A Treatise
On
Control Of Culvert And
Roadway Icing
Prepared by Herman E. Londagin
Research Civil Engineer
State of Alaska, Department of Highways
South Central District, Valdez, Alaska

Performed, funded and staffed as a Research Study
INTRODUCTION

The travelling public expects and requires that their highways be in as good condition for travel in the winter as in the summer. For the Department of Highways to furnish this service, the maintenance crews must be able to use their time to do work over which the engineers and designers have no control.
CONTROL OF CULVERT AND ROADWAY ICING

PREFACE

This treatise was prepared by Herman E. Londagin, Research Civil Engineer, South Central District, Department of Highways.

The identification, compilation, and statements on icing occurrence, control, and prevention were performed, funded, and staffed as a research study by the Alaska Department of Highways, South Central District, Valdez, Alaska.

SUMMARY

Winter ice, or what has been misnomered glaciering, is a mass of surface ice formed by freezing during the winter months of successive layers of water that seep from the ground, springs, or rivers. Icing can cause severe problems when it occurs near highways, bridges, buildings, air fields, or railroads. Lack of knowledge concerning icing has resulted in tremendous expense and outlay of maintenance equipment and personnel. With the unique environmental and geological conditions that exist in the arctic and sub-arctic regions of Alaska, special engineering procedures should be used to provide the most economical solution to icing while minimizing disruption of the environment and the development of the natural resources.

The winter ice that builds up and inundates the roadway is not an uncontrollable condition. Most of the highways in the interior of Alaska are hindered by ice buildup. The condition is the result of water seeping to the surface of the ground where there is poor drainage and very low temperature is experienced. Through succeeding cycles, these processes would eventually inundate the roadway.

Some of the conditions that favor the formation of icing are:

1. The presence of ground water in the active layer.
2. Low temperature of the air and thin snow covering during the early part of the winter.
3. Proximity of the permafrost table to the surface of the ground.
4. Thick cover of snow during the latter part of the winter.

During the winters when there is light snowfall, icing will appear early. Most icing develops along mountain slopes and where the strata is dipping in the same direction as the slope.

To prevent the severe destructive action of icing, it is necessary to drain the ground water. This requires interception and directing the flow of water that feeds the icing, past the area being protected.

Formerly, fire pots and steam trucks were used in such trouble spots at great expense, both in equipment operation and in maintenance man hours. With the advancement of electrical transmission lines paralleling the highways, it has become possible to utilize a more economical installation with electrical heat cables. A very substantial dollar saving is achieved, in spite of the high cost of electric energy, in the interior of the State, not including the man hours saved. With the installation of electric heat cables the maintenance crews have been freed to work more on other required winter road servicing.
As far as this author has been able to ascertain, he was the first to use heat cables for the control of roadway icing. The Department of Highways, South Central District, used these heat cables for the first time in 1963. The first cables used were mineral insulated copper sheath. Continued research has resulted in the present use of mineral insulated stainless steel sheath cables with a rated wattage of 46 watts per foot at 240 volts.

Passive ways to intercept and drain this ground water were developed and practiced more extensively in Russia and attributed to V. G. Petrov, N. I. Bykov, and P. N. Kapterev who instituted the use of frost belts. This is a trench 1 to 10 meters wide and 0.5 to 2.5 meters deep with all the natural insulation material removed. The belts should be made before the freeze starts in the fall and should be kept clear of snow during the winter. For the belt to be effective it should be filled in each spring with waste material or other insulation to prevent the thawing of the permafrost during the summer. This method has been practiced by the Department of Highways but without satisfactory results. The erection of dams and other barriers, such as ice fences, are also used. In Alaska, and especially by the Department of Highways, these fences are constructed out of reinforced plastic sheets stapled to a 2" by 4" wood frame, as another way to intercept the ground water. This method does a fair job of intercepting the flow, but it is very expensive.

