<u>Alternative Pipe Material Choice provides Trenchless Solution</u>

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ABSTRACT
This is a case study presented on the Big Lake (W14) Gravity Sewer Microtunneling Project in Edmonton, Alberta. The gravity sanitary sewer project was designed as a direct bury application with PVC and RCP pipe. It was expected that the subsurface conditions were to vary considerably within the proposed depth of proposed pipeline. The subsurface conditions within the pipe zone were expected to include water bearing peat, fill, and saturated silt and silty sand, all of which were extremely soft, with blow counts as low as 2. To address these conditions, the design included special bedding and embedment envelops to ensure the installed pipe is adequately supported to prevent pipe settlement and structural failure of the pipe. This design component was more essential to the longevity of the PVC Pipe than the Concrete Pipe.

As an alternative, Michels Pipeline proposed to install the pipe by means of microtunneling in lieu of direct bury. In addition they proposed the use of fiberglass jacking pipe for this installation method. The project construction began utilizing 48" diameter FRP jacking pipe, but due to the unfavorable subsurface soil conditions the project was not able to be completed with this pipe material. As a solution to the installation difficulties, the pipe material was changed to 48" FRP Lined Reinforced Concrete Jacking Pipe. This is the first installation of FRP Lined Reinforced Concrete Jacking Pipe in North America.

PROJECT HISTORY
The W14 Sanitary Trunk Sewer is the furthermost upstream stage of the City of Edmonton's (City) West Edmonton Sanitary Sewer (WESS). WESS consists of large diameter sanitary trunk sewers that will provide both sanitary sewer conveyance and storage for new developments on the western edge of the City between St. Albert Trail and 45th Avenue NW. There are currently 14 stages of WESS, commencing at W14 and terminating near EPCOR's Gold Bar Wastewater Treatment Plant. WESS is part of the City' Sanitary Servicing Strategy and is funded through the Sanitary Servicing Strategy Fund (SSSF), which is managed by the City of Edmonton and funded through a partnership between the City and Urban Land Developers.

The W14 Trunk Sewer is comprised of over 7,218 feet of 48" gravity sewer and commences at the intersection of 109th Street NW and 199th Street NW. This section runs south along 199th Street NW crossing Stony Plain Road / 100th Avenue NW and terminates when it discharges to WESS W1 trunk sewer which is located approximately 2000 feet south of 100th Avenue NW.

Once in service, W14 will provide offsite conveyance of sewerage that is generated in the Big Lake Neighborhood and the future Winterburn Industrial Park, which together provides over 3,460 acres of developable land. The Big Lake Neighborhood is located north of Highway 16, east of the City Boundary, south of Big Lake and west of 199th Street NW will be home to over 27,000 Edmontonians. Winterburn Industrial Park is bounded by Highway 16 on the north, 199th Street NW on the east, Stony Plan Road on the south and the City boundary on the west.

GROUND CONDITIONS

Based on the information collected during the project's geotechnical investigation and bore hole program, the generalized stratigraphy along the proposed sewer alignment typically consists of varying thickness of topsoil, clay fill, sand/gravel fill, peat and organic soils. Overlying silty clay was found at depths varying between about 2 feet and 16 feet below ground surface.

It was expected that the subsurface conditions were to vary considerably within the proposed depth of W14. The subsurface conditions within the pipe zone were expected to include water bearing peat, fill, and saturated silt/silty sand. All of which were extremely soft, with blow counts as low as 2 blow per foot.

The project design called for an open trench installation and included two pipe alternatives, PVC Pipe and Concrete Pipe. To address the poor soil conditions, the design included special bedding material and embedment envelop to ensure the installed pipe would be adequately supported to prevent pipe settlement and structural failure of the pipe. This design component was more essential to the longevity of the PVC Pipe than the Concrete Pipe.

HIGH GROUNDWATER TABLE

In addition to the poor soils, the Geotechnical Investigation identified the presence of a high groundwater table over the entire alignment. Due to these conditions, a two stage dewatering plan was developed. The first phase included a trench dewatering/depressurization program prior to excavating the trench. This was specified to prevent base heave of the clay, silt and sand stratum below the pipe bedding. The second phase of the dewatering plan was a trench dewatering program to be implemented where organic materials were found within the trench to ensure the stability of the trench and the safety of the workers.

