PROJECT CASE STUDY – COMPOSITE SOIL COVER FOR SULPHIDE TAILINGS AT MINE SITE IN NORTHEASTERN ONTARIO, CANADA.

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ABSTRACT
During the Fall of 2006, the Ontario Ministry of Northern Development and Mines tendered a construction project to provide a soil cover over the North Impounded Tailings (NIT) area at the abandoned Kam Kotia Mine site in Northeastern Ontario, Canada. The soil cover would effectively impede the entry of water and oxygen into the high sulphide tailings, substantially reducing acid generation and metal leaching effects from within the tailings. The final design incorporated waste rock, sand, gravel layers, a Geosynthetic Clay Liner (GCL), clay and granular cover soils. During the Fall of 2006 and Winter of 2007, Hazco Environmental & Decommissioning Services implemented the construction of this design. Overall, 800,000 m^2 of GCL was deployed and covered. Deployment of the GCL was undertaken by Terrafix Environmental Inc. under the supervision of Hazco and Earth Tech Engineering. This paper summarizes the design and construction of this composite soil cover system.

RÉSUMÉ
Pendant l'automne de 2006, le Ministère d'Ontario du Développement du Nord et des Mines ont offert un projet de construction pour fournir une couverture de sol sur le site abandonné de la Mine Kam Kotia situé dans le nord-est de l'Ontario, Canada. La couverture de sol empêcherait efficacement l'entrée de l'eau et de l'oxygène dans les produits de queue élevés de sulfure, sensiblement réduisant la génération acide et le métal lixiviant des effets dedans les produits de queue. La conception finale a incorporé la roche de rebut, le sable, les couches de gravier, un recouvrement de Geosynthetic Bentonitiques (G.S.B.), l'argile et les sols granulaires de couverture. Pendant l'automne de 2006 et l'hiver de 2007, la compagnie Hazco a mis en application la construction de cette conception. De façon générale, 800.000 m2 de G.S.B. ont été déployés et couverts. Le déploiement du G.S.B. a été entrepris par la compagnie, Terrafix Environmental Inc., sous la surveillance de Hazco et Earth Tech Engineering. Cet article récapitule la conception et la construction de ce système composé de couverture de sol

1 INTRODUCTION

The Kam Kotia Mine in Timmins, Ontario operated intermittently from the 1940s until 1972 producing copper, zinc and gold. Following closure approximately 3 million tonnes of acid-generating sulphide tailings and 500 thousand tonnes of acid-generating waste rock was left on the surface at the site. These waste materials have since evolved to become significant sources of Acid Rock Drainage (ARD) and Metal Leaching (ML), which has had a significant impact on the surrounding environment. The Ontario Ministry of Northern Development and Mines (MNDM) has implemented a multi-staged rehabilitation program at the site to mitigate the ARD-ML effects of the waste deposits. Several phases have been completed to date. This paper will only look at the composite soil cover system installed during the fall of 2006 and winter of 2007. The MNDM currently collects and treats ARD runoff and seepage and operates a High-Density Sludge (HDS) treatment plant to treat ARD impacted runoff. Wardrop and SENES were retained to design a dry soil cover for the North Impounded Tailings (NIT) in 2004 and 2005. This design was tendered for construction in 2006 and was awarded to Hazco Environmental & Decommissioning Services. The design goal for the project is to provide a "dry" soil cover to minimize the infiltration of water and also limit the ingress of oxygen into the tailings. This construction design will reduce the quantity, acidity and metal loading of the leachate reporting to the site's drainage collection system to the point where passive treatment technology could be implemented and the HDS plant could be taken out of service.

2 DESIGN OF THE COMPOSITE SOIL COVER

Ontario's Ministry of Northern Development and Mines commissioned Wardrop Engineering Inc., and SENES Consultants Ltd. to design a soil cover over the NIT, shown on Figure 1. Earth and rock borrow materials were characterized and preliminary designs were assessed using parameters calculated from strandard geotechnical soil testing. Preliminary hydrogeological and geochemical models were run on four design options. The two designs utilizing compacted local clay and geosynthetic clay liners (GCLs) were found to be equivalent in performance and cost. A second round of more detailed laboratory testing was done, including calculating void ratios, freeze-thaw permeability, water retention curves and oxygen diffusion coefficients. After incorporating this data into the analyses, the optimal final design incorporated waste rock, sand, gravel layers, a GCL, clay and granular cover soils.

