Design and Construction of Geogrid Reinforced Access Roads and Drill Platforms Over Peat Deposits in Northern Alberta

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ABSTRACT
Increased activity in northern Canada is putting pressure on the existing infrastructure in oil and gas, mining, forestry public highways and other industries. This is happening at the same time as the demand for materials and manpower grows. This increased pressure has led owners, engineers and contractors to utilize more innovative solutions in both design and construction. An example of the need to meet economic and time restraints is one of Suncor Energy Inc. (Suncor) projects in Northern Alberta. The Suncor site is an in-situ oil recovery project located on leases known as "Firebag". The Steam Assisted Gravity Drainage (SAGD) technology uses underground wells to inject steam into the oil sands deposits and collect the bitumen released by the heat. The challenge is that much of the development is founded on peat, the removal of which would present considerable environmental and cost impact. The use of modern investigative methods and new geogrid products (TriAx®) enabled design and construction to proceed expeditiously. The use of LiDAR (light detection and ranging) was combined with Ground Penetrating Radar (GPR) to determine the extent and depth of the peat deposit at each of the multiple sites as well as the connecting road system. This information was then supplemented with soils information obtained from boreholes and design was carried out using geogrid reinforced embankments and reinforced granular surfacing. The design approach was to make the structures as light and strong as practical in order to reduce the quantity of embankment fill and gravel required for the project. This lighter, stronger structure was not only more economic but was also safer due the reduction of the applied dead load. The reduced cross section also resulted in a reduction of the settlement that otherwise would have occurred. A number of these sites have been completed to date and more are underway. Those sites that are now in service are performing well and observations obtained from these sites are being used to fine tune the design and construction of future sites.

RÉSUMÉ
La croissance de l'activité dans le nord Canadien exercer une pression sur l'infrastructure existante dans les industries du pétrole et du gaz, des mines, de la foresterie, des voies publiques et d'autres. Cela ce produit en même temps que la demande pour les matériaux et la main-d'œuvre est également en augmentation. Cette pression accrue a conduit les propriétaires, les ingénieurs et les entrepreneurs à utiliser des solutions plus innovantes dans la conception et la construction. Un exemple de la nécessité de répondre aux contraintes économiques et de temps, c'est l'un des projets de Suncor Energy Inc. (Suncor) dans le Nord de l’Alberta. Le site Suncor, c’est un projet de récupération du pétrole in situ situé sur les baux dénommés «Firebag". La technologie de drainage par gravité au moyen de vapeur (SAGD selon son sigle en anglais) utilise des puits souterrains pour injecter de la vapeur dans les gisements de sables bitumineux et pour recueillir le bitume libéré par la chaleur. Le défi réside dans le fait qu’une grande partie de ce développement est fondé sur la tourbe, dont l’extraction présenterait un impact environnemental et économique considérable. L’utilisation de méthodes d’investigation modernes et de nouveaux produits, comme des géogrilles (TriAx®), a permis à la conception et à la construction de procéder rapidement. L’utilisation de la technologie de LiDAR (détection et localisation par la lumière) a été combinée avec le géoradar (GPR) pour déterminer l’ampleur et la profondeur du dépôt de tourbe à chacun des multiples sites, de même que le réseau routier les reliant. Cette information a ensuite été complétée par des informations sur les sols provenant des forages, et la conception a été élaborée en utilisant des remblais et des revêtements granuleux renforcés avec géogrilles. La démarche de conception était de rendre des structures aussi légères et aussi solides que possible afin de réduire la quantité de matériau de remblai et de gravier requis pour le projet. Cette structure légère et plus forte était non seulement plus économique, mais elle était aussi plus sécuritaire en raison de la réduction de la charge permanente appliquée. La section réduite a également entraîné une réduction des tassements qui auraient eu lieu. Un certain nombre de ces sites ont déjà été exécutés à ce jour et d’autres
1 INTRODUCTION

Design and construction of roads and yards founded on peat has always presented challenges. These include investigation of seasonally inaccessible sites, availability of acceptable fill, settlement prediction, construction over extremely soft soils, rapidly rising costs of materials and labor, to name a few.

The use of advanced investigation technologies, geosynthetic reinforcement and proper construction procedures has enabled the construction of safer, stronger and more economic structures on a typical project in northern Alberta.

2 PROJECT OVERVIEW

A typical project facing the challenges described is the Suncor Energy Inc. (Suncor) project in Northern Alberta. The Suncor site is an in-situ oil recovery project located on leases known as "Firebag".

2.1 Description

The Suncor Firebag site is located 48 km northeast of Fort McMurray, Alberta as shown in Figure 1 (125 km by road). The project is an in-situ oil recovery project located on leases known as "Firebag". The Steam Assisted Gravity Drainage (SAGD) technology uses underground wells to inject steam into the oil sands deposits and collect the bitumen released by the heat. The challenge is that much of the development is founded on peat, the removal of which would present considerable environmental and cost impact.

