An Update to the Construction of the Suncor Oil Sands Tailings Pond 5 Cover

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Abstract

To facilitate reclamation of its Pond 5 oil sands tailings pond, Suncor began construction of a full scale floating cover over the fluid tailings in the pond in January, 2010. The cover is comprised of geosynthetics overlain by petroleum coke and will function as a first step towards achieving a trafficable surface that would allow for further reclamation activities ultimately leading to the closure of the pond. A paper discussing the design of the cover and the initial construction in the winter of 2010 has been published previously. A series of field trials were conducted on the cover in the summer and fall of 2010, and the results of the field trials in addition to data and observations collected during the 2010 winter construction were used to enhance the construction methodology and improve productivity including the use of different and larger construction equipment. This paper discusses and presents these and other novel aspects of constructing a large scale floating cover on a fluid oil sand tailings pond.

Introduction

Suncor's Pond 5 represents one of the largest field trials of a tailings technology in mining history, with the development and deposition of a then-new engineered tailings material known as Consolidated Tailings (CT). This trial was started in 1995, as discussed in detail by Wells et al (2010). After some 13 years of tailings placement, volumes of the resultant deposits exposed at surface proved too weak to support terrestrial reclamation activities, while commitments made as part of Suncor's operational approvals require Pond 5 to be reclaimed to a trafficable surface. In order to achieve this goal, additional technology developments were required in order to dewater and consolidate this soft tailings material. After a period of technology reviews that included tours of similar global operations, the decision was taken to pursue capping of the soft deposits followed by dewatering through the placement of Vertical Strip Drains. This plan offered the best path to achieve the required timeline for reclamation.

Pond 5 Overview

The upper 10 m (approximately) of the Suncor Pond 5 tailings facility consists of fluid like clay tailings (Mature Fine Tailings) with bulk densities in the order of 1.3 t/m^3. Below the MFT exists a mixture of clay and sand increasing in density and sand content with depth to the base of the pond. Additional details are provided in Pollock et al. (2010). The remoulded vane shear strength is typically less than 1 kPa in the upper material. There is also noticeable lateral variability in the thickness of the material composition as well as the "soil" characteristics such as strength and density.

Coke was previously identified as a cover material candidate as it was readily available and had favorable properties for the challenges that the MFT presented. From a geotechnical perspective, coke is an ideal material for cover construction due to its combined light weight and high strength. In 2008 and 2009, research was conducted on Pond 5 with large equipment to examine the feasibility of constructing a coke cover in conjunction with geosynthetics. This work was presented by Wells et al. (2010).

In the winter of January 2010, Suncor began construction of the full scale Pond 5 coke cover. The design, construction and performance of the cover were presented in Pollock et al. (2010). A road and infill approach was taken which involved constructing a network of roads as the first stage followed by constructing the area between the roads (or cells) in the following stage. Figure 1 shows two aerial photographs, the first taken in the summer of 2009 before construction of the cap commenced and the second taken in the spring of 2010 after the end of the 2010 construction. Figure 2 shows an aerial photograph taken in the spring of 2011 towards the end of the 2011 construction.

Figure 1: Aerial photos of Pond 5; left: June 1, 2009 and right: April 6, 2010

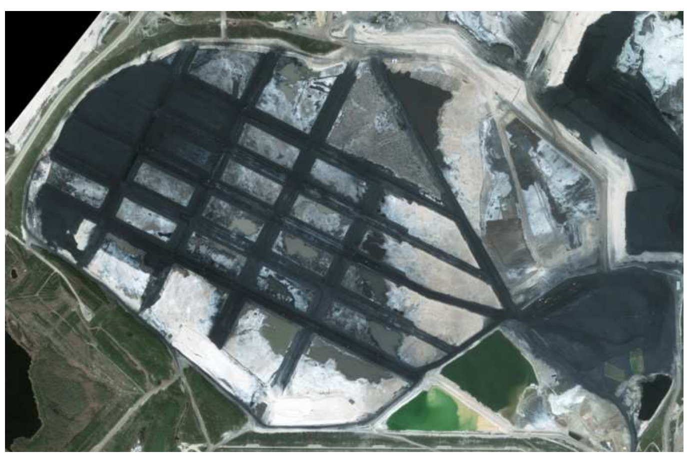

Figure 2: Pond 5 aerial photo (May 14, 2011)

The purpose of the coke cap is to provide a surface that will permit further reclamation activities. At this time, it is envisioned by Suncor that once the coke cap has been completed (i.e., roads and cell infills), wick drains will be installed to enhance dewatering of the tailings. Therefore the coke cap cover needs to be able to support equipment to install the wick drains.

