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COLD WEATHER INSTALLATION OF FUSIBLE PVC USING HORIZONTAL DIRECTIONAL DRILLING

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ABSTRACT: Fusible PVC pipe is becoming a nation wide recognized product in Canada where engineers, contractors, and municipalities are implementing this innovative, cost-effective product into their pipe systems. Up until the last 5 years in North America, horizontal directional drilling (HDD) was accomplished with Polyethylene (PE) or steel pipe; however, PE pipe was the only option that was fusible. Fusible PVC allows users the choice of products in HDD applications with added benefits such as lower installation costs, longer pull lengths and compatibility with the use of readily available standard fittings.

As one of the first projects in the City of Edmonton to incorporate fusible PVC pipe into the City's water system, a local improvement project in 2008 installed approximately 2 km (1.25 mi) of 300mm (11.8 in) AWWA C900 fusible Brute 18 watermain using horizontal directional drilling. This project took place in extreme conditions where temperatures in the winter were lower than -20 degrees Celsius and took place in areas of significant grade changes due to the alignment being in the existing road right of way. These challenging drilling conditions increased the project complexity for the first time installation of the product for the City.

This paper will examine the challenges that were encountered throughout the project related to cold weather installation, significant grade changes along the 2 km (1.25 mi) length and the installation of connections and valves to the fusible PVC once the horizontal directional drilling was completed. The challenges that will be discussed can assist other engineers, contractors and municipalities in similar circumstances when implementing fusible PVC pipe on their own projects.

1. INTRODUCTION

The local improvement project, Our Lady Queen of Peace (OLQP), is located in northeast Edmonton. The site is bordered to the south by the North Saskatchewan River, and to the north by 153 Ave NE. The West border is an existing golf course and the east is bordered by 17th St NE. The scope of work included in the local improvement construction was off-site sanitary servicing with a 100mm (4 in) diameter forcemain and a small portion of 250mm (10 in) gravity sewer and an off-site water servicing accomplished with a 300mm (12 in) diameter pressure main. The sanitary extension was approximately 1km (0.6 mi) in length and the water extension was approximately 2 km (1.25 mi) in length. As shown in Figure 1, the tie in to existing sanitary sewer was 1km (0.6 mi) east of the site on

153 Ave NE. Tie in to the existing water system was 800m (0.5 mi) north of the intersection of 153 Ave NE and Meridian St. The intersection of Meridian St and 153 Ave NE is located 1.1km (0.7 mi) west of the site.