There was also a pipe buoyancy concern due to the high groundwater table in combination with the fact that the pipe during operation would convey only minimal flows due to the amount of undeveloped lands within the sewer-shed. A requirement for of imported backfill material was included in the design to ensure that the proper ballast is placed above the pipe to counteract the upward buoyant force of the displaced water.

DESIGN

As part of the development of the Big Lake Neighborhood, the Developer was originally tasked with the design and implementation of W14. However, due to the complexity of the project, the risks associated with the installation of W14 via open cut, and higher than expected tender prices, the City elected to further quantify these risks and refine the design to mitigate these risks. The City's Drainage Design and Construction commissioned Stantec to undertake the refinement of the open cut design to address the following risks:

- Potential for high sulfide concentration and the risks of future corrosion;
- Poor soil conditions along the entire alignment;
- The use of flexible pipe and the risk of over deflection due to overburden;
- Buoyancy due to high groundwater table;
- Construction coordination with the contractor consortium for the new Stony Plain Road Interchange.

HIGH SULFIDE CONCENTRATION

The flows from the Big Lake area are conveyed to W14 via a 18,370 foot long forcemain. Due to the length of the forcemain, there may be periods of long sewage retention time within the forcemain resulting in sulfide generation. The generation of sulfides within the forcemain increases the risk of odor and corrosion concerns within W14. The existing Big Lake pump station has incorporated chemical treatment systems to manage the risks to the downstream infrastructure, however, the effectiveness of this chemical treatment systems can only be proven under actual operating conditions. Therefore, the design of the W14 included elements to the potential odor complaints and corrosion of the sewer pipe.

To address the potential corrosion and odor control concerns, the focus of the hydraulic design for W14 was to reduce the amount of turbulence at the manholes to reduce the potential release of H_2S. The design included such elements as the reduction of the height of the drops at the manholes. The goal was to also eliminate the formation of hydraulic jumps within pipe segments prior to entering the downstream manhole.

To further reduce the corrosion potential of the pipe within W14, the design team selected pipe material that was resistant to the corrosive attack of sulfuric acid resulting from the high sulfide concentrations. The team selected two pipe materials, concrete and PVC pipe. PVC pipe is naturally chemically resistant to corrosive attack of sulfuric acid; however, the concrete pipe would require a secondary liner to protect it from the sulfuric acid. To protect the concrete pipe, the design included the provisions of a factory installed HDPE Liner that would be installed during pipe manufacturing process. This HDPE liner would provide the corrosion resistance needed for this sanitary sewer application.

BIDDING PROCESS

Once the design was complete, W14 was let out for bid during the summer of 2011. Prior to this, four contractors were pre-qualified for the project based on their previous open cut experience. The contract went out for bid on July 18, 2011 and closed on August 16, 2011. The bid closing date had been extended by two weeks subsequent to the pre-qualified Contractor's request. Among the four pre-qualified contractors, two valid bids were submitted. In addition to their required bid, an alternative bid was submitted by Michels Canada Co. to construct W14 utilizing a microtunneling trenchless method instead of the traditional open cut method as dictated by the design.

The bids received were considerably higher than expected. It was concluded that the higher than expected bids were a result of the significant risks with constructing a trunk sewer within an area of poor soils and high groundwater.

The lowest bid received was the Michels Canada's alternative Bid to construct by means of microtunneling. However, a caveat to this bid was an extension of the construction window from 12 months to 20 months. A construction period of 20 months would provide the City the opportunity to fund the project over a greater period. Potentially a longer construction period may have impacts on the servicing of the new developments.

The Alternate bid by Michels also proposed the use of three materials not incorporated in the original design. The first was a Hobas Centrifugally Cast FRP Jacking Pipe made of unsaturated polyester resin. The second was Permalok steel casing pipe that is joined by interlocking teeth rather than welding. This would be used as a tunnel pipe underneath the roadways. The third was Hobas Centrifugally Cast FRP carrier pipe which would be inserted inside of the Permalok steel casing pipe.

CONTRACT BID AND AWARD

In late fall of 2011, the City of Edmonton issued Michels Canada a conditional acceptance of award based on the approval of the Alberta Transportation Department for the use of Permalok steel casing pipe within the TUC. The contract required a steel casing to be installed beneath Stony Plain Road to protect and house the 1,200mm trunk sewer. As a part of the alternate bid, Michels Canada proposed the use of Permalok steel pipe which is a steel pipe that stabs together rather than using conventional welding to join pipes. Prior to W14, Permalok pipe had not been approved for use by the Alberta Transportation Department in Alberta.