In addition, the construction equipment used to place the coke needs to be supported. Dozers have a limited distance to which they can efficiently spread material, and therefore trucks are required to haul coke over most of the pond. This necessitated having a road network which can support the size of the trucks used in the operation. During the 2010 winter construction, 30 to 40 tonne articulated trucks were be used for the construction while self loading scrapers with 40 tonne capacity were used during the 2011 winter construction.

Beach Roads Construction

East Beach Road

After the 2010 winter construction at Pond 5, Suncor proposed building a coke road on the east beach to connect the coke stockpile with the north dyke referred to as the East Beach Road (EBR). The road was to be constructed during the summer and would create a shorter traffic route between the coke stockpile and the pond. The completed road is shown in Figure 2; it is the east most road visible on the aerial photograph. Although the East Beach Road was to be constructed on a “sand” beach, the sand was very loose, saturated, overlying MFT in places and in an unfrozen state.

Existing CPT data, samples from previous investigations, aerial photographs and results of vane shear tests indicated the presence of potentially liquefiable tailings sand below the proposed location of the EBR. The sand was generally soft CT below the major portion of the proposed EBR. A floating backhoe was driven over the proposed EBR alignment and test pits were excavated into the surface of the pond as part of the investigation. The floating backhoe travelled successfully over the southern portion of the EBR and became stuck in the soft sand towards the middle of the EBR. Back analysis of the floating backhoe (track pressure of about 26 kPa) sinking into the beach resulted in back-calculating an undrained shear strength of 5 kPa or less for the beach at that location.

A geotechnical investigation was then conducted below the entire proposed alignment of the EBR. The investigation included pushing several CPTus to a depth of 10m below the pond surface, collecting samples of the underlying material, and installing electric push-in piezometers, using the CPT rig, approximately 1m and 4m below the surface to monitor the pore water pressures below the proposed road. The data collected from the geotechnical investigation showed the presence of loose saturated beach deposits with an average solids content of about 79% and an average fines content of about 11%.

Based on the results of the investigation, it was decided to build the EBR by placing 70 kN/m geotextile rolls across the width of the road, overlapped by 1m in the road direction, and slowly place 2m of coke, in 2 lifts, over the geotextile. In addition to forming the cross-section of the EBR, the staged coke placement was intended to incrementally “liquefy” the soft sands to form a solid base to the road. Drain pipes were placed over the geotextile and extended to the sides of the road. The intent of the drain pipes was to collect water coming out of the sand and divert it away from the road. The coke was hauled using 30 and 40 tonne capacity articulating trucks and pushed out using Caterpillar, CAT, D6 dozers. At the southern and northern ends of the EBR where more competent beach was expected, a 30 kN/m biaxial geogrid was used or a combination of geogrid and a 30kN/m geotextile were used instead of the 70 kN/m geotextile.

An observational construction approach was used. The following construction conditions were varied depending on observations collected at the particular location of coke advancement:

- The length of 1m lift ahead of the 2m lift,
- How close to the edge of the coke the trucks were allowed to drive (on the 1m lift), and
- The rate of coke placement.

The following visual observations were collected: relative amount of water coming out from under the roads, relative amount of deflection under the dozers and trucks, and width and frequency of cracks on the 1m lift. Additionally, the pore water pressures were continuously monitored using the electric piezometers, connected to data-loggers.

Typically, the pore water pressures, as measured by the piezometers, were observed to start building up when coke placement was 10 to 20 meters away from the piezometer location. The increase in the pressures was accompanied by deflections and cracks on the 1m lift at the edge of coke placement and generation of water flowing out via sand boils at the edges of the roads and through the drain pipes. At certain locations, the cracks were too large and the pore pressures continued to increase therefore the trucks were limited to a certain distance from the edge of coke placement and construction was slowed down to allow for more pore water pressure dissipation.

The large deflections and cracks observed when constructing the 1m lift were not observed when constructing the 2m lift. The construction of the 2m lift commenced at least one day after the construction of the 1m lift, for a particular location, which appeared to be enough time for the majority of the pore water pressures to dissipate, water to drain, and the base of the road to solidify. In fact the performance of the 2m lift was completely different from that of the 1m lift; barely any deflection was observed following construction and a few cycles of truck traffic.