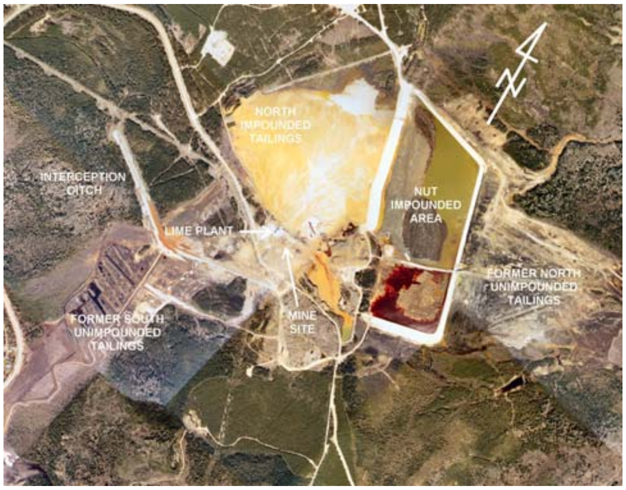

Figure 1. Aerial view of the abandoned Kam Kotia Mine site prior to implementation of a multi-staged rehabilitation program.

2.1 Material Testing and Hydrological Modelling

A comprehensive sampling, geotechnical testing program, and chemical analyses of the waste rock was undertaken to characterize the borrow materials available from the surrounding glaciofluvial (granular) and glaciolacustrine (clay) deposits. In addition to natural aggregate sources, the mine waste rock was also sampled and tested for use in the cover. This material testing and Hydrological Modelling program was conducted under the direction of Mr. Andrew Mitchell, P.Geo., formerly of Wardrop Engineering, and Mr. Jeff Martin, P.Eng., of SENES Consultants Ltd.

Additional detailed testing such as oxygen diffusion, freeze-thaw permeability and moisture retention were conducted under the direction of Dr. Michel Aubertin at Ecole Polytechnique in Montreal, Quebec.

The complete hydrological modelling design and results including the performance of four cover option models was presented at the 58th Canadian Geotechnical Conference in Saskatoon, unfortunately the paper was never published in the conference proceedings. A request for this paper can be made to the author of this case study paper.

2.2 Cover Options and Final Design

The four cover options which were modelled by Wardrop and SENES are as follows, starting from the tailings surface upward:

1: 0.3m rock / 0.25m sand / 0.5m clay / 0.5m sand
2: 0.25m rock / 0.3m sand / 1.0m clay / 0.5m sand
3: Cover incorporating a geosynthetic clay liner (GCL) with appropriate sand bedding and cover.
4: Cover incorporating a synthetic geomembrane (PVC) with appropriate sand bedding and cover.

The final laboratory test program indicated that the silty clay from the site borrow pit was highly frost susceptible and that there could be an increase in the permeability of up to two orders of magnitude with repeated freeze-thaw cycling. This raised concerns for the longevity of a cover designed with clay as the sole water and oxygen barrier. To overcome this propensity of the clay, it was decided that a GCL would be incorporated into the final design. In addition to the GCL, some other final refinements of the design were incorporated to provide a more robust and durable installation. The final cover, for the tailings surface upwards is as follows:

1. A basal layer of crushed mine waste rock of 300mm thickness. This layer formed both an effective capillary break due to its coarse grain size distribution as well as adding structural stability to the design. In addition, using the waste rock in this manner provided an opportunity to deal with this acid-generating waste as part of another element of the mine site rehabilitation, which precluded needing to cover the waste rock pile in a later phase of work – at additional cost.

2. A layer of granular fill of 300mm thickness. This layer completed the required thickness for an effective capillary break as well as providing a suitable subgrade for synthetic liner installation.

3. A polypropylene coated GCL forms the water and oxygen barrier to effectively isolate the tailings from the ingress of water and air into the tailings mass from above. The polypropylene coated product was selected in the final design since it has an order of magnitude lower hydraulic conductivity than the figures assumed in the modelling, which adds conservatism in the design at little additional cost.

4. A layer of silty clay, 300mm thick is placed directly over the GCL to ensure full hydration throughout the service life of the cover. In addition, the lower permeability of the clay will act as a secondary barrier in addition to the GCL, enhancing the oxygen barrier.

