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To control the deicing fluids, a geosynthetic clay liner (GCL) was selected as the barrier layer, the most critical environmental component of the design. A plastic-laminated GCL was selected to mimic a composite liner design. An aggregate-filled cellular confinement system was placed beneath the GCL to provide a drainage layer, frost protection, and structural support. To provide separation and filtration in the underdrain system, nonwoven geotextiles were incorporated into the design. The facility design also includes a 1.6-million gallon pre-cast concrete underground storage tank, 4 million gallons of aboveground spent deicing fluid storage, a pump station, an elaborate system of flow diversion valves, and over fifty-seven thousand feet of welded HDPE pipe, up to 54 inches in diameter. Construction of the new deicing facility began in the autumn of 2005, and was completed in September 2006.

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ABSTRACT

The design and construction of the new deicing facility at the Cleveland Hopkins International Airport involves several innovative geosynthetic applications. Historically, airplane deicing operations at the airport have taken place at the individual airline gates, resulting in an increased potential for uncontrolled releases of aircraft deicing fluids, such as propylene glycol. In response to the threat of discharges to the nearby Rocky River and its tributary, Abram Creek, the Ohio EPA mandated a new centralized deicing facility, where deicing fluid could be applied and collected in a fully controlled manner. The new deicing facility, which covers approximately 40 acres, was sized to allow deicing fluid to be applied to eight airplanes at one time, allowing up to 30 aircraft depart in each peak operation, thus minimizing departure delays. The 38-inch pavement section at the facility consists of (from top to bottom): 16 inches of Portland Cement Concrete; 8 inches of econocrete; 8 inches of crushed aggregate; a hydraulic barrier layer; 6 inches of aggregate-filled cellular confinement system (Geoweb®); and existing subgrade. To control the deicing fluids, a geosynthetic clay liner (GCL) was selected as the barrier layer, the most critical environmental component of the design. A plastic-laminated GCL was selected to mimic a composite liner design. An aggregate-filled cellular confinement system was placed beneath the GCL to provide a drainage layer, frost protection, and structural support. To provide separation and filtration in the underdrain system, nonwoven geotextiles were incorporated into the design. The facility design also includes a 1.6 million gallon pre-cast concrete underground storage tank, 4 million gallons of aboveground spent deicing fluid storage, a pump station, an elaborate system of flow diversion valves, and over fifty-seven thousand feet of welded HDPE pipe, up to 54 inches in diameter. Construction of the new deicing facility began in the autumn of 2005, and was completed in September 2006.

INTRODUCTION

The design and construction of a new centralized deicing facility at the Cleveland Hopkins International Airport (CLE) involved several geosynthetic applications, including a plastic-laminated geosynthetic clay liner (GCL), an aggregate-filled cellular confinement system (Geoweb®), nonwoven geotextiles, and HDPE pipe. This paper presents a discussion of the project background, design, and construction, with a particular focus on the geosynthetic elements. To the authors' knowledge, this is the first use of either GCLs or Geoweb® materials at an airport deicing facility.

BACKGROUND

Ice, frost, or snow present significant concerns for airports in temperate and cold-weather climates. Even small amounts of these materials on aircraft surfaces can pose serious safety concerns. To address this concern, deicing fluids (such as ethylene glycol, propylene glycol, and urea) are typically sprayed on aircraft before takeoff. Historically, airplane deicing operations at CLE have taken place at the individual airline gates (Photograph 1). In the past, individual planes were sprayed with deicing fluids while passengers were boarding, with any drippings and overspray collected by vacuum trucks. For the 2004 to 2005 deicing season, a total of approximately 1.1 million gallons of concentrated deicing fluid (applied as a 50:50 propylene glycol/water solution) were handled in this manner at CLE. While this deicing approach minimizes departure delays – particularly at a hub airport where many flights depart at one time – it also results in an increased potential for uncontrolled releases of propylene glycol. Although propylene glycol is not as toxic as ethylene glycol, it does have a high biochemical oxygen demand (BOD), driving down dissolved oxygen levels in receiving waters, and potentially impacting aquatic organisms.