At the end of the construction of the EBR, another geotechnical investigation was conducted to explore the effects of construction on the material underlying the EBR. CPTus were pushed at the same locations as the ones pushed before EBR construction and samples were also collected at the same depth below the pond surface. Figure 3 shows a comparison between tip resistances and fines contents at the same locations before and after construction. It is evident from the data that the soft sands densified as a result the construction of the road. Road trials were also conducted at the EBR to confirm the results of the investigation. Several loads were driven with different speeds over the road with little noticeable deflection. The maximum load was a coke loaded CAT 777 truck, 130 tonne load, driving at about 40 km per hour.

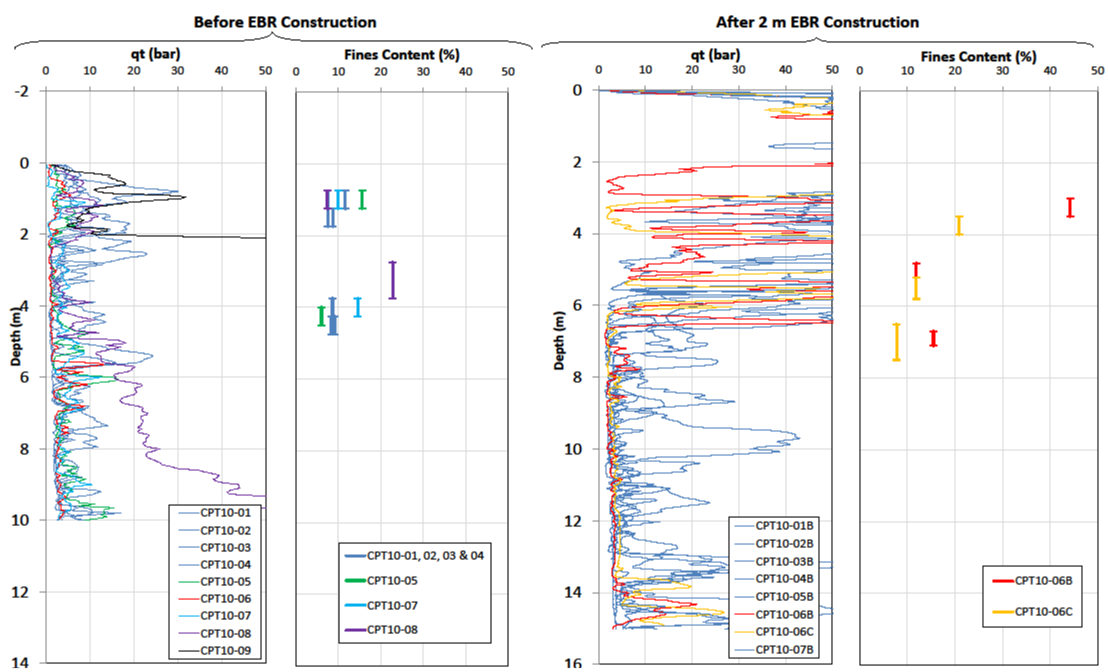

Figure 3: CPT tip resistance and fines content measured below the EBR before and after construction

Down Beach Roads

After the successful construction and performance of the EBR, it was decided to use the same approach to start constructing the eastern portions of the pond roads which were expected to also be overlying sand beaches. The main benefits of this type of construction were being cost effective by using lighter geosynthetics and being efficient by starting road construction in the fall before freeze up. The completed beach roads can be seen in Figure 2; they are generally located on the east side of the pond, generally extend from east to west, and are narrower than the pond roads.

A trafficability study was conducted to investigate the extent of beach below the east ends of each of the east-west roads. The extent of beach would potentially govern how far west each road could be constructed using an EBR type approach before freeze up. The trafficability study included driving several small amphibious vehicles with bearing pressures between 5.5 and 11 kPa down the roads and observing the conditions of the pond surface below the tracks of the vehicles, deflections, sand boils, cracks, evidence of MFT, etc. After the trafficability study, a geotechnical investigation was conducted below the expected extent of the down beach roads, DBRs. The investigation included pushing several CPTus to a depth of 10m below the pond surface, collecting samples of the underlying material, and installing push-in electric piezometers approximately 1m and 4m below the surface to monitor the pore water pressures below the proposed roads. Based on data from the trafficability study, CPTus, sampling, and piezometers, the west extents of the DBRs were determined. These extents were selected as limits on using an EBR type approach and to provide a sufficiently long beach anchor for the floating pond road portion to the west.

A design similar to that used at the EBR was used for the DBRs in which 70 kN x 70 kN geotextile rolls overlapped by 1m were placed at the base of the road. Drain pipes were placed over the geotextile and extended to the sides of the road. Coke was placed over the geotextile; however 3m of coke was placed in 3 lifts. A thicker cross section was used so that larger trucks, CAT 777, could be supported by the DBRs. At that time, the 777 trucks were expected to be used for the winter construction of the pond roads as well and the pond roads were planned to be at least 3m thick. The same construction approach used for the EBR was also used for the DBRs. Soft sands were incrementally “liquefied” and drained during construction to establish a denser base for the roads.

