THAW SOLID ICE IN CULVERTS AND DRAIN TRENCHES IN LESS THAN 60 SECONDS

S.Os
Heatwork AS, Norway
STEINAR@HEATWORK.COM

ABSTRACT

This paper describes an alternative method for efficient and safe unblocking of frozen culverts and drain trenches. The method is based on a closed loop hydronic system, using patented technology and requires two main components:

- Ice Guard System (IGS), alloy steel pipes for fixed installations
- Mobile hydronic heater (MHH)

The IGS is permanently fitted into culverts or waterways which are prone to icing problems during winter season. The IGS has quick release couplings above ground level and when connected to the MHH, the surface temperature of the alloy steel instantly reaches temperatures up to 100°C and transfers heat to the surrounding ice. Field testing conducted by the manufacturer proved the method to be highly efficient. Typically, unblocking the frozen culvert and have the water running from the trench above would take less than 60 seconds. Observations also showed that once the water had free passage through the culvert, it would cut through the ice itself and no further use of IGS and MHH would be necessary.

Based on the results of the field testing, the IGS method was considered of interest for the Norwegian Public Roads Administration (NPRA), Norwegian National Rail Administration (NNRA) and municipality of Narvik. All the above got the first IGS installations for the winter of 2010. These have been tested and used during the last three winter seasons.
Based on the promising results from the winter of 2010, NPRA decided to set up a larger scale research and development (R&D) project on multiple locations in the area of Narvik, Norway. This project is still ongoing and will most likely be expanded to other regions for the winter of 2013/2014.

1. INTRODUCTION

With its northern location, Norway is often regarded as a cold and wet country. In some aspects this is true, because we share the same latitude as Alaska, Greenland and Siberia. However, due to its location in the westerlies, the climate is friendlier than the latitude indicates. From its southernmost point, Lindesnes, to its northernmost, North Cape, there is a span of 13 degrees of latitude. This means that Norway's climate shows great variations.

During the winter season (December – February) the extremity of official registered temperatures shows a variation from +18,9°C to -51,4°C. The rugged topography of Norway contributes to large local differences over short distances in terms of weather conditions [1].

NPRA is responsible for the planning, construction and operation of the national and county road networks, while the municipals are responsible for the local roads. In total, this adds up to approximately 94.000 km of road. Around 18.500 km of this road is located near or north of the arctic circle [2].

The rapidly changing and rough winter conditions are known to cause problems related to drainage of excess surface water. Culverts drain trenches and other water ways are periodically frozen or congested with ice due to temperature changes, precipitation and melt water.

This causes potential dangerous situations for road users and operation and maintenance personnel as well as damage to road structure and construction designs.
The NPRA operations manual for national roads specifies that it is the contractors' responsibility to ensure that water always has an open drainage [3].
In the past, the most commonly used methods for thawing and ice removal has been:

- Excavator
- Steam injection
- Electrical heater cables
- Use of salt

The use of salt is in general debated due to the negative impact on the environment [4], and in this context it is reasonable to believe that it would not be the most efficient way of opening e.g. a frozen culvert. Since many of these culverts are placed in areas without electricity the use of electrical heater cables would have its limitations.
Excavators and steam are often used to open drain trenches and unblocking culverts. However, maintenance and operations contractors have their HSE concerns when it comes to the use of these methods. The roads are often placed near the fjords and in steep, icy terrain. It is not uncommon for workers to wear fall protection harnesses when working with steaming equipment [5]. Also, the high temperature steam could cause scalding of workers.

Picture 1 – Using excavator to remove ice from culvert outlet Photo: NNRA

The use of heavy machinery like excavators often requires need for transportation to the site. Depending on the situation at the work site, the use of an excavator often means temporarily suspending traffic in one or both directions during road work.

“With Heatwork we may unload the equipment and leave it to thaw the ice. It does not require any personnel or other machine resources while thawing. It is placed outside the track and does not interfere with train traffic” Knut Karlsen, senior engineer - NNRA


Picture 2 – Railway damage Photo: NNRA

Picture 2 shows the damage to the railway due to frozen culverts unable to drain excess water. In addition to the maintenance costs involved of such damages, the socioeconomic impact of infrastructure not being able to serve its purpose, are likely to be considerable.