3 SITE INVESTIGATION

Site investigation consisted of drilling test holes, ground penetrating radar (GPR) and Laser Imaging Detection and Ranging (LiDAR).

3.1 Drilling

Site drilling was carried out using an ATV mounted continuous flight auger. This program was also assisted by manual probing of the muskeg to obtain additional samples and calibrate the depth of muskeg obtained from the GPR program.

3.2 Laser imaging Detection and Ranging (LiDAR)

Laser Imaging Detection and Ranging (LiDAR) is an optical remote sensing technology that can measure the distance to, or other properties of, targets by illuminating the target with laser light and analyzing the backscattered light (Figure 2). Lidar was used to provide contour mapping of the sites as shown in Figure 3.

LiDAR (field readings and analysis) were provided by Challenger Geomatics Ltd. The equipment used was an Airborne Challenger 3D Scout Tool. The data enabled the project team to plan and position well sites, access roads and pipelines from their offices in Calgary. The 3D Tool uses LiDAR Digital Terrain Model with an Orthophoto overlay to produce a detailed 3D model of a proposed site including computing design elevations and cut/fill quantities. The 3D Scout Tool also utilizes Google Earth (if needed) to provide a more up to date visual aid to assess potential locations.
3.3 Ground Penetrating Radar (GPR)

Ground Penetrating Radar was used to map the depth of muskeg across the site. GPR is a general term to describe methods that use radio waves to probe subsurface objects or geologic features. GPR is a non-invasive electromagnetic (EM) geophysical technique for subsurface exploration and characterization. Using radar principals, GPR systems transmit impulse electromagnetic energy (i.e. radio waves) into the ground and detect echoes, or reflected wave front energy at surface. This process is somewhat similar to p-wave seismic reflection methods and theoretical similarities exist between the kinematic properties of elastic and electromagnetic wave propagation.

Surface Search Inc. carried out the GPR site survey programs using a 100 MHz bi-static GPR antenna array system towed behind an all-terrain ARGO™ vehicle as shown in Figure 4. GPR profile measurements were recorded every 0.5 m (± 0.2m) while driving along existing seismic trail cut-lines and exploratory well site access roads, at speeds ranging from 3 – 5 km/hour. Survey position control for each GPR trace measurement was accomplished through real-time digital interfacing of the GPR data logs with Differentially Corrected Global Satellite Position (DGPS) readings.

The GPR profile results were processed to enhance all observed laterally continuous peat bottom signal reflections events and to supress random background Radio Frequency (RF) noise (Figure 5). Peat bottom depth picks with corresponding location coordinates (from the DGPS readings), were digitally extracted from each individual GPR data profile set and coalesced into one large peat bottom mapping database, which included the site drilling data obtained within the footprint of a proposed site well pad and associated access road areas. These data were then used to create detailed depth of peat contour maps for each site (Figure 6).
Figure 6. Example of peat bottom depth contour map derived from high-density GPR survey data coverage and site drilling logs. Blue-green contours reveal peat depths of 0.3 to 1.5 m approximately and red-pink reveal peat depths in the order of 2.5 to 4.0 m.
The design of each site had several aspects. First the foundation soils had to be evaluated to determine the stability and settlement potential for the supported embankments (roads and drill pads). Secondly, the stability of the embankment fill had to be verified followed by the design of the granular surface to support traffic loadings.

4.1 Foundation

The foundation for each site was predominantly fine fibrous to coarse fibrous peat overlying firm clay till or the occasional sand layer. Moisture contents of the peat typically varied from 300 to 800 percent. The odd test hole yielded moisture contents as high as 1,200 percent. Amorphous peat was rarely encountered. Peat depths varied from no peat to depths of up to four meters. Average depths were in the order of two meters. In accordance with regulatory requirements, peat depths shallower than 0.4 meters are removed. For design purposes the undrained shear strength of the peat was taken as 5 kPa.

Settlement was taken as a function of the depth of peat and the weight of the supported structure. The rate and magnitude of this settlement was monitored starting with the construction of the earliest sites and is an ongoing work in progress. The settlement is taken as a function of the peat thickness, the applied embankment weight and the consolidation characteristics observed on the local fine fibrous peats observed in the geographical area over the years. For design purposes, observation from the site indicates that the long term settlement is the lesser of half the peat thickness or 37 percent of the fill thickness.

![Figure 7. Typical Estimated Settlement](image)

Once the data from the LiDAR, GPR and drilling programs was available, it enabled the civil design group (Complete Crossings and GeoTrek Land Survey), to complete the grade drawings. The design was then reviewed by Tensar International Corporation Inc. and the finished stamped product was then submitted to Suncor for approval.

4.2 Embankment Fill

Fill for the drill pad and roadways mostly consisted of medium plastic clay till. The borrow pits were excavated selectively to avoid non to low plastic clay which were not ideal as a fill source. The clay used had an average in situ moisture content of 13 percent with a range of 8 to 19 percent and was compacted close to optimum. The compacted fill had an average density of 20 kN/m³ and was estimated to have a friction angle of 27 degrees. No cohesion was assumed in the stability analysis if the structure.