5. A layer of granular soil, 500mm thick isolates the clay and GCL from physical disturbance and also provides a store and release function to mitigate the effects of sustained high precipitation or drought. The thickness of this layer was increased from the preliminary designs to provide greater protection from frost and root penetration. In addition, it provides the required confining stress on the GCL and enhances the durability of the cover.

6. A layer of organic mulch an topsoil, 100mm thick, obtained from the removal of overburden from the clay source will be turned into the upper 50-75mm of the granular layer to provide a growth media for surface vegetation.

The final design incorporated into the cover to provide greater resistance to frost induced disruptions and a layer of the silty clay available locally was incorporated into the sequence to provide continual hydration of the GCL, which is essential to maintaining low gas permeability in the comparatively thin bentonite clay layer afforded by the product.

3 NEW GEOSYNTHETIC CLAY LINER / POLYPROPYLENE COATED

A geosynthetic clay liner containing a polypropylene coating was used to provide a unique hydraulic property. This product which has been available since 1999 adopts merging a typical textile coating procedure to that of a needle-punched geosynthetic clay liner. Originating from the textile industry, this process yields a composite clay geosynthetic barrier (GBR-C) / geosynthetic clay liner (GCL) product with unique hydraulic properties and physical performances that make it well suited to many new design approaches. The product includes a polypropylene coating applied to the woven geotextile side of a GCL, providing a low permeability typical for a geomembrane at 5×10^{-13} cm/sec (ASTM E96).

3.1 PROPERTIES / TEST METHODS ON POLYPROPYLENE COATED GCL

Testing of the polypropylene coated GCL for this project was done by Sageos/CTT Group (Canada) under the supervision of Earth Tech Engineering (Winnipeg). Hydraulic testing on the coated GCL is a difficult task in the traditional permeameter due to the lower flow characteristics of this new GCL – attributable to the polymer membrane coating. Whereas, a typical non-coated GCL will yield permeability values on the order of 3×10^{-9} under 35 kPa effective confining stress and 14 kPa head pressure, testing in accordance with the Hydraulic Conductivity Test Method ASTM D5084. Polypropylene coated GCLs have shown to force side wall leakage to occur. Thus making it difficult to measure the performance in the traditional permeameter.

To more accurately determine the true flow through the membrane portion of this type of GCL, a water vapour transmission test was performed. An equivalent hydraulic permeability (k) was calculated using the procedure outlined by Koerner (1997). Via ASTM E96, a value of less than 5×10^{-13} can be expected.

The coating is typically applied to the woven portion of the GCL. This coating has added another dimension to GCLs with an increase in peel values and internal shear values. The fibres which have been needled through the composite are subjected to the coating and as the coating becomes an integral part of the GCL, the fibres are bonded within the coating. Another added benefit of a polypropylene coated GCL is its effectiveness as a root inhibitor (Lucas 2002).

4 PROJECT OVERVIEW

Construction of the 80 ha composite cover soil system started in early November of 2006 with an initial deployment and completion of 10,000 m^2 on the first day of the project. Initial plans were to deploy 120,000 m^2 during the fall prior to closing the project down for the winter. These initial plans were changed and 800,000 m^2 was deployed from November of 2006 to February of 2007. Deployment rates at times reached over 30,000 m^2 per day.

Although the rate of deployment of the GCL can reach high deployment rates, this deployment is restricted by the cover soil placement over the GCL. For this project the cover soil used was a silty clay which was available locally at the mine site. Once Hazco's truck fleet was up and running, deployment rates as mentioned reached over 30,000 m^2 per day (shown in Figure 2).

Figure 2. Hazco's truck fleet carrying the clay from a nearby clay source available on site being transported as a cover soil over the geosynthetic clay liner.

The GCL was deployed over a stable subgrade of granular fill as mentioned previously in Section 2.2. A 0.3m overlap was done, recorded, and supervised by Earth Tech Engineering (shown in Figure 3).

Figure 3. Deployment of the GCL. One foot overlap being done. Polypropylene side of the GCL facing down.