In response to past glycol releases to nearby Abram and Silver Creeks (both tributaries of the Rocky River, which empties into Lake Erie), the Ohio EPA mandated a centralized deicing operations at CLE, where deicing fluid could be applied and collected in a fully controlled manner. The City of Cleveland Department of Port Control contracted R.W. Armstrong and Associates, Inc. to design a new centralized deicing facility and oversee its construction. The design is discussed in the following section.

DESIGN OVERVIEW

The CLE centralized aircraft deicing facility (CDF) covers a total area of 76 acres, which includes Deice Pad 1, Deice Pad 2, associated taxiways, Site A and Site B (Figure 1). Since the primary deicing operations will take place at the two CDF Pads and their associated taxiways, these areas were sized to allow deicing fluid to be applied to eight commercial airplanes at one time (30 planes/hub movement). Site A will provide a staging and storage area for deicing applicator equipment, while Site B will contain two 2-million gallon aboveground storage tanks for either onsite recycling or discharge to the Northeast Ohio Regional Sewer District (NEORSD) sanitary system.

As shown in Figure 2, the typical 38 inch thick CDF pavement cross-section consists of (from top to bottom): 16 inches of Portland Cement Concrete; 8 inches of econocrete; 8 inches of crushed aggregate; a hydraulic barrier layer; 6 inches of aggregate-filled cellular confinement system; and existing subgrade. The cellular confinement system with aggregate infill was placed beneath the GCL to provide drainage, frost protection, and structural support. Nonwoven geotextiles were provided below the cellular confinement system for subgrade separation and on top to cushion the hydraulic barrier above. Nonwoven geotextiles were also incorporated into the underdrain system to provide separation and filtration.

The CDF has a total fluid capture capacity of 5.6 million gallons – 4.0 million in two aboveground storage tanks (ASTs) at Site B, and 1.6 million in an underground storage tank (UST) beneath Site A. The underground tank was constructed using pre-cast concrete arch top structural sections – the first of its kind for this type of application. A GCL was installed beneath the UST as secondary containment in case of tank leakage, with a separate underdrain system installed between the tank bottom and the GCL. A network of HDPE pipes will collect runoff from the pads and transport it by gravity to the UST for retention, then either directly to the stormwater system (clean run-off from the entire airport during the summer), or to the collection system (glycol-laden water during the winter). Based on the glycol concentrations, runoff will be segregated and managed through the use of five diversion vaults. One of the vaults will divert the highest concentration flows from the primary glycol application area to an isolated section of the UST. High concentrate runoff that accumulates in this 150,000 gallon vault will be pumped into trucks for further processing, recycling, or off-site disposal. The remaining four diversion vaults will route runoff to either the storm sewer or to the low concentration section of the UST. From here, the glycol-impacted water will flow over 3,500 feet through a sealed pipe system to a deep wet well. A 10 cfs pump station will transfer glycol-laden runoff to the aboveground tanks located outside the airfield fence at Site B. From there, fluids will be metered into a gravity sanitary sewer line connecting the aboveground tanks to the NEORSD sanitary sewer system. In-line measurements and telemetry reporting will be used to ensure that the NEORSD influent limits (summarized in Table 1) are not exceeded. These limits were established to prevent excessive BOD/COD loads associated with propylene glycol from overwhelming the processing capabilities of the sewer treatment plant.

TABLE 1 - NEORSD DISCHARGE LIMITS

Parameter	Daily Maximum	Daily Loading
COD	650 mg/L	21,150 lb/day
BOD	406 mg/L	13,200 lb/day
Ammonia	72 mg/L	600 lb/day
Flow	2,700 gpm	3.9 MGD

The specific geosynthetic elements of the CDF design, which are critical to this project's success, are discussed in the following section.