One approach that has been used extensively in past years in Alaska highway maintenance is fire pots. These fire pots use a mixture of gasoline and diesel as the combustible fuels. This operation was used to heat the stream or ground water so that it would continue to flow without freezing past the troubled area.

Among the active methods of combating icing suggested by Russian authors and adapted and used by this author is the creation of reservoirs by damming and the subsequent regulation of flow, with outlet drains at the bottom. Another method used is the construction of deep narrow channels. The flow is given little chance to freeze because of the small surface in contact with the atmosphere, and the loss of heat is held to a minimum. This method has been used on small flows only (.5 c.f./sec. to 3 c.f./sec.) by this author, but he sees no reason why a similar type method could not be used on large river flows. Another method, used by this author, is to provide an insulating cover over drainage channels.

One method suggested by the Russians with this author's modifications, that holds future promise for use in combating icing where highways are on side hill construction, is de-watering the springs and other seepages with buried insulated pipes and draining the water beyond the protected area. The author's specifications are being studied and are expected to be utilized in the final design of the Richardson Highway from Mile 182 to 183.

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1 V. G. Petrov, Protection of Road Construction From Naleds, 1930, Vol. 6, No. 3-4, pp. 69-74, SIP 14122.
4 Ibid.
ENGNEERING PROBLEMS IN COMBATING ROADWAY Icing

In the design and construction of highways, the right of way has become a great problem in Alaska. As most of the active methods of combating icing are outside of the highways’ right of way, this leaves very little to be done in the active method, either now or in the future.

With this being one of the controlling factors, we must develop the most economical passive method of controlling this roadway icing.

RICHARDSON HIGHWAY 63.5 MILE

No name stream channel cover: The active method of combating icing is used here. This stream does not start icing up to any extent until it is within the right of way. It has a flow during the winter months (November, December, January and March) of approximately .04 c.f./sec. Until four years ago this stream was controlled in the passive method, using fire pots and ice fences. For the past four years this icing has been controlled in the active method using old striping paint drums cut lengthwise and laid in the channel.

The purpose of the cover is to provide insulation by the snow cover on top of the drums as well as limiting the heat loss of the water. This type of icing control has become very economical. The last year that a fire pot was used at this location the cost to the Department of Highways was a total of $2,350.00 for the winter. This included wages, mileage and fuel. The first year the drums were used it cost a total of $350.00. This included wages for cutting and installing the drums and use of the backhoe to fix the channel. There have been no charges at this location until this last winter when the stream froze and through inspection it was found that the area under the drums had filled with gravel. There will be a small charge this year for channel cleaning.
No name drainage channel: As this is a known problem area and the ground water seepage changes the outflow location during the winter, and since these outflows originate outside the right of way, heating cables were selected as the passive method of control. Furthermore, because the drainage channel has no distinction, a channel cover would not be feasible. The temperature is 30 degrees below zero and the water is flowing; if this culvert is not kept open, the water would be flowing onto the highway in a very short time.
This drawing exemplifies a typical heating cable installation and shows how the heating cables form a channel for the water to flow to and through the culvert.
The heat cable that is shown in this 48 inch by 110 foot culvert was installed in the curly full. The ice shown in the two pictures above was a gradual buildup over a two months’ period. The ice formed until it was approximately six feet thick. During the night before these pictures were taken, a ground water seepage came to the surface upstream and off the highway right of way. By morning the water in the above pictures was over two feet deep. The heat cable was energized at 7:45 a.m., and the outlet pictures were taken between 10:00 a.m. and 10:30 a.m. on the same date. With the heat cable energized inside the thaw pipe, within two hours the water was flowing and the ice around the thaw pipe for approximately six inches was becoming very rotten. After the heat cable had been energized for seven hours there was a hole six inches in diameter for the water to flow, and this ground water seepage had been taken care of and controlled.
This cavern is approximately four feet in diameter and also shows some of the 3 cubic feet of water that flowed all winter. When this picture was taken the heat cable had not been energized for over six weeks.