The DBRs were successfully constructed by the time freeze up occurred when the winter construction phase of the pond roads was then initiated.

Design Basis and Approach for the Pond Roads and Cells

The design of the coke cover of Pond 5 was discussed in Pollock et al (2010). This section summarizes learnings from the road trials performed mostly during unfrozen summer/fall conditions and the subsequent changes to the design of the roads and cells that were made during the 2011 winter construction.

Road Trials

In order to more confidently adjust the construction approach to the cover placement, a series of field trials was conceived and conducted between the spring and fall of 2010 after the end of the 2010 winter construction. Seven sets of trials were conducted in March, May, June, August, September, October and November of 2010. The following factors were varied between the different trials:

- Thickness of coke: varied between 2 and 4.5m,
- Truck loads: varied generally between 40 and 165 tonnes; including empty, coke-loaded, and/or sand-loaded John Deere 400, CAT 740, CAT 631E, CAT 773, CAT 777, and HD465,

- Truck speeds: varied between 0 (static tests) and 30 km/hr,
- Location of the trials: varied between different roads across the pond and varied between different lanes on the selected roads,
- Conditions below the roads, frozen versus thawed MFT, are also believed to have been different during some of the tests.
- Surveying, monitoring of several instruments, and visual observations were conducted during the trials. The quantities/properties recorded during the tests included some or all of the following depending on the trial:
- Deformations of the road around test location,
- Before and after elevations of the coke surface,
- Stresses and strains at instruments adjacent to truck locations,
- Water levels within standpipes installed near test locations,
- Width and frequency of cracks.

Figures 4 and 5 show a summary of the results of all of the field trials conducted on the 2010 roads. Figure 4 shows incremental displacements due to different static loads for roads with different coke thicknesses. Figure 5 shows maximum deflections due to different dynamic loads for roads with different coke thicknesses.