The surface grade of the drill pad had to be designed as essentially horizontal due to the physical requirements of the drilling rig. Minor grade slopes were used to achieve surficial drainage. The intent of the embankment design was to keep the fill thickness below a maximum thickness of three meters which was determined to be the maximum thickness that could be achieved without resorting to staged construction. The time constraints on construction usually precluded the staging option. The minimum design thickness was taken as 1.5 meters which (after settlement) would keep the traffic surface sufficiently above the water table to maintain trafficking serviceability.

Drainage of the peat was augmented by attaching Nilex Strip Drains with flex ties (two meter spacing) to the upper surface of the geogrid. The drains (3.0 mm thick and 102 mm wide) are spaced at two meter center to center spacing. The intent is to ensure that an efficient drainage path is in place that will facilitate a more timely rate of settlement.

The base of the embankment fill was founded on a layer geotextile placed beneath a geogrid reinforcing layer. The geotextile was not required for initial construction but was selected to facilitate removal of the fill when the site is reclaimed at the end of the service life of the site. A non-woven, needle punched textile was selected for its elongation and durability characteristics.

The decision to select biaxial geogrid (Tensar® BX1100) was based on over thirty years of successful experience on similar projects with similar fill thicknesses. At the time that the project started construction, BX1100 would have been replaced with the newer TriAx® Geogrids but the lighter versions of these newer geogrids were not yet readily available so the project started with the older BX type geogrids. The full range of TriAx® Geogrids is now available and the next series of structures will use TX130 instead of BX1100. The grade of TriAx® used to reinforce the granular driving surface was, however, available.

4.3 Granular Structural Surface

A crushed gravel wearing surface was placed on top of the clay fill. For design purposes, the strength of the clay fill was taken as having a California Bearing Ratio of two percent. The slightly conservative CBR 2 was taken in order to model a year round serviceable road that would be less susceptible to spring-thaw softening. The gravel surface layer was reinforced in order to achieve a stronger, more cost effective surface. The cost of gravel in...
this area of the province is escalating significantly. Current prices are in the order of $100/m$^3$ (compacted and in place). The granular surface thickness was 300 mm reinforced with Tensar® TriAx® 140 Geogrid placed at the base of the gravel. TriAx® 140 was selected as it yielded the optimum 300 mm design target thickness. Three hundred millimeters is considered the minimum thickness that should be used in order to provide ongoing serviceability year round.

In accordance with AASHTO 2009 design procedures, the thickness design was based upon performance specifications rather than material specifications. For this project the performance requirements were defined as follows:

1. Equivalent Single Axle Load (EASL) $1.2 \times 10^6$
2. Maximum rut depth 40mm
3. Aggregate CBR 80%
4. Subgrade CBR 2%

Based upon the Giroud-Hann design method and full scale calibration, Tensar® TX140 Geogrid was identified as meeting the requirements. This was determined using SpectraPave4 PRO™ software which uses the Giroud-Hann method.

5 CONSTRUCTION

Construction of this project goes back to 2000-2001 with the construction of the first drill pad and associated roadways.

5.1 Site Preparation

Ideally, the site clearing is started during winter months. Spring construction is also avoided due to regulatory requirements concerning the protection of migratory bird nesting. This enables a more efficient removal and also minimizes disturbance to the peat, the upper surface providing a frozen crust. If clearing has to be carried out during summer months, lighter equipment has to be used and even hand clearing. Trees and taller brush are knocked down either by excavator or mulcher and laid as flat as possible over the muskeg. This vegetative mat on the peat helps ensure that the underlying vegetation remains in an undisturbed state.

5.2 Embankment Fill

Fabric, geogrid and strip drains are placed first and then followed by the fill. In the winter, embankment fill is placed in lift thicknesses of about 300 mm, compacted and the density tested. In the summer, the peat is not strong enough to support thin lift construction methods. The first lift is 900 mm. The surface of this lift is then compacted and tested. Subsequent fill is placed in 300 mm lifts, compacted and tested in the usual manner.

5.3 Granular Surface

Once the clay subgrade has been allowed to settle, it is then compacted and tested. Allowing settlement to occur first facilitates grade corrections to be achieved using the considerably less expensive clay fill. Tensar® TriAx® 140 is then placed and capped with 300 mm of crushed gravel.

6 CONCLUSION

To date, the completed drill sites are performing well although settlement in some earlier locations has required grade corrections. This has been achieved using expensive crushed gravel – not the ideal solution. Current construction methods (described herein) are expected to mitigate future occurrences.

Settlement plates have been installed on current sites and will be, installed on future pads. An ongoing program of observation and analysis is supplementing design efforts and each completed site enables “fine tuning” for the next site.

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REFERENCES


