The Practical Limits of Cold Temperature Geomembrane Installation in Northern Canada

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Challenges from North to South
Des défis du Nord au Sud

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ABSTRACT
Many industry specifications for geomembranes call for a low temperature installation limit of 0C. These limits were mostly set up for US installations and are rarely practical for more extreme northern Canadian installations. Short Canadian summers inevitably see projects extend into the fall where any day can slip below 0C. In recent years liner installations have been extended so that now it is common for geomembranes to be installed in all months of the year. If 0C is no longer a suitable low temperature limit then what is a suitable guideline for Canadian geomembrane installations?
This paper will look at a project completed in the winter of 2014 near the North West Territories. This triple-lined pond was installed in temperatures well below -30C. Cold temperature cracking of materials occurred during handling and deployment and one area of cracking developed in a unique area of the pond. Material samples were removed and tested by the manufacturer and were found to meet all project specifications. Back on the site the installers laid out special temperature monitoring stations at the top and the bottom of the pond slope and started compiling detailed records. Comparing field experience with the recorded temperatures allowed us to establish reasonable guidelines for northern Canadian low temperature installations. The paper also discusses the use of newer generation flexible polyolefin geomembranes which help to reduce the amount of field welding and overall installation costs.

RÉSUMÉ
De nombreuses spécifications de l'industrie exigent une limite de 0 °C à basse température pour les installations de géomembranes. Ces limites ont été majoritairement mises en place pour les installations aux États-Unis et elles sont rarement pratiques pour les installations plus extrêmes dans le Nord canadien. En raison des courts étés du Canada il devient inévitable de prolonger certains projets jusqu'à l'automne où la température risque de descendre en-dessous de 0 °C d'une journée à l'autre. Au cours des dernières années, les installations ont été prolongées de sorte qu'il est maintenant courant d'installer des géomembranes à n'importe quel mois de l'année. Si la limite de 0 °C n'est plus appropriée, alors quelle serait la recommandation pour les installations de géomembranes au Canada?
Cet article examinera un projet complété à l'hiver 2014 dans les Territoires du Nord-Ouest. Un étang à triple couches a été installé à des températures inférieures à -30 °C. La fissuration des matériaux causée par les basses températures a eu lieu lors de la manipulation, ainsi que le déploiement, causant une zone de fissuration dans une zone unique de l'étang. Des échantillons de matériaux ont été retirés puis testés par le fabricant qui a déterminé qu'ils étaient conformes aux spécifications du projet. De retour sur le site, les techniciens ont établi des stations de contrôle de la température en haut et en bas de la pente de l'étang et ils ont commencé à compiler des rapports détaillés. En comparant l'expérience de terrain avec les températures enregistrées, cela a permis d'établir des directives raisonnables pour l'installation de géomembranes à basse température dans le Nord canadien. L'article aborde également l'utilisation de nouvelle génération de géomembranes de polyoléfines flexibles, qui aident à réduire la quantité de soudage sur le terrain et le coût global des installations.

1 INTRODUCTION

One of the challenges of the Canadian climate is low temperatures. This paper discusses how low temperatures affect the welding of geomembranes and cites a recent example that set limits on a particular geomembrane material.

There is a discussion of where the current specified low temperature limits came from, winter geomembrane installation practice in Canada, and a case history in extreme conditions.

2 LOW TEMPERATURE INSTALLATION LIMITS

There are a number of limits to the installation of geomembranes in cold temperatures. The first is welding and the second is installation practice.

2.1 Low Temperature Welding Limits

"Most federal and state environmental regulations call for special procedures for field seaming of geomembranes when sheet temperatures are less than 0°C" (GRI-GM9 2013). Low temperature installation limits exist in many specifications in many jurisdictions. This GRI-GM9 guideline outlines a technique to evaluate welding to a low temperature of -15C but information on installations at temperatures lower than this are rare.

In the geomembrane industry the main specification is the Polyethylene Installation Guideline published by the International Association of Geosynthetics Installers (IAGI 2007) of which the Author's company is a member. The IAGI guideline clearly suggests a low temperature limit of 0C (IAGI 2007 section 3.03).