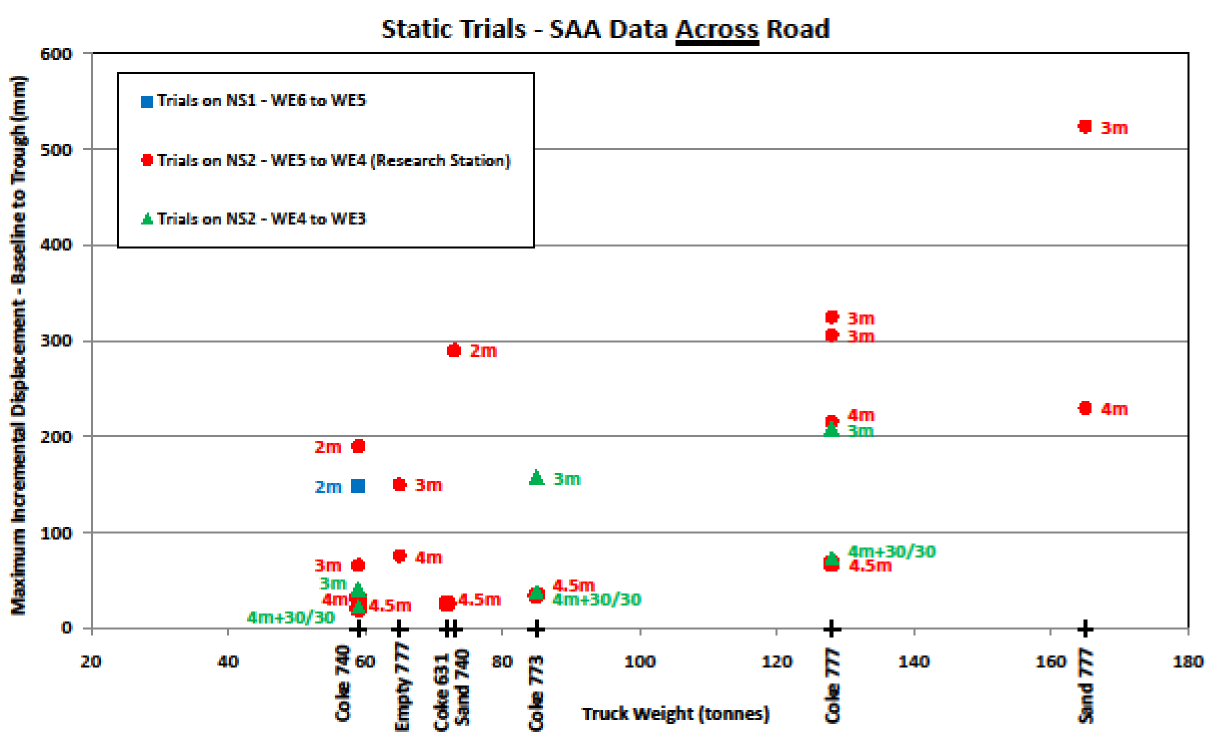

Figure 4: **Summary of the static loading results of the 2010 road trials**

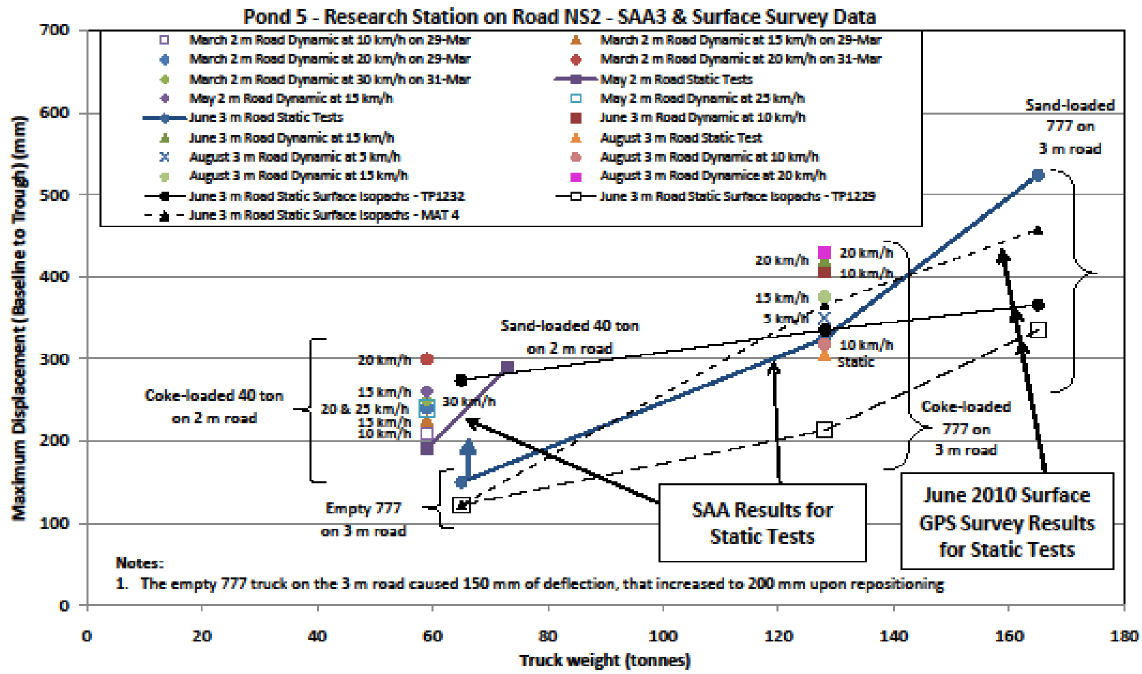

Figure 5: **Summary of the dynamic loading results of the 2010 road trials**

2D FLAC modeling was completed before and after the construction of the roads. The general objective of the field trial was to monitor the behavior of the roads under different loading conditions and to compare test results to results predicted by the modeling. The following general conclusions were made:

- The amount of overall deformation measured in the field was generally greater than what is predicted by deformation modeling. While the measured incremental deflection during truck traffic was noticeably less than predicted by the modeling.
- The loads on the pressure plates were within the ranges predicted by the modeling. On the other hand, the measured strains were significantly less than that predicted by FLAC.
- The roads safely withstood loads higher than anticipated. However, some high loads and/or high speeds caused significant cracks and deflections at the road surface. The deflections would not have been tolerated by truck drivers on a continuous basis and the cracks would have probably made the road unserviceable after prolonged loading cycles.
- As expected, the larger the coke thickness, the larger the moment of inertia of the road section and therefore the lower the deformations.

Road Design

Initially, for winter 2011, the new pond roads were designed to be constructed using CAT 773 trucks. The design was based on the following premises:

1. The new pond roads would deploy a 105 kN/m x 155 kN/m seamed HSWG (82.5 kN/m post-seaming) immediately overlain by a 30 kN/m x 30 kN/m geogrid replicating the configuration and construction practices deployed in winter 2010 which would permit the effective placement of a staged 3 m lift during winter 2011.