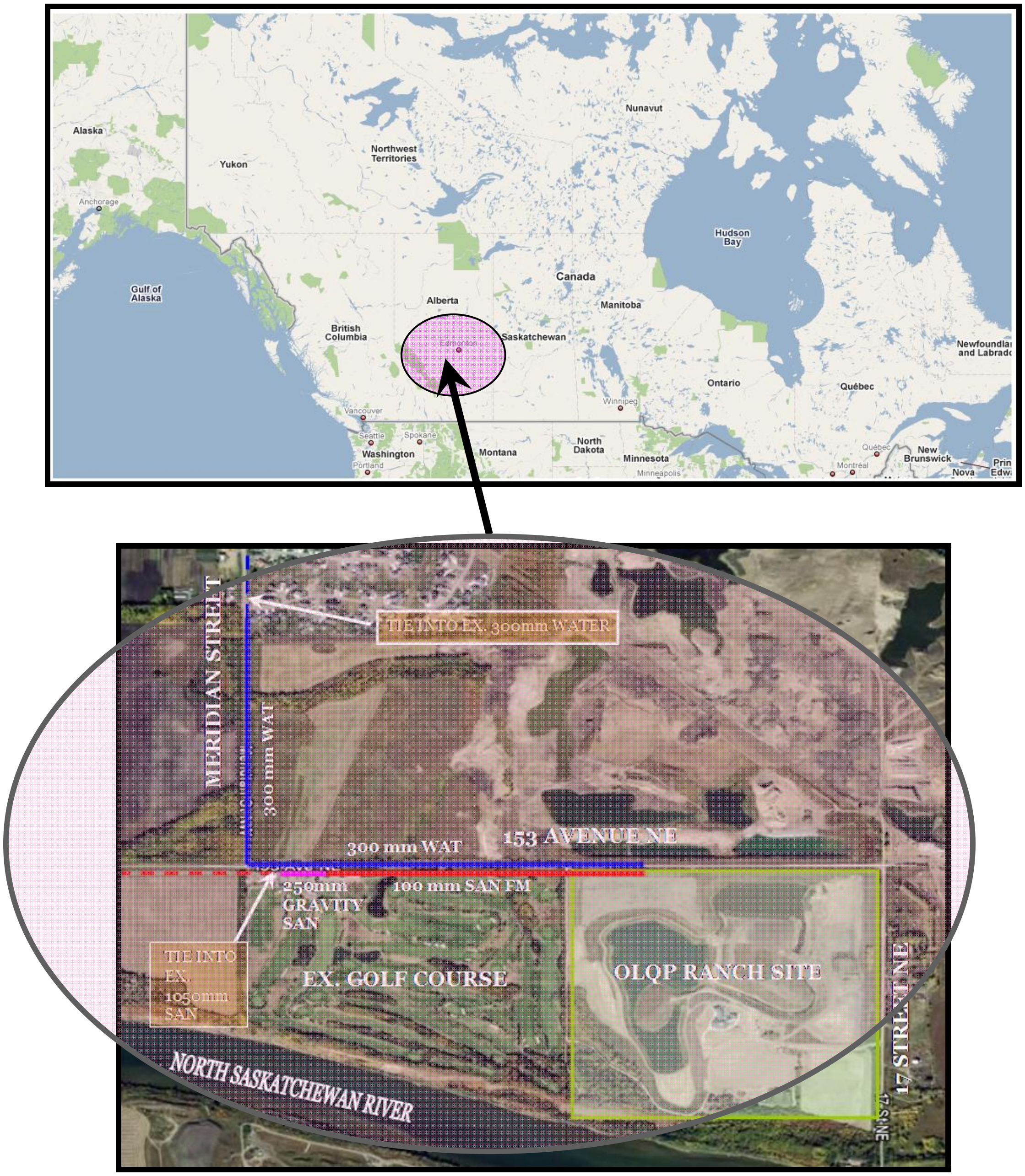

Figure 1. Location of OLQP, Northeast Edmonton, Alberta (Google maps, 2009)

2. CONSTRUCTION ALTERNATIVES

Planning for the construction of services occurred in the summer of 2007. An analysis of the different alternatives for the sewer construction methods was performed. Initial servicing options looked at locating the water and sanitary servicing in a single trench within the existing pavement on 153 Ave as it ensured the infrastructure, which would eventually be the responsibility of the City, would stay within known City right-of-way. This option would involve construction using open cut methodology with the depths of services ranging from 3.0 m to 4.0 m (10 to 13 feet) from existing ground level. Trenching for this open cut installation would require cutting the existing pavement which would impact a large portion of the busy roadway being used as a haul route for a gravel operation and other construction activities. The impacted area could have been reduced using caging for support of the open trenches throughout the entire length of the project at a premium cost. This alternative was eliminated due to the high cost of road restoration and other alternatives within the road right of way, outside the existing pavement, were examined. Elements that were considered during the alternatives analysis were soil conditions, physical space requirements, cost of compensation of trees removed along the alignment, safety, social impacts, schedule, and construction costs.

One of the trenchless options analysed was installation using horizontal directional drilling (HDD). HDD could be accomplished within the road right of way outside of the existing pavement with minimal disruption to the existing conditions.