This view shows the heat cable being held eight inches off the stream bed. The intercepting cavern is about three feet in diameter and also shown is part of the two cubic feet per second of water that continued to flow all winter.
Where commercial electricity is available, it is this author's opinion that electric heat cables are the most economical passive method of combating roadway icing. During the first winters that heat cables were used, we did not know how much heat was required or for what duration. During these early years we melted the ice with the heat cables and made trenches in the icing areas. Today we allow the icing to build to about five or six feet deep before any control is used. At that time the heat cables are energized and the culvert is opened and an intercepting cavern is melted out; if any holes are melted to the open air, they are covered with plywood and snow. Once the caverns have been formed and have intercepted the seepage, the cables can be de-energized. If the ground water that has been intercepted continues to flow, we have found, in some instances, that the heat cable will not have to be energized again all winter.

This intercepting cavern is approximately four feet in diameter. The ice on the crown is over two feet thick and the ground is unfrozen to a depth of six inches. The outside air temperature on this day was in the 30 below zero range; the temperature inside the cavern was in the high 30 degree above zero range.
This is a permanent installation that the author designed and installed at Mile 73.71, Richardson Highway. It shows how 1\(\frac{1}{4}\) inch pipe is connected to the culvert thaw pipe, how the pipe is held approximately eight inches off the stream bed, and how the heat cable is pulled through the full length. The cable that is visible in the foreground of the picture is the cold lead that goes to the service pole.

This is the same installation as in the above photograph, except it was taken later in the winter. Between five and six feet of ice has been formed. The cavern is about 30 inches in diameter at the time of this picture. The cable had not been energized for fifteen days. The seepage at its original location has almost stopped. There was not enough flow to keep the ice from forming and, as this photograph shows, the ground ice has started forming. The seepage had reintroduced itself at a different location. The week after this picture was taken, the cable had to be re-energized to control this small flow.
The heat cable in this instance was installed in the culvert thaw pipe. The advantages of this type of installation are its permability, and BTU's generated are used to maximum capacity. Our original concept of placing the cable on the bottom of the culvert had the disadvantages of allowing ice and rocks to roll down the culvert, increasing the tendency to break the cable. Also there was a loss of heat by conductivity to the culvert and the frozen ground, and the old original layout had to be removed each summer.
The Department of Highways is suffering from old inadequate design that gives no thought to the control or prevention of icing. As evidence of this, the area between Mile 182 and 183 had no icing control used when this section was designed and built. This is probably the worst icing area on the Richardson Highway. There is sidehill construction, narrow drainage ditches, small 18 inch cross drain culverts that have high and low points at the flow line, and the surface ground water makes up most of the seepage for icing buildup.

This is a very peaceful and quietly flowing culvert during the months of July, August and September. In front of the inlet of the culvert is the steam pipe; this pipe is ten feet tall.

This is the same area as in the above picture, except during the troublesome periods in January, February and March. The same steam pipe is protruding through the ice. This is an area where the maintenance crews have to work with the steam boilers periodically each day during the winter months.
Shown is an icing fence installation depicting the amount of ice formed and the resulting narrowing of the roadway.

This view gives an idea of the extent of the area of icing on the Richardson Highway between Mile 182 and Mile 183.
As the reconstruction of the Richardson Highway south of Paxson is not in the projected five-year construction program, the area is being investigated through two different research projects. One is a Federal Highway Administration funded project and the other is a Department of Highways, South Central District funded project. The Federal funded project’s objectives are to provide the necessary data to determine the cause or causes for this icing and to recommend possible methods of controlling or eliminating this roadway condition. The Department of Highways funded project is part of the South Central District’s research project titled, “Control and Prevention of Stream and Roadway Icing No. X-51830”. The objective of this project is to determine and recommend design and installation practices for the control of icing on new construction. As was previously stated in the introduction to this treatise, one active method that holds promise for combating icing in this area is the de-watering of the side hills with insulated pipes and draining the surface water past the toe-of-fill. If the final funding is approved, this de-watering method will be installed and studied in the next two years.