2. Construction would be based on a staged 3m lift. The 1 m lift was limited to dozer traffic only, while CAT 773 haul trucks were used on the 2m and 3 m lifts. It was assumed that the lifts would be kept about 20 m apart.
3. An additional geogrid would be installed at the +3 m position on some existing and new roads, and a 4th lift of coke would be placed. This would be based on performance or to make a “super road”, which would be able to support coke loaded CAT 777 traffic.

The results of 2D FLAC analyses provided an estimate of the Factor of Safety (FOS) for the geosynthetic package at the base of the road relative to Ultimate Limits State (ULS) across the road, prior to any weakening effects caused by wick drain installation. The FOS for a coke-loaded 773 truck (assumed 40 m^3 of coke) was predicted to be 1.7. The FOS for a coke-loaded 773 truck after weakening effects caused by wick drain installation was predicted to be 1.3.

Cell Design

The primary objective for the six cells that were to be constructed in winter 2011 was to support full scale wick drain trials beginning in summer/fall 2011. The design approach selected for these six initial cells was similar to that used for the Pond 5 roads, as it includes PP105/155 HWSG with a geogrid overlay at the base of the coke. Unlike the roads, the grid was to be deployed perpendicular to the HSWG, rather than parallel to the HSWG, to provide a strength that is as isotropic as possible in both directions. This will give greater flexibility in traversing the cover in the future to install wicks.

Pond Roads and Cell Construction

Based on the road trials and the 2010 winter construction, it was clear that the roads could safely withstand high loads. However with several high load cycles the roads deflected significantly and cracked. The design then changed from Ultimate Limits State (ULS) design to Serviceability Limit State (SLS) design. Winter construction in 2011 started with an observational design approach wherein the roads were initially built to a cross section with a 2m thickness of coke and more coke, 0.5 to 1m layers, was added at locations where serviceability was observed to deteriorate with additional loading. Haul speeds and volumes of truck traffic at each road lane were controlled to minimize cracks, minimize deflections, incorporate feedback from operators, and ultimately maintain the serviceability of the pond roads during construction. This approach, along with other construction factors presented in this section, led to successfully completing all of the pond roads and six of the cells. Figure 2 shows an aerial photograph of Pond 5 taken in spring 2011 towards the end of the winter construction. A close up of coke roads is shown on Figure 6.

Figure 6: Close up of built roads and uncovered cells at Pond 5

Length of Season

The presence of ice allowed for a good working surface to install geosynthetics (HSWG and geogrid) and also supported the placement of coke material on pond roads and cells. However, it was difficult to quantify the support provided by ice as its thickness and condition varied widely below the roads especially late in the winter season when thawing started at the surface of the pond.

After the summer/fall construction of the DBRs and soon after the onset of freezing conditions, construction of pond roads started on Pond 5. During the 2010 winter construction, packing snow on the pond surface began in December 2009 and geosynthetics placement began in mid January 2010. All construction activities were suspended in late March 2010 due to the early warm spring weather. During the 2011 winter construction, packing snow and geosynthetics placement began in late November 2010. Geosynthetics placement was suspended in mid April 2011 after the pond surface started thawing. However, since a significant area of roads and cells had been covered with geosynthetics ahead of the coke, coke placement continued until late May 2011.

The longer construction season achieved in 2011 compared to 2010 was a function of both colder weather and experience gained during the 2010 winter program which was used to implement several changes to the construction method. These changes, discussed in following subsections, led to more efficient and faster construction. Figure 7 shows a comparison between daily temperatures measured in Fort McMurray during the 2010 winter construction and the 2011 winter construction.