Table 1 outlines the comparison between using open cut vs. HDD installation. After evaluating the

Table 1. Open Cut vs. HDD Installation for OLQP Project

Elements	Open Cut(w/o caging)	HDD
Space Requirements	3-4m within existing pavement	Completely outside existing pavement
Social Impacts	Partial Closure of roads	Roads open
	2-3 months construction time	5-6 week construction time
Safety	Trenching in areas of high groundwater	No confined space for installation of pipe
Schedule	No Construction during winter months	Construction year-round
Construction Costs	Approx. 2.5 times higher	Less construction costs

advantages and disadvantages for both construction methods studied, the City of Edmonton determined that for OLQP, HDD installation for both sanitary and water servicing would be the most suitable for the project. The next challenge; however, was to find the suitable pipe that would be acceptable for HDD installation and meet the City's construction standards.

3. SELECTION OF MATERIAL USED FOR THE HDD WATERMAIN INSTALLATION

Selection of the pipe material used for the water main installation for OLQP was based on consultation with EPCOR Water who is the municipal provider and source for consumption grade water in Edmonton and the surrounding areas. The City of Edmonton primarily uses PVC water mains for replacement and new developments. When EPCOR was consulted on the selection of material for the HDD application for OLQP, and fusible PVC was brought to the attention as a viable option, both the City of Edmonton and EPCOR were highly interested in using an innovative product. One of the major advantages for implementing fusible PVC into the existing system was the ability to replace or make additions to the new line with existing inventory for appurtenances, and having the ability to make a new connection without the aid of an outside contractor skilled in fusion technology (i.e. HDPE appurtenances).

Figure 2. 153 Ave NE Road Right of Way Showing Fused PVC Pipe on Rollers

A comparative evaluation was conducted with two options, FPVC and HDPE. Table 2 outlines the various properties of the FPVC and HDPE pipes (Underground Solutions, 2009).

Table 2. Properties of PVC and HDPE (Underground Solutions, 2009)

Property	Specification	PVC	HDPE 3408/3608[1]	HDPE 4710[2]
Tensile Strength (PSI)	ASTM D638	7,000	3,200	3,500
Specific Gravity	ASTM D1505	1.40	0.95	0.94
Hydrostatic Design Basis @73°F (PSI)	ASTM D2837	4,000	1,600	1,600
Modulus of Elasticity- Short Term (PSI)	ASTM D638	400,000	110,000[3]	110,000[3]
Hardness (Rockwell R)	ASTM D785	117	52	NA
Coefficient of Linear Expansion (in./in. °F)	ASTM D696	0.30×10^{-4}	1.2×10^{-4}	1.2×10^{-4}
Water Disinfectant Induced Oxidation[4]	-	Highly Resistant	Low Resistance	Low Resistance
Hydrocarbon Permeation[5]	-	Highly Resistant	Highly Permeable	Highly Permeable

1. HDPE 3408/3608 also referred to as PE80
2. HDPE 4710 also referred to as PE100
3. PPI – PE Handbook- Long Term Modulus of Elasticity is 28,200 psi
4. Carollo Engineers 2008, Choi 2008, Chung 2008, Fumire 2008, Rozental 2008, Castegnetti 2007, Audouin 2007
5. AWWA Research Foundation 2007 (now WRF)

When comparing FPVC and HDPE, there are a number of advantages and limitations for both materials. Overall both materials have the advantage of high resistance to internal and external corrosion, zero-leakage at fused joints, high flexibility and low internal resistance to flow. Limitations of HDPE are that the wall thickness required is larger than FPVC and fusion waiting periods are longer than FPVC, however, HDPE is highly resistant to impact failure especially in cold temperatures (Najafi, 2005). HDPE also has a smaller maximum bending radius which allows contractors to manipulate the pipe for pullback much easier than FPVC. One of the disadvantages with

FPVC is that it is a much more brittle material when compared with HPDE, therefore contractors are required to take extra care with the material to avoid brittle fracture.

