SURVEY RESULTS OF THE INCIDENCE OF PREMATURE BRIDGE DECK ICING

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The occurrence of frost on bridge decks is a serious problem in Minnesota. So that we could become better acquainted with differential frosting, our maintenance personnel were asked to collect data. A total of 35,198 observations were made during two winters. Originally, we thought that we would be able to predict when a bridge deck would frost; this was not the case. Frosting occurred over a large temperature range and did not depend on any logical combination of variables. Since predictions of deck frosting cannot be made reliably by visual observations, we intend to install a frost detection sensor and to correlate the sensor alarm with the visual observations.

•THE problem of differential frosting between bridge decks and roadways has been in existence as long as there have been bridges. In the past, when the small amount of traffic was slow, frost was not too much of a problem. However, since the day of the 200 to 300-hp (149 to 224-kW) automobile, the speeds we travel at have been greatly increased. To maintain these speeds and increase the roadway user's safety, alignments and surfaces were improved, and many more bridges were constructed. The combination of increased traffic volumes and speeds along with the building of many more bridges made differential frosting of decks a traffic hazard. Since one of the most important functions of highway design is traveler safety, this project was begun with two objectives in mind:

1. To define the scope and extent of the problem, and
2. To investigate probable solutions to the problem.

In late 1972, we began to determine methods of eliminating, reducing, or at least forecasting the phenomenon of differential icing between bridge decks and adjoining roadways. The first step was to conduct a literature search. It appeared that the problem could not be solved from the information reviewed. We then listed a series of questions, whose answers we thought could lead us to a solution:

1. Under what atmospheric conditions could we expect frost? For example, was it only near freezing temperatures [32 F (0 C)] and, if not, under what temperature ranges could we expect problems?
2. Would we find frost only in the fall and spring?
3. Is differential frosting really a problem, or is it rare enough not to be a significant problem?
4. Are different types of construction, such as wood, concrete, and steel, more susceptible to frost?
5. Are bridges over rivers more likely to frost than others?

To investigate these questions, we thought we needed a statewide data base. Therefore, we asked each of our area maintenance engineers to have a daily check made between October and March of representative bridges in their areas. These checks showed only the month, day, and whether frost did or did not occur. In addition, one metropolitan area also reported the time of frost occurrence, temperature, wind direction and velocity, and sky cover. Their data were collected by the dawn patrol, a

Table 1. Observations of bridges over water and railroads or highway from November to March 1972 through 1974.

	Water			Railroad or Highway		
Month	Total	Frost	Percent	Total	Frost	Percent
November	2,148	221	10	3,236	308	10
December	3,205	264	8	4,015	371	9
January	3,708	603	16	5,519	742	13
February	2,808	149	5	4,635	206	5
March	2,586	65	3	3,338	67	2

unit that patrols the most heavily traveled roads during the night and early morning to look for problem areas.

During the two winters (November 1972 through March 1974) when we conducted this study, 35,198 observations were made (Table 1). Since they were made basically when frost should occur, night and early morning, and they were not timed, the total percentages of occurrences cannot be interpreted as the percentage of time or hours the decks were icy. However, some interesting conclusions can be made. If people were asked to describe when frost will occur, they most likely would cite spring or fall, a temperature near 32 F (0 C), a clear sky, no wind, and a time close to sunrise. This general consensus is regrettably only one of many combinations.

We found that differential frosting occurred during every month studied (October through March) and that the most frequent occurrences were during January. Other findings were as follows:

1. Temperatures varied from -22 to +36 F (-30 to +2 C),
2. Sky cover varied from clear to 100 percent cloud covered,
3. Wind blew from all points of the compass, at 0 to 30 mph (0 to 48 km/h), and
4. The time of occurrence covered our entire reporting time of midnight to 8 a.m.

Since other facts we found appear to be contrary to logic, they should be listed separately:

1. The type of superstructure of the bridges had no effect on frost formation;
2. The type of deck surface had no effect on frost formation; and
3. The location of the bridge, whether over land or streams, had no effect on frost formation.

We also found that differential frosting occurs on 2 to 15 percent of the days in a month; therefore, it can be a substantial problem. Regrettably, our accident information is coded into the computer in such a way that we cannot determine the exact cost of accidents on frosty decks. However, the Midwest Research Institute conducted a project that estimated the annual cost of nationwide accidents due to frosty decks to be about $70 million.

As stated above, we did not collect data that would show what structures would frost first during the day; we collected only data that showed which structures did frost.

The recurring pattern of all bridges in a geographic area being either frosty or nonfrosty is extremely noticeable when maps showing daily frost distribution are referred to. We tried correlating these data with the National Weather Service's forecasts but had no success. We felt this lack of success was due to two factors: Forecasts were, by nature, somewhat general because of their wide area coverage, and salt residue on the bridge decks changed the frost formation parameters.

Since we could not reliably predict frost conditions, we were forced to change our course. Our next objective was to determine methods or materials that could be applied to the decks and that could reduce or eliminate the frosting problem. Systems such as heating the concrete electrically or with radiant heaters were examined, but we felt the costs for over 13,000 decks statewide were prohibitive. The costs could have exceeded $250 million for the initial installations, and this did not include the yearly power requirements or maintenance. The standard salt solutions, air circulation, electroosmosis, and hydrated lime were also examined. These were quickly rejected because of expected poor performance. We did try insulating the underside of a few decks, but this proved to be of no value. Three chemicals were tried: propylene glycol, ethelyne glycol, and a formamide-based material. They were nonreactive with concrete or steel and could give up to 1 week's protection from frost. They were all liquids applied with a regular distributor truck and spray bar. The only thing we could agree on is that they did not attack the decks. Although they might have reduced frost if they had been applied at high rates, they would also have reduced skid resistance, our primary problem, and would have proved to be a pollutant. Therefore, we did not know what could be used effectively and ecologically to reduce or eliminate the frosting problem. Again the data were considered, and the only conclusion was that frosting appeared in regional areas and was not governed by structural characteristics or microgeography.

While we were testing various solutions, manufacturers were developing and refining frost detection sensors. We are now in the process of purchasing a sensor that will signal wet, frost warning, and frost conditions. This, in conjunction with our maintenance personnel's knowledge of which decks are the first to frost and our knowledge that it is likely that all within a given area will frost nearly at the same time, may finally give us the solution we have been looking for.

We intend to place a sensor on one bridge and connect it to an alarm at the maintenance headquarters. Of course, the maintenance dawn patrol will continue collecting their data as usual. We will then be able to correlate the sensor alarms to the visual observations. If the correlation proves satisfactory, we should then be able to detect or predict frosty bridge decks sooner than is now possible. We may also be able to reduce the personnel required by our dawn patrol to increase traveler safety.