Michels Canada and the City of Edmonton met with the Alberta Transportation Department in mid-December and formally proposed the use of Permalok Pipe within the TUC. After weeks of deliberation, the Alberta Transportation Department approved the use of Permalok steel pipe within the TUC and thus removing the conditions of approval on the award of the project to Michels by microtunneling.

Once all the product approvals were received, on the City issued a notice to proceed with work on the project on February 14th 2012 to Michels Canada.

PRECONSTRUCTION

After the conditional award had been issued to Michels Canada by the City and during the review period by the Alberta Transportation Department with respect to the Permalok Pipe, Michels proposed to relocate the project's design alignment that ran along the shoulder and TUC of 199th to the middle of 199th Street. This revised alignment allowed Michels Canada to construct the associated tunnel work all year round by removing the soft ground staging issue that the original alignment proposed. Additionally, the revised alignment provided greater access for servicing and maintenance by the City once the sewer is commissioned.

During this phase of the project, Michels Canada proposed to the City of Edmonton to install the 7,352 feet of 48" ID pipe installed by means of pipe jacking using an Akkerman SL52 - Microtunnel Boring Machine (MTBM) in 10 microtunnel drives. This resulted in the construction of 11 Steel Sheet Pile Shafts and accommodated 7 manhole access points. The depth of the W14 sewer line varied from 33 feet below existing grade on the southern end of the project to 12 feet near the northern end of the project near 109th Ave.

SHAFT CONSTRUCTION

Michels Canada installed interlocking steel sheets with the use of an ABI Hydraulic Pile Driving Rig using a vibratory hammer to drive the steel sheets into place. Dewatering wells were installed post steel sheet construction by local subcontractor Summers Drilling. The dewatering wells were commissioned prior to the start of shaft excavation to draw the groundwater down to a depth below the bottom of the steel sheets.

Both the larger (jacking) and the smaller (receiving) shafts were excavated using a long-stick and mini excavators. As excavation progressed down to the design alignment of the tunnel, Michels installed steel wales and steel corner bracing to hold back the steel sheets.

Upon completion of excavations, concrete working floor slabs were poured with great attention to elevation design details. Next, entrance and exit windows were constructed using steel and wooden form work. The window form work was filled with a low strength concrete that the MTBM would cut through upon launch and retrieval to hold back the soft ground outside of the shafts. A steel faceplate for attaching a 25mm rubber launch seal was cast into the entrance and exit windows. Horizontal cuts were made to the sheet piles just beneath the windows to allow the sheet piles to be raised prior to the launch and retrieval of the MTBM. Once the forms were stripped and the concrete cured, a conventional circular rubber gasket was bolted to the entrance or exit window for the MTBM to tunnel through.

With difficult ground conditions along the W14 alignment, the entrance and exit windows allowed Michels to have a water tight seal around the microtunnel pipe (Centrifugally Cast FRP Pipe) at entrance and exit locations and no ground loss was encountered at any of the tunnel shafts. The entrance and exit seals installed were left in place within the shafts rather than removing and reusing these windows or performing a chemical grouting/ground improvement program to stabilize the ground around entry and exit windows to limit ground loss at these locations. This proved to be a much more cost effective approach to managing the risks at the shaft locations.

The construction schedule allowed for six shafts (3 launch and 3 reception) to be constructed in the first year of construction and five shafts (2 launch and 3 reception) to be constructed in year two of the project. Shaft Construction commenced in late April 2012 due to difficulties in obtaining a revised ULA permit to reflect the new alignment. The first six shafts were completed by August 1st 2012. In year two of the project, shaft building commenced in March and the last of the shafts were completed in July 2013.

MICROTUNNELING

Michels Canada performed the microtunneling using an Akkerman SL52 Microtunnel Boring Machine (MTBM) to install the 48" Centrifugally Cast FRP jacking pipe and the 60" Permalok steel casing pipe. Prior to the start of tunneling, Michels shipped the MTBM to the Akkerman facility in Minnesota for refurbishment and a second rear articulation joint to be installed as a contingency should additional steering be required in the projects difficult ground. The rear articulation joint was never activated. Michels Canada utilized an experienced MTBM operator (Mr. Johnie Paul Halkyard) of over 26 years operating TBMs and MTBMs to operate the SL52 in these difficult ground conditions. The Centrifugally Cast FRP jacking pipe and Permalok pipe was jacked into place behind the SL52 MTBM using an Akkerman 840 ton jacking frame. The slurry separation system was manufactured by Michels Corporation and was outfitted with Derrick slurry separation equipment.