Figure 1. Winter install of RPE stream diversion in Alaska

The limitation on welding in the field of no less than 0C was initially published over 25 years ago when welding equipment was less reliable. The limitation was primarily to prevent moisture in the seam area as moisture of any kind would prevent welding. Limiting installation to temperatures above 0C would limit the exposure to frost or dew on the liner surfaces and was considered a practical limit at the time.

There are a number of different types of field welds that are commonly used on geomembranes. Some materials based on PVC or rubber ingredients can be welded with adhesives and solvents. Adhesives and solvents have strict limiting temperatures. The solvent used to weld PVC for example has a low temperature limit of +10C; below this the evaporation rate of the solvent is too slow to create an effective weld.

Welders featuring a wedge for welding were introduced in the 1980's and have become effective tools for welding most thermoplastic geomembranes. These welders will operate in most weather conditions but are especially sensitive to moisture in the seam area. Early welders also had electronics that were not rated for extremely cold weather. Wedge welders are now the most common type of field welder for thermoplastic geomembranes and have been used in temperatures as low as -40C.

Hot air welders have been in use longer than wedge welders but are not as widely used now. Hot air welders direct very hot air at the interface between the sheets to be welded causing them to melt together. Hot air welders are not as sensitive to moisture in the seam as the hot air tends to drive the moisture off when welding. Hot air welders have also been used in the field at temperatures as low as -40C.

Extrusion welding is a method mostly used on polyethylene geomembranes to extrude a bead of plastic onto the surface of a prepared (roughened) overlap. Extrusion welding is the most sensitive of all weld types. When extrusion welding polyethylene the surface needs to be abraded to remove surface oxidation, then the thickness of the weld needs to be matched to the thickness of the material. If the weld bead is too thick it will melt through the material; too thin and the weld is not effective. Then a hot-air preheat is applied to raise the temperature of the sheeting before the extrusion bead is applied. Because of the size of the extrusion bead there can be stresses in the geomembrane near the weld due to differences in cooling rates. High Density Polyethylene (HDPE) geomembranes were initially thickness limited due to extrusion welding limits (could only weld thicker materials reliably). Current practice and equipment can now weld most thicknesses of HDPE. The limits of cold temperature installation are mostly due to the limits of extrusion welding and will be part of the discussion in this paper.

2.2 Low Temperature Installation Practice

The authors have been involved with the installation of geomembranes in Canada for over 25 years.

In many cases if the weather was too cold for field welding a fabricated geomembrane would be used. A fabricated geomembrane is one that is pre-welded in the warmth of the fabrication plant to the size need on the project site. For many smaller projects the liner could be fabricated into one piece. Geomembranes used for projects such as secondary containment in tank farms are still regularly fabricated and installed without field welds.

Figure 2. RPE irrigation canals in the winter in Alberta

Since the 1980s a material called Reinforced Polyethylene (RPE) has been fabricated to large sizes for winter installations. Projects using RPE included the stream diversion at an Alaska mine site in Figure 1 and many kilometers of irrigation canal installed in Alberta in the winter in Figure 2.

Seaming of the RPE materials in the winter consisted of overlapping the seams 1.5m and then backfilling. Where additional waterproofing was needed a butyl tape was used in the overlap. For seepage control in fresh water applications these geomembranes were effective for winter installations.

Challenging projects where welding in winter conditions were initially rare but have developed into a more common practice. A particularly challenging project type was the installation of a geomembrane for frozen core tailings dams. Two of these projects were carried out in the mid-1990's in Siberia and in the high Arctic. In this case a flexible polypropylene (PP) material was fabricated to larger sizes and then joined in the field with wedge welders. In a tailings pond in the high Arctic welding took place to a low temperature of -45C at which point the material started cracking during handling. One of the benefits of installing tailings dams in the winter is that the hydrogeology of the area is frozen and stream diversions and other temporary works are not needed.

2.3 Low Temperature HDPE Installation Practice

The authors have been involved in HDPE installations in cold weather since 1987. Initially installations were limited to fair weather days however as the project stretched into the fall installation was often hampered by wet conditions and rain. Short periods of rain would stop the project for days as the subgrade would need to dry out before proceeding.

Figure 3. HDPE installation using temporary shelters.

In late fall freezing temperatures froze the ground and effectively stopped the mud and wet conditions from being a problem. Roll edges that were deployed on the previous day had frost or dew on the edges; however, rolls that were not yet deployed still retained clean, dry edges. After removing the frost from the previous edge installation could continue.

