluation is proposed, testing so far has been limited to friction measurements on treated and untreated roadways (not open to traffic) and observation of ice melting properties of the chemicals when applied to small areas. For safety considerations, it was felt that friction characteristics of the chemically treated surfaces should be evaluated prior to use of the materials under conditions involving traffic. The

Application of water to form test sections for measuring friction of treated and untreated surfaces.



Application of liquid deicer.

Measuring friction on ice covered test section.

Figure 4. Field testing procedure for measuring the friction characteristics of the chemical deicers.

friction tests, however, have provided some opportunity to observe the effectiveness of the chemicals as anti-icing and deicing agents. In performing friction tests, sections of ice were prepared on a dry road surface by controlled application of water at subfreezing temperatures (Fig. 4). The liquid chemicals were then applied to the ice-covered test sections by means of spray equipment normally used for roadside weed control, but adapted for this project by the addition of a rear-mounted spray bar (Fig. 4). Application rate was governed by pressure regulation and vehicle speed, after calibrating the spray bar in the laboratory.

The friction tests were performed at the I 96 weigh station west of Portland on three consecutive days during which temperatures at the start of testing ranged from 14 to 18 F. One liquid chemical was tested on each of the days, applied at the rate of 1 gal/2,000 sq ft for the initial series of friction tests. At twenty minute intervals the chemical was reapplied, at the same rate, with friction tests immediately preceding and following each reapplication. A total of three applications was made for each chemical.

Friction characteristics of the test areas were measured for two conditions: 1) when the deicers were applied as a preventive measure (application prior to ice accumulation) and 2) when applied as an ice removal aid (application of chemical on existing ice). For comparison, friction values were also measured for untreated ice. Three different test sections were prepared for each chemical:

1) A control section of ice formed on bare pavement which remained untreated throughout the test.

2) A "preventive section," created by treating the bare pavement with chemical, then forming a 1/16-in. layer of ice on which to measure friction values with time.

3) A "removal section," with ice formed on bare pavement then treated with chemical and friction tested.

Friction values were measured with the MDSH skid resistance research vehicle, operating at 20 mph with no water applied during the tests. Friction values obtained for the two types of uses are shown in Figure 5, along with values measured on the untreated control section. These results indicate that application of the chemicals offered no improvement over bare ice conditions regardless of which chemical was used or whether used as a preventive or a removal aid. In addition to measurements on the test sections of ice, friction values were also obtained on dry pavement areas treated with each chemical. Results of all the friction tests are summarized in