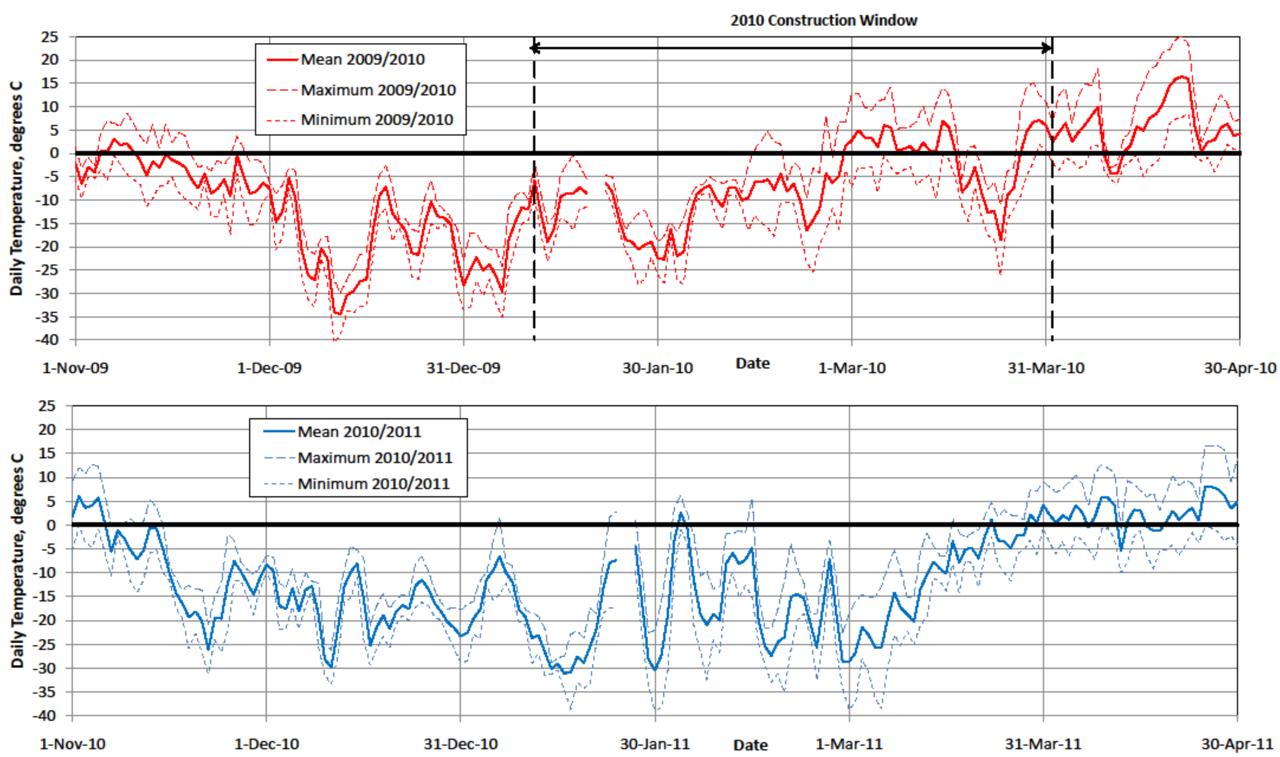

Figure 7: Daily temperatures measured in Fort McMurray

Coke Placement

Due to the large volume of coke material required to cover the roads and cells and the necessity to use relatively small haulage trucks, placement of coke material became a limiting factor for the construction schedule. To increase the advancement of coke and based on road trials and at experience gained during the 2010 winter construction the following changes were implemented: different trucks were used, haul speeds were increased, the distance between the lifts was decreased, and large dozing equipment was allowed to place the coke material on both the 1m and 2m lifts. It should be noted that these approvals were based on having an adequate frozen layer below the roads and were subject to change if the frozen tailings layer became thinner or if it was observed that the road conditions were deteriorating. These changes significantly increased the rate in which the coke could be hauled and placed, thereby increasing the rate of road/cell advancement as well as the volume of material that could be hauled.

Trucks

Either CAT 773 or CAT 777 trucks were originally selected to transport the coke and construct the pond roads. However, just before the beginning of the winter 2011 construction it was decided to test self-loading CAT 631E scrapers on the DBRs. A few scrapers were brought to site and used to transport coke. The scrapers showed more efficiency in transporting coke, loading and unloading and were therefore selected for the winter construction.

During the 2010 winter construction, coke was excavated from Suncor's stockpile by excavators, loaded onto 30 or 40 tonne capacity articulating trucks, transported and dumped by the trucks near the advancing edge of the coke road where the material was then pushed with snowCATs and dozers. During the 2011 winter construction, the 40 tonne capacity CAT 631E scrapers were used to transport the coke material from the coke stockpile to the roads and cells. The scrapers would drive over the stockpile, scrape up a full load of coke, transport it and dump it within the advancing edge of the coke road. Using the scrapers had several major advantages to using the articulated trucks. The use of excavators/loaders at the coke stockpile was eliminated in addition to the subsequent wait time associated with loading all the articulated trucks using two loaders. The scrapers essentially spent no additional time loading other than the time it takes to drive to the stockpile and back to the edge of coke placement. The mechanics of the scrapers was also an advantage at the unloading side of construction. A scraper would drive down a road, dump the load at the edge of the 2m coke lift while turning and then drive back to the coke stockpile. Figure 8, shows a photo of a scraper dumping and spreading a coke load at the edge of a road. On the other hand, the articulated trucks had to be driven to the edge of coke placement, turned around 180 degrees, backed up to where the coke needs to be dumped, then driven back towards the stockpile. Furthermore, the scrapers would spread their load around while dumping hence assisting the dozers in their operations. The articulated trucks had to dump the entire coke load at the same location which sometimes lead to several trucks having to wait for dozers to push enough coke out to allow for more unloading. Finally, the scrapers were operated at higher speeds which in addition to all the other advantages led to a significant increase in production in the 2011 winter construction season. The scrapers can be considered one of the key elements in the success of this project.