GEOSYNTHETIC ELEMENTS

Geosynthetic Clay Liner

Successful completion of the CLE deicing facility project involved contributions from several civil engineering specializations (transportation, structural, hydraulics, and environmental). Since the major design objective is to prevent leakage of deicing fluids, the most critical environmental component of the project is the pavement's hydraulic barrier layer. A needlepunch reinforced, plastic-laminated GCL was selected as the hydraulic barrier layer. Over 2.1 million square feet of GCL were used to line the deicing pads, associated taxiways, and Sites A and B. The GCL consisted of 0.75 lbs/ft^2 of sodium bentonite encapsulated between woven and nonwoven geotextiles. A 4-mil HDPE plastic geofilm was laminated to the nonwoven geotextile for improved hydraulic performance and chemical resistance. An additional nonwoven geotextile was laminated to the HDPE geofilm to provide increased durability and puncture protection. The GCL was selected for the following reasons:

- **Low hydraulic conductivity.** The plastic-laminated GCL product is certified by the manufacturer to have a maximum hydraulic conductivity of 5 x 10^{-10} cm/sec when permeated with distilled water. Because the plastic geofilm is virtually impermeable, the actual hydraulic conductivity of the plastic-laminated GCL is expected to be lower.

- **Compatibility with deicing fluids.** Past testing performed by the manufacturer (summarized in Figure 3) showed that, when permeated with a 50:50 solution of ethylene glycol, a standard GCL (without any plastic backing) exhibited a long-term hydraulic conductivity of 7.0 x 10^{-10} cm/sec. The manufacturer test results are consistent with past findings in the literature. Petrov et al. (1997) found that GCLs are compatible with nonpolar, miscible organic compounds, provided that the organic concentration is less than 60 percent.

- **Bentonite self-healing characteristics.** The potential for punctures was another consideration in selecting a GCL as the hydraulic barrier layer. The swelling and sealing properties of bentonite give a GCL the unique ability to recover from punctures. Studies performed by Shan and Daniel (1991) on GCL samples that were deliberately punctured found that the GCL was able to self-heal holes up to 1 inch in diameter, and still maintain a low hydraulic conductivity. This self-sealing ability allowed for rapid installation around penetrations, such as inlet structures, pipes, and manholes.

- **Protection against ion exchange.** Since the CDF pavement includes crushed limestone aggregate (AASHTO #57 stone), a plastic laminate was incorporated into the GCL to reduce the risk of ion exchange in the sodium bentonite posed by dissolved calcium leaching from the aggregate.

- **Schedule.** A major project driver was schedule – the Ohio EPA had mandated that the new facility be operational by the Fall of 2006. Due to the amount of time involved in getting funding in place, agreement from the airlines, and receiving OEPA approval of the Permit To Install, the construction duration was compressed to one year. This aggressive schedule required construction through the winter months of late-2005 and early-2006. After evaluating various materials, the decision was made to install GCL in lieu of geomembrane or compacted clay. At low ambient temperatures, it would have been extremely difficult to control clay temperature, moisture content, and hydraulic conductivity. Geomembrane panels should only be installed and seamed when ambient temperatures are greater than 40^{o} F, while GCLs have been successfully installed in many cold weather settings. Cold weather delays related to either geomembrane or clay could have pushed the project completion date into 2007, resulting in significant fines.

- **Simplicity of installation.** Another benefit of using a GCL as the hydraulic barrier is ease of installation. While geomembranes require thermal seaming methods, GCLs are seamed by overlapping adjacent panels and applying supplemental granular bentonite to the overlap area. In addition, a pneumatically-powered geosynthetic installation device was used to deploy the GCL. The installation device was mounted on a large-capacity tractor, as shown in Photograph 2. As the tractor operator drove forward, a ground operator used a control cable to unroll the GCL onto flat panels. Using this equipment, several acres of GCL per day were deployed, accelerating the installation.