FPVC was both the City of Edmonton and EPCOR's preference over HDPE. Comparatively, both HDPE and FPVC are fairly similar in advantages and disadvantages. They are also similar in cost. The fusible PVC pipe could cost slightly more than the equivalent HDPE, however, the installation of appurtenances for FPVC could provide cost savings when compared to HDPE. The deciding factor for the selection of FPVC was based on operations and maintenance. The ability to use in-house staff and existing inventory for future servicing or effective maintenance made FPVC the alternative for this project.

4. SCHEDULE

The decisions to select an HDD installation with fusible PVC pipe for the water main took place over the course of about a year and a half. Detailed design drawings were issued for construction in the fall of 2008. The schedule for construction was a major factor in the success of the project as the owners wanted to open the ranch facility in the spring of 2009. Construction would, therefore, need to take place in the winter months to achieve the opening date. The selection of fusible PVC in an HDD installation would work well for the planned schedule; installation would take approximately 5-6 weeks to accomplish and HDD could take place year round.

5. CHALLENGES

The challenges faced during construction were directly related to two major factors:

1. Using a relatively new untried product in the municipality for the first time
2. Construction taking place during extreme cold weather conditions, as low as -30 degrees Celsius

The weather affected most of the steps involved in this project from planning the laydown sites to the pullback operation. This project was one of the first fusible PVC installations that the Contractor had performed, and the first installation for the City of Edmonton Design and Construction department.

The challenges encountered by the Contractor specifically affected these stages in construction:

1. Handling the Product
2. The fusion process
3. Equipment maintenance throughout the winter
4. The pullback operation
5. Installation of appurtenances

Figure 3. Construction in Mid-January

6. HANDLING THE PRODUCT

The Contractor prepared for the possibility of pipe damage by taking extra care beyond the published procedures to ensure that the pipe was not compressed, damaged or deformed prior to installation. The pipes were unloaded in pre-planned laydown areas where the fusion and pulling operation would take place. The Contractor used the detailed design drawings to mark out where the laydown areas would be prior to the start of construction based on exit pits at locations with valves or hydrants (open cut locations). This preparation work, which is consistent with the detailed pipe handling procedures by Underground Solutions, positioned the Contractor to install the pipe quickly and relatively trouble-free. Pipes were stored and placed on level ground and left inside the unit packaging provided by the manufacturer. During the winter months, the temperature reached as low as -30 degrees Celsius during the installations. Another key factor in preparations was ensuring that the pipe was at optimal temperature prior to being fused in the tent. This pre-heating was accomplished by using insulated tarps at the laydown area and heating the pipes under the tarps to a temperature range where fusion would be achievable. The tarps also functioned as a barrier between the harsh environment and the pipe. It prevented the pipe from abrasion, and unnecessary damage that could be detrimental to the integrity of the pipe. The Contractor made extra effort to ensure that the pipe was handled properly with respect to the type of conditions in which they were working.

7. THE FUSION PROCESS

The fusion process for OLQP was carried out in the winter months of 2008. Fusion, at the time, was only possible with certified fusion technicians from the United States, trained by Underground Solutions. The certified fusion technician was not available until after the American Thanksgiving holiday, and therefore the fusion process took place in the month of December. The Contractor made necessary preparations keeping in mind that the historic temperatures in Edmonton’s winter months range between minus 20 to 30 degrees Celsius. The goal of the Contractor was to make certain that a highly sensitive process, the fusion process, would be completed in a controlled environment. The steps the Contractor made to ensure that a controlled environment was ready for the fusion process was setting up heated tenting using kerosene heaters and providing monitoring equipment to achieve a constant state for the 10 days that would be required for the fusion of the pipe to be completed. Figure 4 shows the fusion tent set up in the road right of way.