Figure 8: Photo of a CAT 631E dumping and spreading coke at the edge of a pond road

Dozers

At the beginning of 2010 construction, the D6 dozers were restricted to the surface of the 2nd lift because it was unknown if the frozen tailings would support the weight but after some trial tests were performed with favorable field observations, the use of D6 dozers on the 1st lift was approved. Towards the end of construction when the frozen layer was thinner, D6 dozers were again restricted to stay on the surface of the 2nd lift. However, road trials were performed on the roads after construction in the summer and fall of 2010. The results of the trials in addition to all the observations gathered during the 2010 construction programs raised the confidence level in the design of the roads such that during the entire 2011 construction season between November 2010 and May 2011 D6 dozers were mainly used to push out coke both on the 1st and 2nd lift.

Geotextile

Geotextile panels (each panel factory seamed from five rolls, 4.5 m x 100 m) were deployed perpendicular to the road alignment. Panels were deployed by towing them with an amphibious machine (typically a hydratrek) into position at either one of the ends. The machine was also used to unroll the panels across the road. After a particular panel was unrolled across the road, the roll at the edge of that panel would be aligned with the roll at the edge of the existing panel, overlapped approximately 3 feet (0.9 meter), then folded and seamed to the edge roll of the existing panel. After seaming, the panel would be pulled out and extended along the road. During the 2011 winter construction, a helicopter was brought to site for one day to haul geotextile panels. Several panels were deployed by the helicopter along the footprint of the roads to speed up deployment.

During the 2010 construction, two different seaming contractors were employed. Both contractors fabricated mobile shacks that were heated for the seaming crews. The shacks were pulled along the seams using amphibious vehicles. One contractor used handheld stitching machines that produced one row of stitching at a time (2 separate rows of stitches were completed per seam) while the other used a machine that was suspended from the top of the shack that produced one row of stitching at a time (2 separate rows of stitches were completed). The handheld sewing machines were found to be faster and more maneuverable than the suspended sewing machine and could be used over rough terrain, in corners, in ponded water and in areas with little overlap. The handheld machines were used in the 2011 winter construction. The use of these sewing machines is believed to have sped up the construction. They proved useful especially towards the end of the project when the surface of the MFT started thawing and maneuvering the amphibious vehicles in the mud and water became a challenge. Figure 9 shows a photo of the crew sewing fabric in on the cells without the use of a seaming shack after thawing started at the surface of the MFT.

Figure 9: Seaming geotextile in one of the cells on April 1, 2011

Geogrid

After the geotextile panels were deployed, geogrid rolls were towed by amphibious machines, placed on top of the geotextile and unrolled from either end of the road using manual labor. The geogrid panels overlapped each other by approximately 3 feet (0.9 meters). During the 2010 winter construction, the overlapping panels were tied together with plastic zip ties which had to be manually installed one by one by a laborer at approximately every 7 to 10 feet (2 to 3 meters). During the 2011 winter construction, metal hog rings were used instead of the zip ties. The hog rings were installed by a hog ring gun operated by a labourer. The labourers were careful not to catch the underlying fabric in the hog ring. Using hog rings proved to be much more efficient than using zip ties. In general, the installation time for geogrid was short in comparison to the geotextile installation and coke material placement. Installing geogrid became challenging when snow started melting and water was ponding on the surface of the geotextile. The major difficulty was installing the hog rings.

Conclusion

It was observed that a 2m coke cross section held up during winter construction; however, after thawing started some roads started deteriorating after repeated load cycles. Coke had to be added at these locations to extend the service life of the roads to meet the performance objectives.

Experience gained in 2010 suggested that the frozen MFT over which the roads were constructed during the winter does not fully thaw until late summer. Therefore, the actual ultimate performance of the new 2 m roads constructed in 2011 under CAT 631E traffic would not be evident until late summer or early fall of 2011 (after writing of this paper). It is recognized that placing additional coke on some of the 2 m roads may be required in the fall of 2011 prior to the 2011/2012 construction season, when these roads will be used as haul routes to the remaining cells.

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