Typical Canadian practice is to continue installations well into the fall and production rates typically increase significantly after the ground freezes. After the ground is frozen the limiting factor becomes snow. Snow normally has to be removed before welding can take place. The other limitation is if the geomembrane needs to be backfilled. If backfilling is a requirement it is normal to require dry, free-flowing backfill, or backfill that has been heated to keep it free-flowing. Frozen clumps during backfill will inevitably cause damage.

A significant problem with winter work is getting the subgrade smooth enough for a geomembrane installation. Earthmoving equipment is challenged by frozen soils and the inclusion of ice and snow in fill materials. It is possible to prepare a subgrade in the winter but very difficult and this often limits the ability of a project to go ahead in the winter. If the subgrade can be prepared before winter there is a better likelihood of project success.

Since 2008 winter installation has become a common practice in Canada. A couple of examples include Figure 3 which is an HDPE installation of a process pond for an oil sands project in northern Alberta. Temporary shelters were used to shelter the welding area. These shelters were helpful under certain conditions however the extra work to move the shelters did not justify their continued use.

Figure 4. Placement of geotextile on frozen tailings pond.

Another significant winter installation showing the limits of winter weather is in Figure 4. This project was the installation of sewn high strength geotextile on top of a frozen tailings pond. Geotextile sewing machines are sensitive to the cold so this required heating sewing shelters in addition to cold weather deployment. This project was outlined in a paper presented at the Pan-Am CGS conference in 2011 (Mills, 2011).

In 2008 installation demand was so strong that projects continued throughout the winter. Since that time winter installation has occurred every winter creating challenges that have had to be addressed.

Figure 5. Subgrade preparation in wet conditions.

3 WINTER INSTALLATION CASE HISTORY

The example project was a water containment pond built for storing water for oil field operations. The project was located north of Ft Nelson BC near the NWT border. The project was a triple-lined pond with leak detection underneath each layer. A substantial sump was located in the east side of the pond base.

Each layer had HDPE pipe leak detection pipes that ran down the slopes to eliminate penetrations at the bottom of the pond. Piping on top of the primary liner was 600 mm. To protect the geomembrane layers from abrasion and movement in these primary pipes a narrow layer of Bituminous Geomembrane (BGM) was placed on top of the primary HDPE geomembrane underneath these pipes.

From the bottom of the containment the geosynthetics used consisted of a drainage geocomposite, a 1.5 mm smooth geomembrane, an HDPE geonet, another 1.5 mm smooth geomembrane, another HDPE geonet, and then a protective 1.5 mm single sided textured HDPE geomembrane for protection of the other layers.

The project started on October 26th with crews on site to weld the HDPE pipe for the sumps. Because the crews were on site early for this preparatory work there is a good photo record of the site preparation. Figure 5 shows the condition of the subgrade in October and Figure 6 shows the final subgrade preparation. The earthwork crews did an excellent job on this project under difficult conditions.

Liner installation started on November 11th and continued until the 17th of March. Significant cold weather was experienced with measured site temperatures as low as -45C.

Figure 6. Installation under the lights.

The first indications of problems were with cracking of the BGM material during deployment in December. With temperatures of -29C and a wind chill of -35 the BGM cracked as it was unrolled and installation of the BGM was set aside until later in the project.

Installation of the HDPE geomembrane proceeded slowly through December with snow hampering progress. On January 13th there was an incident where the textured HDPE material cracked when being cut. Temperatures were -33C with a -41C wind chill. Then on January 29th additional material cracked while being handled (temperature was not recorded). Samples were taken and immediately sent for testing.

Review of the project testing showed that the material manufactured for this project had been sent to an outside lab for cold temperature testing. In a test report from TRI Environmental in Anaheim California dated 26 November 2013 the single sided textured material made for this project had passed a Low Temperature Impact Test (ASTM D746) at -70C. This HDPE material was passing the specifications for cold temperature but was showing some cracks in the field. A review was held and it was agreed to monitor temperatures and to limit installations in severely cold conditions.

Figure 7. Cracking of the geomembrane.