The IGS has been developed by Heatwork to overcome the challenges maintenance and operations contractors experience when culverts and drain trenches freezes during winter season. The focus has been to find a method that minimizes the risk of hazardous situations for road users and improves working conditions and safety for road workers. At the same time IGS should contribute to lower road operation costs, reduce damage to road structure as well as preserve the local environment.

2. TECHNOLOGY DESCRIPTION

Using hydronic methods to transfer heat is based on known principles and technology. The Heatwork product range has developed from primarily focusing on ground thawing into covering a wide variety of industries and areas of use

The use of hydronic heating for ground thawing was introduced in North America in the mid 1990’s, and has since gradually taken over as the preferred method even in Northern Europe. Compared to conventional methods using i.e. hot air, hydronic heating seems to be more effective and versatile [6].

To further investigate the method of hydronic heating, the Cold Climate Technology Research Centre (CCTRC) in Narvik established a Frost in Ground Laboratory (FiG-lab). Heatwork released its first MHH product to the market in 2005 and has cooperated with the FiG-lab since 2007. So far, several Bachelor and Master theses as well as one ongoing doctoral degree have be written around Heatwork’s hydronic technology. This work is important to get the scientific documentation of the method and the results are valuable for continuous product line development for Heatwork.

2.1. Mobile Hydronic Heater (MHH)

The core of our technology is our mobile hydronic heating systems (MHH) that are able to deliver up to 103kW heating capacity for a closed loop system containing a mix of water and propylene glycol (VTV). The propylene glycol used is classified as non-hazardous in accordance with 1271/2008 and 1999/45/EG [7].

Picture 3 – Heatwork HW3600 Mobile Hydronic Heater (MHH) Photo:Heatwork

The temperature of the VTV fluid is set by the operator of the MHH to a desired temperature between 0-100°C. Since the VTV fluid has anti-freeze characteristics, the MHH components are frost resistant when not in use during winter season. This means that the MHH may be stored outdoors without the risk of frost damage. It also simplifies the work instructions for operating the equipment.
Innovative design, control systems and high quality components ensures that the MHH boilers are able to utilize 94% of the energy of the diesel fuel to heat the VTV fluid.

2.2. Ice Guard System (IGS)

The development of IGS is a good example of the versatility of hydronic heating.
The IGS is a patented solution that consists of an adapter with quick couplings and independent VTV fluid- flow and return paths. The adapter has threads for assembly on a 60mm alloy steel pipe.

Illustration 1 – Heatwork Ice Guard System (IGS) adapter (left) adapter and alloy steel pipe assembled (right)   Source: Heatwork

The preheated MHH is connected to the flow path quick coupling of the IGS (**A**). The heated VTV flows through the center of the IGS alloy steel pipe in a rubber hose (**B**) and is released at the end of the plugged IGS alloy steel pipe (**C**). The heated VTV flow then heats the surface of the IGS alloy steel pipe (**D**) on its way back to the return flow path quick coupling (**E**).