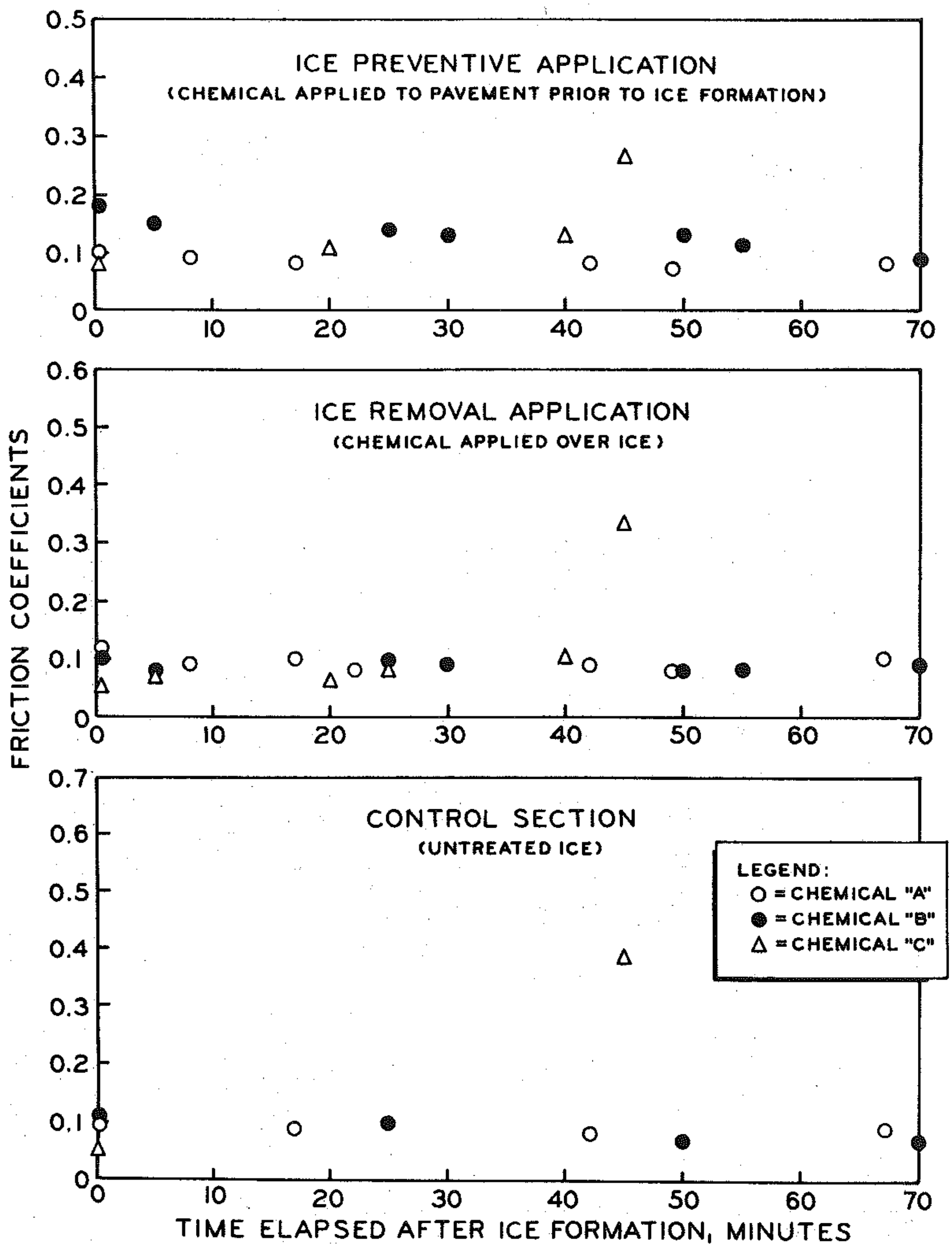


Figure 5. Results of field friction testing.

Table 1. Tabulated values are the average of the individual values shown in Figure 5, with the exception of the series of measurements on bare pavement, where the values are the average of three repetitive measurements.

TABLE 1
SUMMARY OF COEFFICIENTS OF WET SLIDING FRICTION

Measurement Condition	Avg wsf values		
	Chemicals		
	A	B	C
Ice preventive application: chemical applied to pavement prior to ice formation	0.08	0.13	0.11
Ice removal application: chemical applied to existing ice on pavement	0.09	0.09	0.07
Control section: glare ice with no chemical applied	0.09	0.17	0.05
Standard friction test: ASTM E-274 at 20 mph	0.72	----	----
Modified friction test: chemical applied to bare pavement and tested as in the standard friction test using no nozzle water	0.64	0.54	0.48
Dry friction test: ASTM E-274 at 20 mph using no nozzle water	1.03	----	----

Even though the friction tests represent only a part of the total evaluation planned for the chemicals, some pertinent observations concerning their ice melting ability are indicated by these tests. First, the fact that an ice layer could be formed on pavement recently treated with the chemicals (preventive test section) indicates limitations of the materials when used for ice prevention purposes. Friction values of treated surfaces remained relatively unchanged throughout the duration of test, indicating limited effectiveness of the chemicals as ice melting agents. Also, build-up of blowing snow was observed at times on the test sections recently treated with the chemicals (Fig. 6).

Figure 6. Build-up of blowing snow on chemically treated test section.

CONCLUSIONS

Results of laboratory and field tests conducted during this portion of the study point to the following conclusions, limited to the conditions under which the tests and observations were made. Extrapolation to other conditions would not be warranted at this time.

Laboratory Tests

1) Bond strength between ice and concrete surfaces was reduced by application of the chemicals (Fig. 3).

2) The chemicals can melt ice at a rate comparable to that of rock salt when applied in sufficient quantity, under certain conditions (Fig. 2).

Field Tests and Observations

3) The chemicals were not effective for melting ice at the temperature tested, even after several applications. This is evidenced by the relatively unchanged friction values shown in Figure 5.

4) Application of the chemicals did not reduce slipperiness of frozen surfaces. For safety purposes, adequate friction must be achieved by some other means.

RECOMMENDATIONS

Because the chemicals used in this study were effective to some degree and because test conditions were limited with respect to weather, traffic, and surface type, a more extensive in-service evaluation is recommended during the coming winter. It is further suggested that these tests be conducted on in-service bridge decks, selected where traffic can be regulated and where maintenance equipment and personnel are available to participate in the tests. At least three such sites should be selected, each of which should be provided with proper equipment for applying the liquid chemicals. Performance should be evaluated by applying the chemical to the traffic lanes of one direction, while maintaining the opposite traffic lanes in the usual manner, using rock salt as needed. Information pertaining to each storm would be recorded on a data sheet that would include the following.

1) Nature of the storm; temperature, type of storm (snow, freezing rain, etc.).

2) Amount of chemical required to achieve a satisfactory pavement condition (number of passes, gallons applied).

3) Amount of mechanical clearing effort required, such as the number of scraper passes, to achieve a satisfactory pavement condition.

4) Success of treatment; could a satisfactory pavement condition be achieved or were chlorides eventually required?

A data sheet containing this information should be prepared for each type of treatment, conventional and liquid chemical, for each storm.

During this study additional personnel should be assigned to each site so that test conditions can be observed and recorded without hindering normal ice control operations.

An overall evaluation should compare any additional costs over normal operations (using salt) with any benefits that might be derived such as increased concrete and steel life.