At this point the field crew started recording the temperatures in the morning, at noon, and in the afternoon. On the 10th of February additional cracking occurred in the textured material. The temperature in the morning was -37C but warmed to -23C by noon. The cracking appeared to happen later in the morning. After discussion it appeared that the temperatures at the base of the pond were colder than the temperatures at the top of the slope. Additional measurements were taken at both the base of the slope and the top of the slope. At this point the crews decided to wait until they had -20C before proceeding with welding.

From the 14th to the 20th of February welding of the liner materials proceeded slowly but without incident. Then on the 21st of February an area of the textured HDPE geomembrane material shattered when snow was being removed in the sump area. Temperatures at the time were -36C in the morning and -23C at noon. Samples of the shattered material were rushed to a testing lab. In the test report from CTT Group in St.

Hyacinthe Quebec dated Februrary 26th the shattered material passed a Low Temperature Impact Test (ASTM D746) at -70.2C.

The area where this cracking occurred was in a complex three-dimensional transition between the corner of the pond and the sump area. A repair was made in this area using smooth HDPE geomembrane.

Again the material was passing the material specifications but problems were occurring during installation. In Figure 7 the cracking is evident next to an extrusion seam. As outlined earlier extrusion seams can develop stresses in the geomembrane especially when cooled quickly. The conclusion was that the extrusion welds were placed at too cold a temperature. Additional temperature monitoring would be put in place to limit problems. Over the following week there were no welding issues as the field crews waited until temperatures warmed to -20C before welding.

On February 26th with the temperatures rising to -12C at noon another attempt was made to install the BGM material. The rolls were tarped and heated prior to installation. Even with this heating there were some cracks during unrolling. The cracked were capped and the BGM installation was completed.

The last cold snap of the project started on February 27th and lasted until March 7th. During this time the morning temperatures were between -33C and -37C measured at the top of the berm. The temperatures at the base of the pond were measured at -37C to -45C. During this period the field crews started 2 hours later in the day to avoid the coldest part of the day. During this period there were no problems with geomembrane cracking as all welding was delayed until -20C could be reached.

The project was completed on March 17th and is currently in service.

4 A LOW TEMPERATURE LIMIT FOR HDPE

A number of lessons were learned from this project. First of all textured HDPE materials are not as resistant to cold weather installation as smooth HDPE. HDPE is a surface-sensitive material and scratches and notches on the surface can accelerate chemical and mechanical problems. In this case it appears that the textured surface led to cracking at temperatures that were not as cold as expected. The current test method for Low Temperature Impact (ASTM D746) is not a reliable guide to low temperature application.

A second lesson learned is that the temperature at the base of a pond can be significantly different from the temperature measured at the top of the berm. Temperature measurements at the site trailer may not give a correct indication of site welding conditions.

Based on the experience on this project the low temperature installation limit for textured HDPE geomembrane is -20C. Smooth HDPE geomembrane can be installed at slightly lower temperatures; however, a clear limit was not determined on this project as the textured material was the limiting factor.

5 DISCUSSION

While HPDE was used in this example on smaller projects a prefabricated geomembrane can be used to avaoid field welding. Prefabricated materials can be made into large panels that will limit or eliminate welding in the field.

Larger projects that require winter field welding can use a number of strategies. With an HDPE installation monitoring of temperatures and limiting installation to days with suitable weather is recommended.

Choosing a geomembrane material with a lower density can also help lower cracking risks on site. HDPE is a crystalline, brittle material. Materials with lower crystallinity such as LLDPE and other proprietary materials are not as susceptible to cold temperature cracking can also be used effectively.

Another theory that is used to describe cracking in HDPE is the depletion of anti-oxidants. Depletion of anti-oxidants can occur when the HDPE is heated too many times. Recent studies have shown that cracking can occur when extrusion welds are placed close together or next to wedge welds. One method proposed to help alleviate this issue is to use fortified geomembranes. Fortified geomembranes contain high loadings of UV stabilizers and anti-oxidants. These additional additives can help protect the geomembrane from antioxidant depletion leading to stress cracking.

6 CONCLUSIONS

Winter installations of geomembranes in Canada must deal with significant low temperatures. There are advantages to installing geomembranes in the winter including control of surface water, control of muddy conditions, site access, and project scheduling benefits. The drawbacks are that welding and installation are much more difficult.

In this project it was found that there is a low temperature welding limit of -20C for textured HDPE geomembranes.

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