Deicing fluid collection system (HDPE Pipe)

Another critical environmental component of the CDF design is the liquid collection system. The collection/drainage system consists of over fifty-seven thousand feet (almost 11 miles) of HDPE pipe and underdrains. (Photograph 3). Reinforced concrete pipe (RCP) is typically used for airport drainage applications. However, RCP systems can allow significant infiltration if not installed correctly and can degrade over time. Both possibilities were unacceptable – particularly when repairs would impact airfield operations. HDPE pipe with fusion welded connections, which is compatible with glycol, was selected instead of RCP, to limit glycol exfiltration and groundwater infiltration potential. The HDPE collection system for all anticipated glycol flows was provided from the inlets, through the diversion valves, and downstream to the disposal facilities. The pipe diameters range from 24 to 54 inches, with motor-actuated gate valves. Because of their size, both the piping and valves were specially fabricated for this project, and required a long lead time (the lead time and pipe cost unexpectedly escalated in the fall of 2005 due to the Hurricane Katrina's impact on manufacturing plants along the Gulf Coast). The collection pipes draining the CDF area were sized to accommodate a 10-year summer storm event. To evaluate expected winter flows and storage requirements, a model was developed using the past 50 years of rainfall data, the existing fleet of aircraft, assumed glycol application rates, and estimates of glycol drippage and overspray. This resulted in sizing the total project storage at 5.6 million gallons – consisting of the ASTs, the UST, and storage in the pipe system. The designers also worked with the HDPE pipe manufacturer to determine the minimum pipe thicknesses needed to withstand the expected loading associated with the pavement and the design aircraft.

Drainage Layer/Underdrain System

The native soils at CLE consist of glacial tills (primarily silts and clays), with highly variable geotechnical properties. The 38-inch thick pavement section has been designed based on a subgrade California Bearing Ratio (CBR) of four. Typically, when existing conditions are encountered with CBR values under four, the subgrade needs to be improved by disking and drying; adding cement or lime treatment; or removal of the yielding soil and replacement with stabilization aggregate. However, even when adequate subgrade conditions were present during construction, the relatively shallow water table in the vicinity of the site presented an increased likelihood of saturated soils, which would further reduce the soil's strength and bearing capacity. The water table has been found to rise up to within a couple of feet of the ground surface during the wet seasons in northeast Ohio. To address these subgrade limitations, a 6-inch drainage layer was incorporated into the pavement design. The drainage layer was placed directly on subgrade which was sloped to allow groundwater to move up into the drainage layer and flow to the perforated underdrain system that runs along all edges of the airfield pavement. The intent of the drainage layer and underdrain is to collect shallow groundwater, thus preventing saturated soil conditions, as well as providing structural support and frost heave protection. The underdrain system includes two geosynthetic components: a polyethylene cellular confinement system and nonwoven geotextiles.

In addition to the "standard" groundwater underdrain system addressed above, the CDF also must provide a drainage path for the glycol-laden water that makes its way down through the top of the pavement and is blocked by the clay liner. To capture this fluid and keep it from saturating the pavement section over time, a second perforated underdrain system was constructed above the liner. This system is assumed to collect glycol-impacted water for 12 months of the year. Therefore, the outlet pipe cannot be tied into the storm drain system, but will flow by gravity to the pump station for disposal to the sanitary sewer. The entire glycol underdrain system is composed of welded HDPE pipe.

Polyethylene Cellular Confinement System

As discussed previously, the glacial till soils present on the CLE airfield are subject to great variability. While the soil typically performs well when near optimum moisture levels, saturated soils are not satisfactory for pavement subgrade. This problem was exacerbated when working during the winter months. In order to bridge some of the softer areas of subgrade, a flexible, three-dimensional polyethylene cellular confinement system (also known as a Geoweb®) was placed over the subgrade. The cellular confinement system used at CLE is shown in Photograph 4 - over 1.3 million square feet were used.