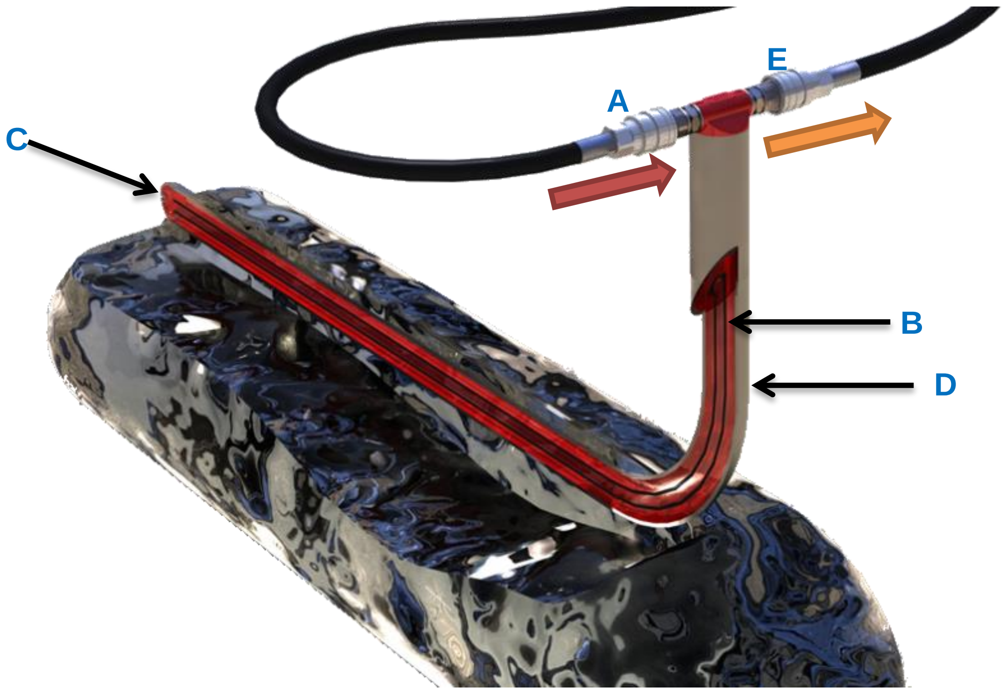

Illustration 2 – Heatwork Ice Guard System (IGS) principle drawing   Source: Heatwork

The high capacity VTV pump in the MHH ensures that the surface of the IGS alloy steel pipe maintains at a temperature as close to the VTV flow temperature (100°C) through the full length of the culvert or drain trench. The return fluid is then reheated to 100°C in the MHH and the cycle is repeated as long as desired by the operator.

Illustration 3 – IGS mounted in culvert Source: Heatwork

Illustration 3 shows IGS installed in top of a culvert. In the R&D project with NPRA it has been conducted tests with the IGS being mounted top, center and bottom of the culvert. Experiences so far indicates that installing the IGS at the bottom of the culvert gives the best overall result since the surrounding ice seems to have an insulating effect, preventing the open drain from freezing as well as avoiding water seals along the length of the culvert. Also, installation of IGS in bottom of the culvert is less time consuming. However, with the project still ongoing, more recorded data would be necessary before reaching a final conclusion on this specific matter.

Picture 4 – IGS installed in frozen culvert (left). Excess water way through solid ice (right)

Picture 5 – Frozen culvert and drain trench with excess water

Picture 5 shows the MHH connected to the IGS at one of the NPRA project installations along the national road, E6, just outside the city of Narvik.
With the IGS quick couplings above ground level, the culvert is easily located and connected to the preheated MHH. Since the weight of the MHH starts from less than one metric ton (incl. fuel), it is conveniently placed on the hard shoulder and may be towed between jobs using regular vehicles. The compact design of the MHH minimizes the impact on road users while the work is conducted.

Picture 6 – Culvert outlet draining excess water Photo: Heatwork

Picture 6 shows the running water at the culvert outlet a few minutes after arrival at one of the NPRA project installations. The time required to open the culvert depends on the amount of excess water in the drain trench above. Observations shows that IGS is more effective in cases where the drain trenches holds enough excess water to assist the process of melting the ice in the culvert. In most cases the culverts is open and draining excess water somewhere between 30 seconds and five minutes. If the culvert outlet is difficult to find or access in a safe way for the workers, the operator will be able to see a vortex where the IGS breaks the surface of the excess water, as well as monitor the return temperature gauge on the MHH. Once the return temperature starts falling below the starting point, it is an indication that the excess water flow absorbs more energy from the IGS than the MHH can deliver. At this point the IGS and MHH do not contribute much to the process and may move to the next job.

2.3. Thawing drain trenches using MHH heater hoses

During testing of IGS in the NPRA project, there was also uncovered a great need for efficient way of thawing ice in drain trenches in a more ad hoc manner. The IGS as a fixed installation makes it an efficient solution for culverts and drain trenches with recurring icing problems. However, since no two winters are alike and the severity and location of ice buildup may vary greatly from year to year, there is also need for tools that do not require any permanent installations.

Since the Heatwork MHH originally was developed for artificial thawing of frozen ground, it is equipped with 630m onboard EPDM rubber hoses.
The EPDM material has characteristics that make it ideal for transporting and transferring the energy of the 100°C VTV fluid to its surroundings, while still being flexible and durable.