Figure 4. OLQP Fusion Tent

The fusion process was performed with great success. Fusion was estimated by the Underground Solutions representative to take approximately 14-17 days. The fusion process took 10 days to complete. The lag time between preparing pipes for the fusion process and securing the pipes into the fusion machine were minimal. This quick transition was due to the fact that the pipes were placed on rollers to avoid cold spots and pre-heated prior to entering the tent. The facing of the pipes where pipe ends are squared and made as symmetric as possible took approximately 5-10 minutes to complete. The heating and fusing of the pipes where an electronically controlled heating element heats the ends of the pipe to form a bead of fusible material took approximately 4-5 minutes. Once the heating plates were removed, the pipe ends were placed evenly together and cooled for 20 minutes to allow the pipe to reach a temperature below 100 degrees Fahrenheit. The cooling process was accompanied by venting the tents to allow for quick cooling so workers could handle the pipe safely. (Underground Solutions, 2008).

8. EQUIPMENT MAINTENANCE

It was imperative for the installation of the water main to be completed in the estimated 5-6 weeks. The Contractor had to ensure that the equipment used on-site would be in good working order every day. During the reaming operations, pumps were used to move drilling mud through the bore hole. The drill mud that the Contractor used in OLQP was a bentonite slurry. Ice is capable of building up in the pump and can potentially split the frame is high in -20 to -30 degree Celsius weather (Trenchless Technology Online, 2009). Anitfreeze was used to prevent freezing from occurring in the pump nightly. During the extreme cold weather conditions, machines were left running through the night to ensure that the motors would not seize. The Contractor was proactive with equipment maintenance and no issues due to equipment seizing or failure occurred during the course of this project.

9. REAMING AND PULLBACK OPERATIONS

The success of the reaming and pullback operations relied upon a number of factors. These factors include:

1. Minimizing drag forces and minimizing pulling forces
2. Precautions for keeping pipe dirt-free and water-free
3. Prevention of Freezing pipes

Table 3. outlines the engineering properties for the specific type of Fusible PVC product used for the OLQP water main.

Table 3.Engineering Properties for 300mm C-900 DR18 Water Main

Size (in)	Pipe Stiffness	O.D (in)	Min Wall Thickness (in)	Avg I.D. (in)	Weight (lbs/ft)	Safe Pulling Force (lbs)	Max. Working Pressure (psig)	Critical Buckling Pressure (psig)	Min. Allowable Bending Radius (ft)
12	DR 18	13.20	0.73	11.65	18.71	80,300	235	190	275

The Contractor's first consideration was the loft angle for the pipe into the bore path. The angle used was 7 degrees. Typical angles range from 6 to 15 degrees. This angle allowed the pipe to enter the borehole using a bending radius less than the maximum and prevented the possibility of equipment failure by ensuring that there was not an overextension on the drilling equipment (National Driller, 2004). Drilling mud used was a bentonite slurry standard for horizontal directional drilling operations. Bentonite particles swell when mixed with water and penetrate the spaces in the borehole wall to provide stability (HDD Practice Handbook, 2005). The drilling mud was monitored throughout the project to prevent the mud from creating drag forces on the pipe. An incident did occur where the pullhead required modification early on in the project due to drilling mud migrating into the pipe. A bolt-on pullhead was used for pullback. This pullhead required a drill hole be created through the pipe material and bolted to the material. The drillhead was modified by using a pipeline shrink sleeve that created a jacket to form over the bolt hole sealing the drill head. The pulling force that was used was 35000 lbs. The safe pulling force for the product used (see Table 3) is 80,300 lbs. This low pulling force ensured that if excess pulling forces during reaming and pullback operations occurred such as over-steering or deflections from the bore path, then a safety factor would be present to keep the puling force below the maximum.

Precautions were made to keep the pipe free of dirt and water. This precaution allowed for less cleaning and maintenance for the pipe prior to testing procedures. The Contractor installed air plugs in the pipe to take into consideration potential leeching from the surrounding soils. The air plug also worked as a secondary function to avoid freezing from occurring within the pipe. Another method used on-site to prevent pipes from freezing was the use of rollers prior to pullback (see Figure 5). This method allowed for the pipes to remain off the ground and away from debris, rocks, etc. It also eliminated drag forces on the pipe before entering the borehole. This precaution facilitated in the success of maintaining the initial schedule for OLQP.