Historically, the drainage layer design consisted of combining a poorly graded aggregate (AASHTO #57 stone) with an asphalt or concrete binder. The layer would then be placed on subgrade with an asphalt or concrete paver. After hardening, the drainage course would form a porous and flexible slab. However, since asphalt plants are not in operation during the winter, and cold winter temperatures would prevent cure of cement binder, a aggregate-filled cellular confinement system was selected to bridge the soft spots as the drainage course. A secondary benefit was that the drainage layer became a structural layer. During design it was determined that the 6 inch drainage layer would improve subgrade soils with a CBR value of two, up to the required design CBR of four. The aggregate-filled cellular confinement system produced a stable structural base that distributed loads laterally, and reduced subgrade contact pressures. This was not only beneficial in terms of the overall pavement stability, but also in terms of a stable interim construction platform. By spanning weak soils that would otherwise need to be dug up and moisture conditioned, construction was allowed to proceed uninterrupted through the winter months.

Geotextiles

Since the cellular confinement system was placed directly on top of fine-grained soils, an 8 oz/yd^2 nonwoven polypropylene geotextile was used as a separation layer between the two distinct soil types. Separation was needed in this application to prevent contamination of the granular infill (and consequently, loss of shear strength) and to prevent punching or migration of the infill material into the subgrade. An additional 8 oz/yd^2 nonwoven geotextile was placed between the top of the aggregate-filled cellular confinement system and the bottom of the GCL for puncture protection. The puncture risks posed by both the cellular confinement system (below the GCL) and the crushed aggregate concrete subbase (above the GCL) were evaluated during the early stages of construction by building a field test pad. The test pad was constructed using 8 oz/yd^2 nonwoven geotextiles on either side of the aggregate-filled cellular confinement system. Various heavy construction vehicles (loaded dump trucks, graders, etc.) were driven repeatedly across the pad, simulating worst-case construction conditions. The GCL was then exposed and inspected for signs of damage. Since no significant damage was observed in the test pad samples, the 8 oz/yd^2 nonwoven geotextile beneath the GCL and the 3.2 oz/yd^2 nonwoven geotextile laminated to the top of the GCL were deemed adequate for puncture protection. The favorable test pad results indicated that there would be little concern regarding swelling GCL under the rigid pavement or above the underdrain layer. As a constructability issue, the contractor took due care to make sure the GCL did not sit unconfined for a long period such that it would hydrate. As a practical matter, the needlepunch-reinforced proved quite able to withstand the construction process without issue.

SUMMARY

The design and construction of the new centralized deicing facility at Cleveland Hopkins International airport involved several innovative uses of geosynthetics. In response to historical glycol releases to nearby streams, Ohio EPA mandated that a new centralized deicing facility be built within one year to capture and control airplane deicing fluids. The design of the deicing facility had to meet these regulatory requirements, while at the same time, minimize departure delays. Geosynthetics were critical in successful completion of a project with such strict regulatory constraints and customer expectations. The overall project, which had a budgeted cost of $46.89 million, was constructed within budget and within the EPA-mandated schedule of one year. Because of the tight deadlines, much of the construction activities took place during the winter months in late-2005 and early-2006. The cost of the construction effort was borne by the airlines, and will ultimately be recovered from airline customers, through a Passenger Facility Charge added to the price of each ticket.

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FIGURE 1 – CLE CENTRALIZED DEICING FACILITY