Michels approach to the tunneling was to progress from the southern end of the job (low point of the design) tunneling North up 199th Street to 109th Ave. Michels Canada completed 8 of 10 microtunnel drives with the average daily production rates between 40 feet to 60 feet per 10 hour shift. The highest production rate achieved was 120 feet in a 12 hour shift. The shortest tunnel run was approximately 500 feet with the longest run just less than 1000 feet. The tunnel drive lengths were reduced in length to help mitigate the difficult ground conditions on the project. The Centrifugally Cast FRP jacking pipe and the Permalok steel pipe were both jacked into the tunnel alignment behind the MTBM in 20 foot lengths.

Michels Canada completed the first three tunnel runs south of Stony Plain Road jacking the Centrifugally Cast FRP Pipe with an MTBM skin OD of 49.2". Michels then skinned up the SL52 MTBM to an OD of 60" to install the next two tunnel runs with the Permalok Steel Casing Pipe beneath Stony Plain Road. Upon completion of the steel casing, Michels Canada used the jacking equipment to then install the Centrifugally Cast FRP 48” carrier pipe with the Permalok steel casing. This completed year one of the project with tunnel activities ceasing on December 23rd.

MORE DIFFICULT INSTALLATION CONDITIONS

As the project has progressed, Michels Canada evaluated the existing ground conditions and conducted additional geotechnical investigation with a number of additional boreholes drilled along the project alignment to evaluate areas with peat in or directly above the pipe zone. Upon review and evaluation, Michels Canada made a material change from the Centrifugally Cast FRP jacking pipe to a Flowcrete jacking pipe.

Flowcrete jacking pipe is a concrete pipe with a Filament Wound Glass-Fiber Reinforced liner which is inert to H_2S attack. This pipe has a greater density to offset buoyancy issues anticipated for two of the five final tunnel drives due to the peat zones. Flowcrete jacking pipe had been used in Europe and the Middle East with success, but this was the first attempted installation in North America.

The original direct bury pipe material options included the option to use an Reinforced concrete Pipe with an HDPE liner. The proposal to use Flowcrete Jacking Pipe (Reinforced Concrete Pipe with FRP Liner) was a pipe material using a similar concept, but with some distinct advantages over other lined concrete pipe materials. Below is a list of the advantages that the Flowcrete FRP lined RCP offered over other lined RCP materials. Also, see Table 1 for comparison of lined RCP pipe materials.

- Flowcrete FRP lined RCP has a liner that has enough structural integrity to resist external hydrostatic pressures without any embedded anchors into the RCP.
- Flowcrete FRP lined RCP has its own joint system. This means that field welding of liner joints is not required. This is required on PVC and HDPE lined RCP pipe products.
- Flowcrete FRP lined RCP is capable of being applied in both pressure water and sewer applications. The joint and liner are rated for pressure up to 450 psi without utilizing the structure or the RCP.

Table 1: Summary of Lined RCP Pipe Materials

Liner RCP Product	Corrosion Resistance	Joint Corrosion Protection Required	External Hydrostatic Pressure - Buckling Resistance	Gravity Sewer Application	Pressure Sewer Application
PVC Liner	Yes	Yes	No – Requires Anchors in RCP	Yes	No
HDPE Liner	Yes	Yes	No – Requires Anchors in RCP	Yes	No
FRP Liner	Yes	No	Yes	Yes	Yes

Michels Canada approached the City of Edmonton to review and approve the merits of the Flowcrete jacking pipe and after consultation and submission review, the City approved the pipe for use on the project. The final two tunnel drives were completed utilizing 1400 linear feet of the Flowcrete FRP lined RCP jacking pipe.

LESSONS LEARNED & CONCLUSION

The project was completed on time and within budget. Some of the lessons learned on this project include the following:

- Value Engineering and "thinking out of the box" provided considerable cost savings to the project.
- Alternate Materials and methods provided added value to the project.
- Use of experienced MTBM operators greatly improve the ability to tunnel in such difficult ground conditions.
- Microtunneling can be successfully installed in difficult ground conditions (2 to 10 blow count) on line and grade.
- Microtunneling is and trenchless technology can be a cost effective solution to the traditional open cut installation.