Following the deployment of the GCL, loose bentonite was placed between panel edges. Loose granular bentonite should be placed between the panels at a rate of 2 kg per lineal metre of seam if the GCL is the primary hydraulic seal. The addition of bentonite to the seam is optional when the GCL will be acting as leak isolator for an overlying membrane. Spreading of the loose bentonite is shown in Figure 4.

Figure 4. Spreading of the loose bentonite between GCL sheets.

Following the deployment of the GCL, a 0.3m thick silty clay layer was placed directly over the GCL as shown in Figure 5.

Figure 5. Clay being applied over the GCL.

5 SUMMARY

One can obtain many types of GCLs: stitched, glued, needle-punched, different bentonite content, different geotextile weight, scrim reinforced, and enhanced polymer etc. This list is long. Over the years and through increased use, this area of geosynthetics engineering seems to see ever-cheaper GCLs being requested for particular projects. This may mean thinner textiles and/or less bentonite, almost to the point of becoming less a GCL than a double-layered textile. What is the lowest mass per unit area of bentonite that a GCL can have and still achieve, for example, the quoted manufacturer's hydraulic conductivity? It's getting to the point where 12 kg/m^2 seems acceptable from the standard 18 kg/m^2. The design community originally used 24 kg/m^2. There has to be a limit, but only specific project engineers will ask for those limits.

Engineers when asking for a geosynthetic clay liner must request for an accurate breakdown of the GCL instead of simply asking for a GCL. The recommended list of data when requesting for a GCL is as follows:

- Top geotextile shall be X g/m^2 nonwoven.
- Bottom geotextile shall be X g/m^2 woven or X g/m^2 scrim-reinforced nonwoven.
- Swell index of the bentonite.
- Fluid loss of the bentonite.
- Bentonite mass per unit area at X moisture content.
- Grab strength of the GCL.
- Peel strength of the GCL.
- Permeability of the GCL.
- Index flux of the GCL.
- Internal shear strength of the GCL.

Scrim = woven.
Scrim-reinforced nonwoven = woven + nonwoven.

Scrim-reinforcement = needle-punching of a woven and nonwoven geotextile together.

Figure 6. Needle-punching board.

All GCLs have a nonwoven top geotextile for needle-punching purposes.

The bottom geotextile is either a required woven on its own <u>or</u> a scrim nonwoven geotextile if required for rough soil conditions or steep slope applications.

The Geosynthetic Research Institute recommends that the bottom geotextile of a GCL must contain a scrim-reinforced nonwoven geotextile. Possible failures which may occur by not using a scrim-reinforced bottom geotextile are internal erosion of the bentonite through the geotextile in hydraulic head conditions (Rowe and Orsini 2002), and possible shrinkage of the GCL itself in the composite lining system (GRI White Paper – 2005).

As per the Geosynthetic Research Institute's White Paper of April 2005: *Do not use GCLs with needle-punched nonwoven geotextiles on both sides unless one of the geotextiles is scrim-reinforced. There are numerous possibilities in this regard, but all should have a woven component embedded within, or bonded to, the nonwoven component.*

The project described herein contained a bottom woven geotextile. As mentioned, a polypropylene coating is applied to the GCL used in this case study paper to decrease the permeability of the product (GCL) to the range of a geomembrane.

One should never use trade names when requesting an item for a specific project. One should always list the testing values required from a specific product, i.e. ASTM testing values. Products and their names change over time hence the requirement to avoid using trade names. Another factor is to avoid having the purchasing agent and/or general contractor make a decision during the tender process.

Remember, you get what you pay for in life. Want cheap? Expect it, but don't expect quality and performance from it. Someone will sell it to you. Will they provide you with a warning? It's to be hoped that they will provide you with the limitations of the product. Want something reliable? Every company can offer reliability at a reasonable price. Want the "crème de la crème" with all the built-in safeguards and back-up systems? Every manufacturer would love to sell its premium brand, but expect to pay a premium for that. In our world, however, the cheapest price often prevails. A manufacturer's premium brands probably represent only 10% of their overall sales – if that.

The geosynthetics arena is no different. The variety of available geosynthetic products is great that clients seek advice from a particular distributor, supplier and/or manufacturer. But are clients provided with all of the information? Suppliers would love to provide their particular premium brands, of course; but at the end of the day, the cheapest price frequently prevails. Buyers beware.

Products are never equal when using trade names. Products are equal when values are provided and hence can be compared. Ask for them in your tender request.

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