Picture 7 –Field testing heater hoses in frozen drain trench Photo: Heatwork

Picture 7 shows a Heatwork performance test setup along a county road in the Narvik area. Various width and depth experiments were conducted. The MHH was placed on the hard shoulder of the road and left unattended during the thaw process. The built in GPS/GSM monitoring system automatically reports potential abnormalities by SMS as well as respond to proactive remote requests from the operator.

The performance tests early revealed that the heater hoses should be put in a bundle to avoid problems with single hoses being trapped in the ice. Also, if the cut through the ice is too wide, it would freeze up faster. In terms of depth of the cut, there is no theoretical limit. Our own tests were limited to a depth of around 4m. The thaw rate seemed to be fairly uniform throughout the entire process.

Our recommendation was 6-8 heater hoses in a bundle. When using all 610m of heater hose and the three VTV circuits, the length of the cut could be around 100m in one operation. The thaw rate for solid ice would typically be 10cm/hour.

Picture 8 – Subcontractor thawing drain trench for NPRA (left). Bundle of eight heater hoses (right) Photo: Amarkussen AS

Picture 8 (left) shows a subcontractor thawing a cut in the ice for NPRA at national road, E6, just outside the city of Narvik. The subcontractor is using a container based version of the Heatwork MHH, placed on the outside the safety rail of the road. Picture 8 (right) shows the bundle of heater hoses.

Picture 9 – thawed ice cut leading to culvert from both sides along national road E6
Photo: Heatwork

Picture 9 shows the ice cut along the drain trench leading to the intake on both sides of the culvert.

Since the hose reel in the MHH is hydraulic powered using the VTV fluid system, the entire operation of laying out hoses could be done with as little a one worker at the site. Since there is no need for excavators, wheel loaders, trucks etc. the costs are dramatically reduced. Road graders are also often used for ice removal along the side of the road. However, the feedback from both NPRA and their largest contractor is that this method often causes damage to both the road and the safety rail.

Also, the road users are not affected during the work since both workers and the MHH are placed outside the safety rail. This also improves HSE for the workers.

The entire operation is normally done in just a few hours of arrival. The workers do not have to be present at the site while the thawing process is ongoing and other maintenance and operations may be conducted while the MHH is working. The MHH may also be rigged at the end of the work day and left overnight for ice thawing.

Picture 10 – close-up of ice cut through solid ice Photo: Heatwork

Picture 10 shows the clean cut through the ice. The bundle of flexible hoses will adapt to the thickness of the ice as well the underlying terrain.
Since this thawing method melts the ice all the way down to the soil and even heats up the ground, both Heatwork and the NPRA maintenance and operations contractor, Mesta, have experienced that these ice cuts stays open longer than similar operations performed with e.g. excavator and ripper tooth or similar. The reason for this is probably that the conventional methods are not able to remove all the ice all the way down to the soil, which again causes the trench to freeze up faster. Also, if the cut in the ice is made to wide, it seems to get the characteristics of a frost pocket and hence expedite the frost process. Further scientific work on this matter might be relevant for the continuation of the ongoing R&D project.

3. SUMMARY

The IGS and MHH technology from Heatwork has so far proven to be a valuable supplement to the existing methods used for draining excess water during the winter season. The closed loop design of the IGS makes it favorable for the long culverts due to its fairly uniform temperature characteristics throughout the entire length of the culvert.

With the possibility to preheat the MHH while towing, the ease of operation and use of quick couplings, thawing the frozen water way is very time efficient and does not require more than one worker. The compact design of the MHH also means that placing it on the hard shoulder or outside the safety rail reduces risk for both road users and road workers during operation.

When using the onboard heater hoses to cut through the ice in drain trenches to make free water ways to the culverts or away from the road shoulder, there is no longer need for lots of machine- and personnel resources. This reduces operational costs as well as improves safety for road workers. Also, the road users are less affected by the ongoing road work since there in many cases will not be necessary to suspend the traffic in one or both directions. Less use of heavy machinery along the road could also provide better safety for road users.

The NPRA project is likely to be expanded to other regions in Norway for the winter of 2013/2014. The largest road and highway contractor related to operations and maintenance for NPRA, Mesta Drift AS, has ordered the first MHH's from Heatwork for delivery winter 2013/2014 based on the positive experiences in the NPRA project.

Other operations and maintenance contractors in different industries have also indicated that they would like to increase the number of IGS installations based on the efficiency and ease of use of the products from Heatwork.

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