CONCLUSION

Very few generalized statements can be made about passive or active methods of icing control. It is apparent, though, that through studying each icing area it can be understood, and when understood it can be controlled or prevented.

To control or prevent this icing, economics becomes one of the main items of concern. If all icing could be controlled at no cost either in dollars or man hours, there would be no problem. One general statement that can be made from an economical standpoint is that fire pots should be the very last method used for control of icing. Fire pots do less than a fair job, plus they are the most expensive method of control. A case in point is the Richardson Highway, Mile 75.6 during the winter of 1966 (December, January, February and March). There was one fire pot used almost continuously, and for a part of the time two fire pots were used at a total cost (including wages, fuel, vehicle mileage) of $4,742.00. The next year electric heat cables were installed and the total kilowatts used were 29,900 for a total cost of $2,033.00. When electric heat cables can be placed in permanent installations with automatic controls or timers, at that time heat cables will be even more economical to operate.

Through continued increase and knowledge from research and investigation, there is no doubt that there will be other economical methods discovered for the active control of icing.
APPENDIX

I. Meter readings taken from accounting records, furnished by Department of Highways, South Central District, Valdez, Alaska.

II. Standard culvert thaw wire installation # D9 taken from the Department of Highways Book of Standards.
GLOSSARY

Active Layer: Annual thaw layer and frozen area.
Active Method: Method which eliminates icing by treating its cause.
Anchor Ice: Ice formed on the bottom of rivers and lakes.
Annual Thaw Layer: A layer above the permanently frozen ground which is alternately frozen and thawed each year.
Aquifer: A geological formation or structure that transmits water to supply springs.
Berm: A bench or horizontal ledge.
Capillarity: A hairlike bore or opening as a tube or vessel.
Capillary Fringe: The area above the water table in which water is held by capillarity.
Closed System: A condition of freezing to the ground when no additional supply of ground water is available.
De-watering: The lowering of the water table surface by artificial means.
Duff: Fallen leaves, branches, dead logs, etc., in a forest.
Flood Ice: Icing.
Free Water: Gravity matter which will freeze at normal temperature.
Frost Belt: A ditch that causes an early freezing of surface ground, forming an obstruction to percolating ground water.
Frost Dam: Artificially induced freezing of ground to intercept sub-surface seepages which cause icing: equivalent to frost belt.
Frozen Ground: Ground that has a temperature of 0°C (32°F) or lower, and generally contains water in the form of ice.
Frozen Zone: Permafrost.
Glacier: A body of ice descending along a mountain valley: misnomered in Alaska to denote ground ice, or surface ice, formed by successive freezing of ground or stream seepages. In this treatise it is designated icing.
Hydraulics: That portion of hydrodynamics which treats fluids in motion.
Hydrostatic: Pertaining to fluids at rest.

Ice Field: Icing.

Icing: Surface ice formed during the winter by successive freezing of water that seeps from the ground, river or spring.

Kilowatt: The amount of energy used by heat cables.

Muck: Mixture of vegetable mutter in decayed form and silt-like material.

Naleds: Russian for icing.

Passive Method: Method where icing is not eliminated but measures are taken to relieve its effect on roads and other structures.

Permafrost: The perennially frozen ground, rock or soil that has remained in a frozen state below 0°C -32°F for a long period of time.

Permafrost Table: The surface that represents the upper limit of permafrost.

Seepage: The percolation of water through the ground surface, as from large openings in it, or artificial excavations. May be influent seepage, seepage into the ground: or effluent seepage, seepage out of the ground.

Soil: The layer or muntle of mixed material that is penetrated by roots.

Underflow Movement of ground water in an underflow conduit.

Underflow Conduit: Permeable deposit that underlies a surface stream channel which flows downstream.

Water Table: The water table is the upper surface of free water which completely fills all openings; pervious to permit percolation.
SELECTED REFERENCES


# METER READINGS FOR HEAT TAPES

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