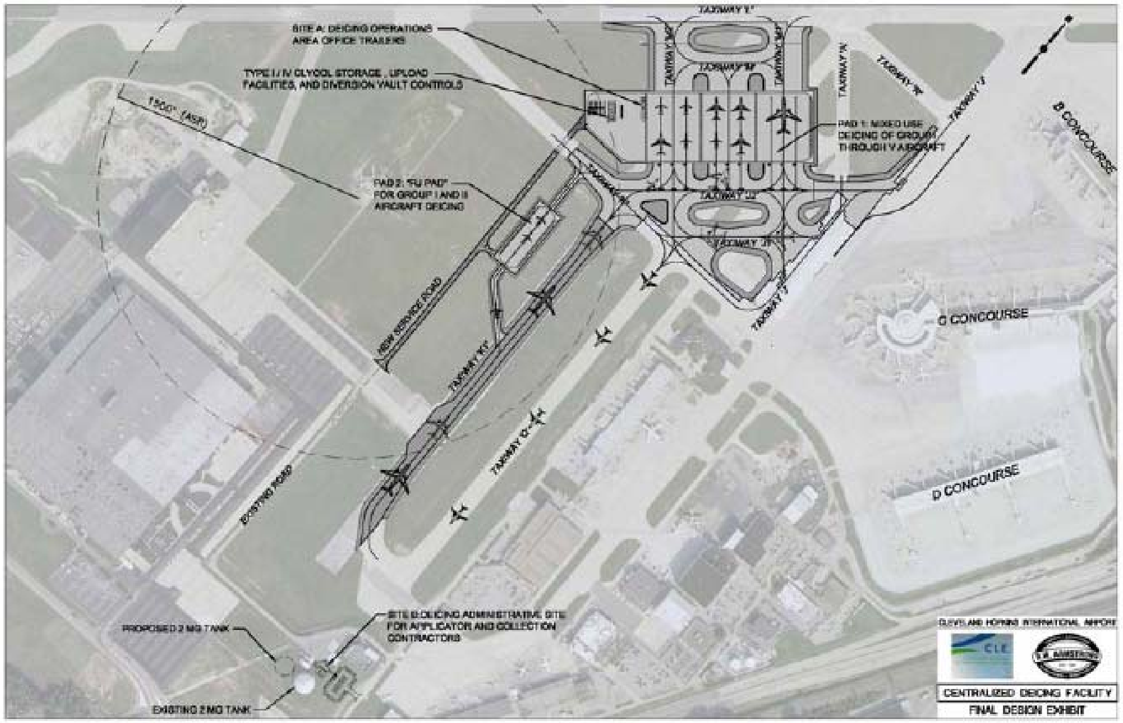


FIGURE 2 –TYPICAL CDF PAVEMENT CROSS-SECTION

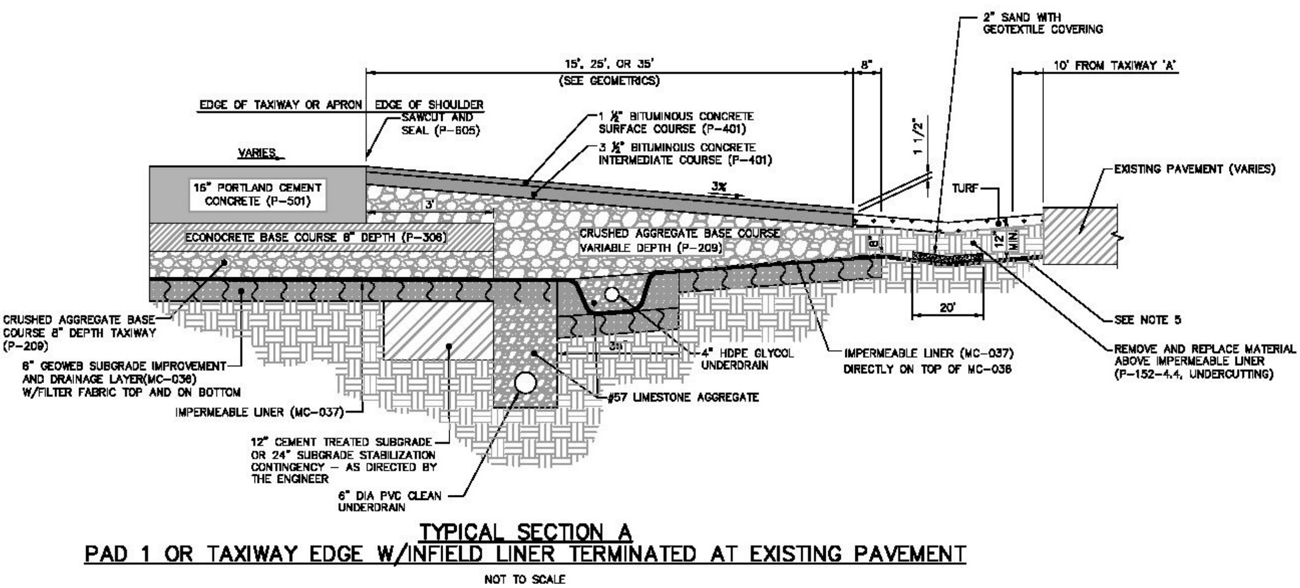
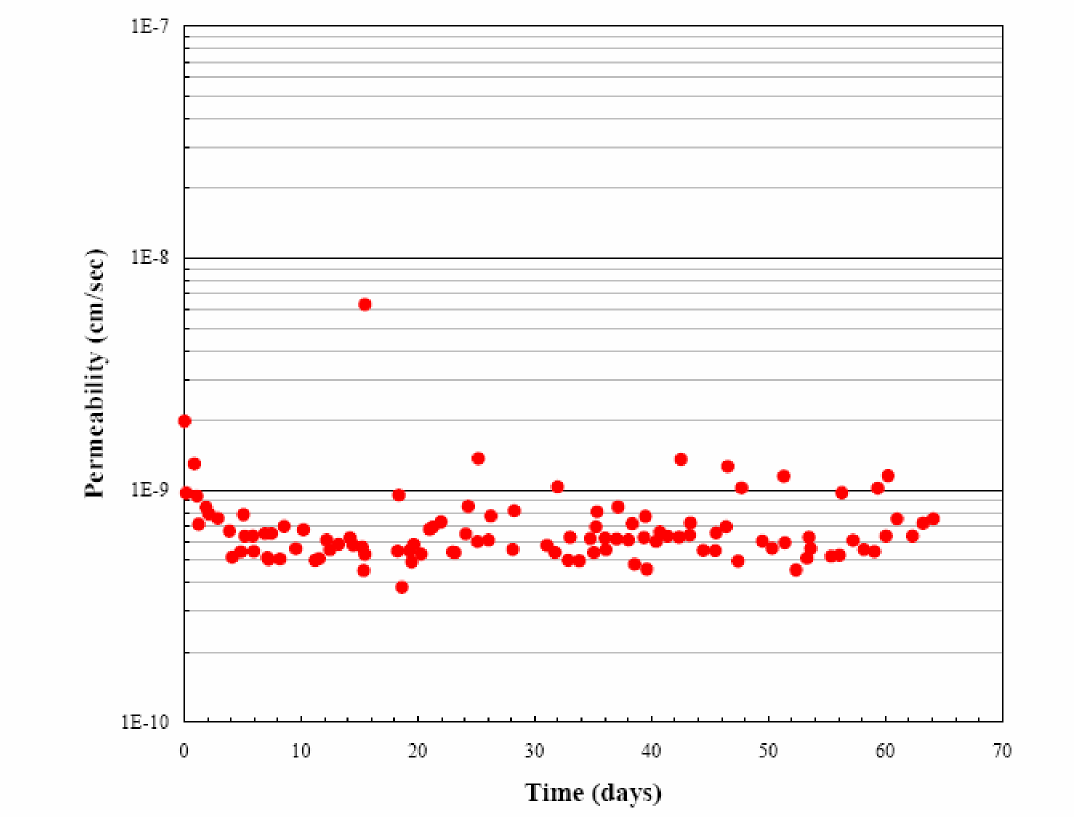


FIGURE 3 - GCL COMPATIBILITY WITH AIRPLANE DEICING FLUID



PHOTOGRAPH 1 – AIRPLANE DEICING OPERATIONS

PHOTOGRAPH 2 – GCL INSTALLATION

PHOTOGRAPH 3 – HDPE PIPE INSTALLATION

PHOTOGRAPH 4 – GEOWEB® INSTALLATION