Figure 5. Rollers Used for Pullback Operations

10. INSTALLATION OF APPURTENANCES

Many of the issues that occurred over the course of the OLQP project were related to the installation of valves subsequent to the installation of the pipe. During the design stage of OLQP, clear guidance on the need for mechanically restrained joints was not available and the design only called for mechanically restrained joints in areas of high potential movement such as steep grades. The majority of the valves installed were connected back to the pipe by Hymax couplings and thrust restrained with concrete thrust blocks. The problems were not apparent during the time of installation; however, during the pressure testing process, it there was leaking at a number of the valves installed. Figure 6 shows one of the valves along 153 Ave that was leaking.

Figure 6. Leaky valve at 153 Ave NE

The initialization of the water pressure during testing caused a water hammer effect where the surge caused the pipe to deflect or move away from the valve assembly. PVC has less ability to resist water hammer when compared to the more flexible HDPE. There is significant reduction in the intense initial pressure surge but the working pressure rating of the pipe is lower than the pressure being experienced at the time (Ricky. A. Ponder, 2006).

Because the valve assembly and the pipe are different materials, the potential for differential pressure is greater than in a situation where equivalent materials are connected. Another factor that may have caused leakage at the valve locations was that the reamer hole was approximately 1.5 times the diameter of the pipe, allowing more movement lengthwise in comparison to an open cut installation where the pipe would be completely backfilled. In an HDPE installation, mechanical restraints are required, however, in a fusible PVC pipe installation, information was not readily available to aid in the design and construction of the appurtenances.

Pressure testing for OLQP was estimated to take place over a period of 4-5 days. Due to the issues encountered with the valve restraints, testing occurred over a period of 10-11 days. This delay impacted the project by escalated costs for time, material and labour for increased testing. The resolution was to mechanically restrain the valves with Ford Meter Box restrainers.

11. CONCLUSIONS

OLQP LI faced many considerable challenges having chosen a relatively new and untried product. In the end, many of those challenges were well planned for and carefully executed to minimize problems that could have detrimentally affected schedule, performance and costs. The decision to construct the 2.0 km (1.2 mi) water line by horizontal directional drilling enabled the Contractor to work along the established roadway without reducing traffic lanes or closing any roadways. The cost benefit for a HDD fusible PVC installation versus an open cut installation resulted in significant savings. Not only was there minimal disturbance to traffic along the route, but choosing HDD over open cut prevented construction from taking place in the roadway. HDD allowed the Contractor to work well into the winter whereas with open cut installation, frozen ground would have been an issue. Overall, the fusible PVC installation was successful. Fusion was in a controlled environment making the process indifferent to the weather conditions. Having the ability to control temperatures resulted in a better fusion process, allowing for even more control comparative to most installations during summer or fall. The drilling process caused little to no issues as recommended guidelines were followed where they were available. As there is a generous safety factor applied to the recommended guidelines, the product was installed without known defect or breakage. The only major issue that was faced during this project was the valve installation. There was unclear direction as to what guideline or standard was available at the time for implementing appurtenances to the water line. However, once the joints were mechanically restraint, leakage and movement of the pipe ends was eliminated.

It is clear from this experience that a successful HDD installation with an innovative and non-traditional material is possible even in extreme weather conditions.

11. REFERENCES

Bayer, H.J. (2005). HDD Practice Handbook , pp69-70

Gokhale, S and Najafi,M. (2005) Trenchless Technology Pipeline and Utility Design, Construction and Renewal, pp177-189.

Author Unknown, National Driller (2004). HDD Good Practices Guidelines- Part 2.

Ponder, R.A. www.nastt.org (2006), HDPE: The Water System of the 21st Century,

Underground Solutions Inc. (2008), Technical Sales Bulletin 8-533

Underground Solutions Inc. (2009), www.undergroundsolutions.com, Website:Engineering Info section

Young,T. (2009), Cold Weather & Your Drilling Pumps, Trenchless Technology Online