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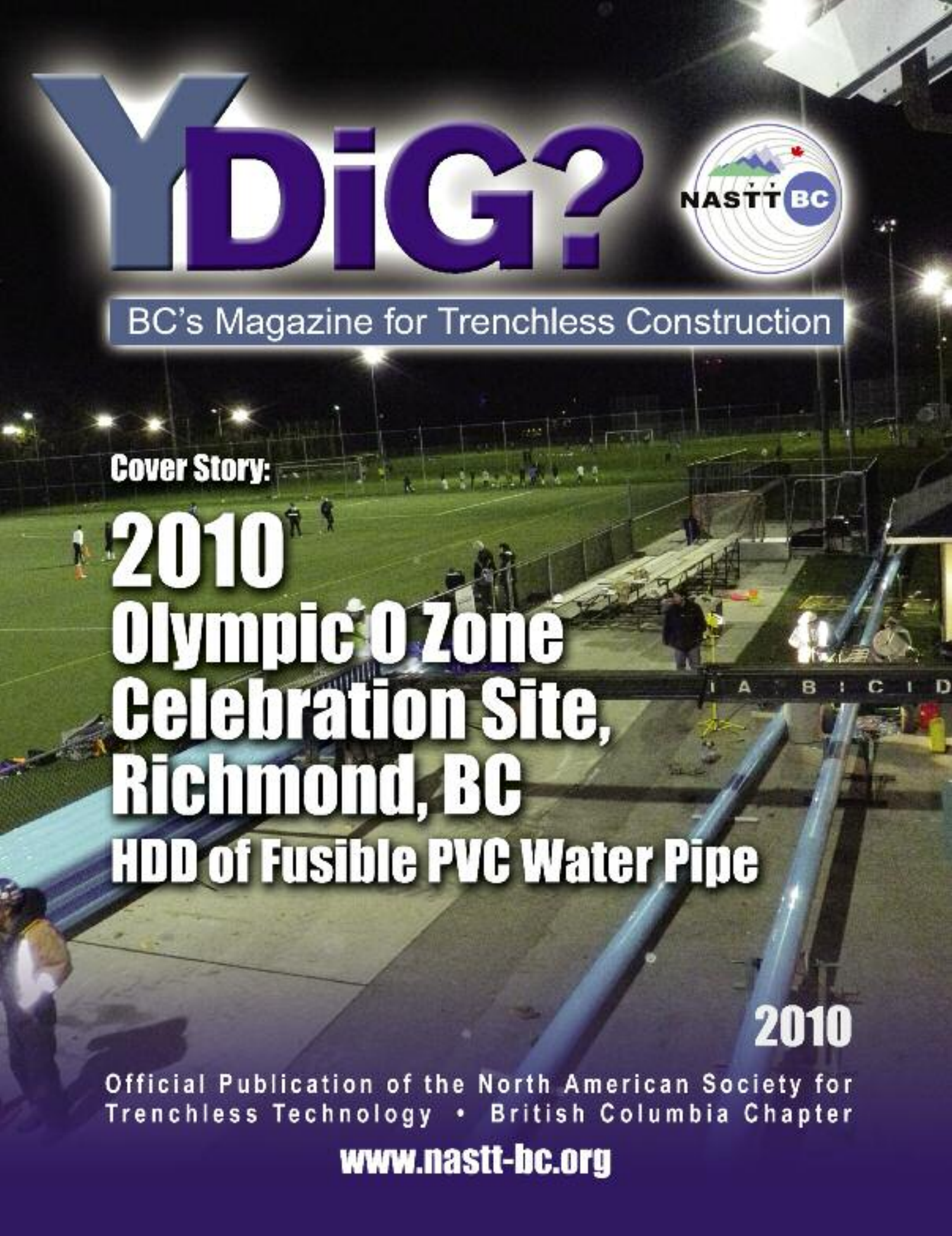

Cover Story:

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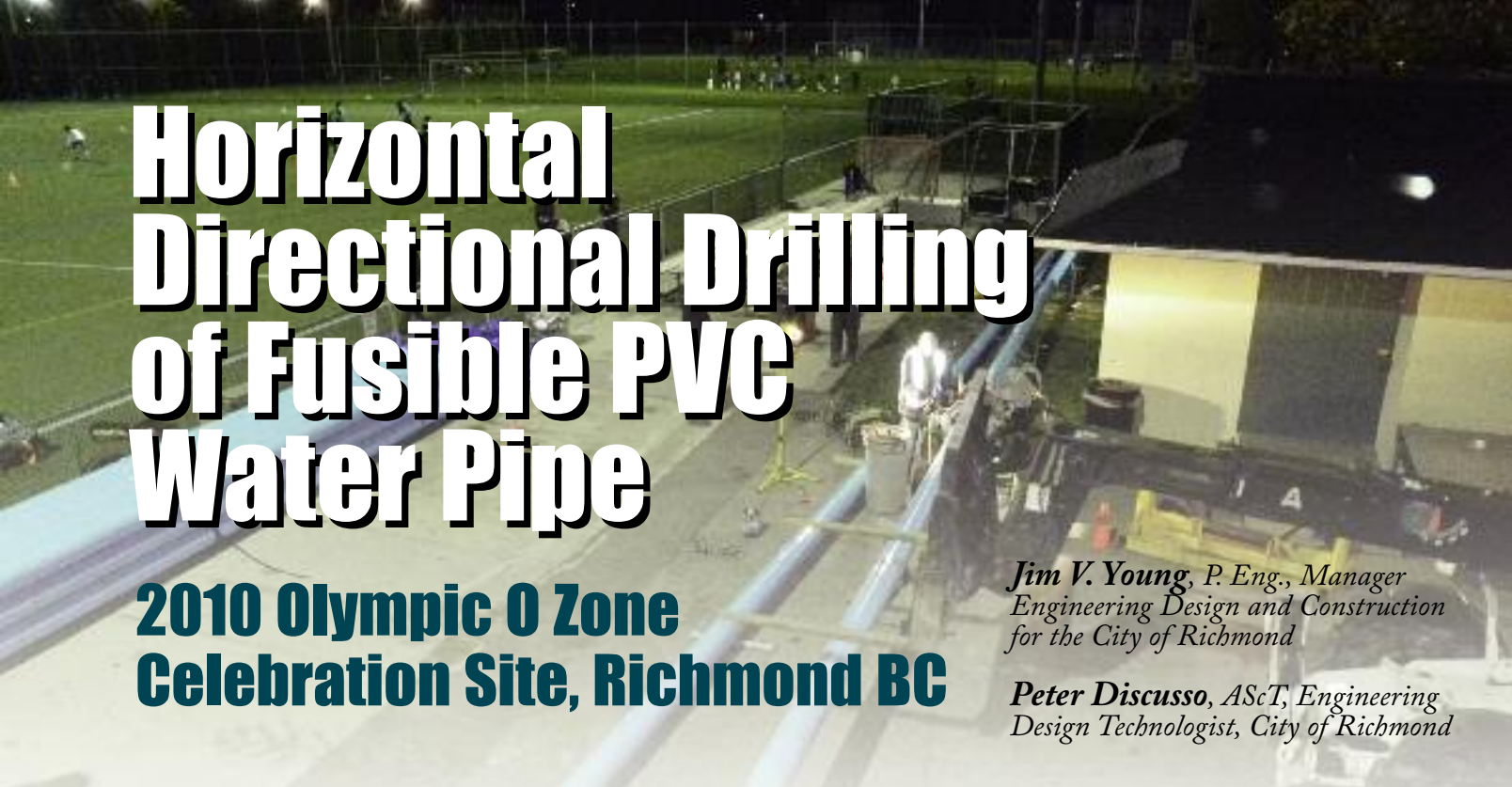

Horizontal Directional Drilling of Fusible PVC Water Pipe

2010 Olympic O Zone Celebration Site, Richmond BC

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ABSTRACT

The City of Richmond is part of Metro Vancouver in British Columbia, Canada and is located on a flood plain with elevations ranging from approximately 0.6 metres to 2.5 metres above sea level. These physical attributes present numerous challenges and opportunities with underground utility design and construction. Design and construction of water mains in combination with soft soil, river delta ground conditions in particular, lends itself to trenchless construction opportunities.

The City established an Asbestos Cement water main replacement program in the 1990's and the Minoru Park water main replacement project was designed to be undertaken through directional drilling. As a first for the City, the City used a fusible C900 DR18 PVC water pipe system as supplied by IPEX, as an innovative "trenchless" opportunity and one that would reduce costs, minimize schedule and bring to a minimum the impacts on the highly utilized Minoru Park, located in the forefront of the City center and the location of the Richmond 2010 Olympic celebration site. Implementation of this alternative method proved to be successful and was recognized as an opportunity for future water main installation work.

BACKGROUND

The City of Richmond is located on a flood plain with elevations ranging from approximately 0.6 metres to 2.5 metres above sea level. These physical attributes present numerous challenges and opportunities with underground utility design and construction.

The City purchases potable water from Metro Vancouver and has a distribution system of approximately 750 km of water mains ranging in diameter from 100 mm to 1050 mm. Approximately 52% (387 km) of the water mains in Richmond are Asbestos Cement pipe.

THE RICHMOND 2010 OLYMPIC WINTER GAMES O ZONE

As a Venue City for the 2010 Olympic Winter Games, Richmond has the privilege of producing and hosting one of the official 2010 Olympic Winter Games Celebration Sites, the Richmond O Zone. The O Zone, located in Minoru Park, is one of the most important components in the City of Richmond Olympic Plan to help achieve the City's Olympic and Community goals. Produced by the City of Richmond, the O Zone is a live celebration site in the Richmond City Center that will be open to the public for Olympic viewing, family fun, entertainment, activities and more.

One of the many challenges with the O Zone was the ability to provide a reliable source of potable water to the numerous venues, including the unique outdoor skating path/rink. The existing 150 mm (6-inch) water main crossing Minoru Park was constructed using Asbestos Cement pipe in 1969 and was nearing the end of its useful service life. More alarming was the significant and recent history of breaks – a water main break(s) in the O Zone during the 2010 Olympic Winter games would be considered disastrous to the success of the O Zone and to the City of

Pipe staging and fusing looking north

Richmond's reputation in general.

Horizontal directional drilling is gaining popularity in the Metro Vancouver area as an accepted method of installing watermains. In the City of Richmond's Minoru Park, approximately 476 meters (1560 feet) of aging 150mm (6-inch) diameter Asbestos Cement pipe was replaced using horizontal directional drilling and Fusible PVC C900 DR18 Pressure Pipe, a first for Richmond.

ASBESTOS CEMENT WATER MAIN REPLACEMENT PROGRAM

The City established a proactive water main replacement program in the 1990's with particular emphasis on replacing the asbestos cement (AC) mains. AC mains were installed as the small diameter watermain material of choice over the period 1952 to 1985 in the City and were in common use throughout the municipal sector in most areas of Canada and North America. In general, those AC mains that are under 300 mm (12-inch) in diameter have been prone to a decreased life expectancy through an accelerated loss of structural strength leading to diminished water system reliability. There is also the unfavorable public perception of drinking water being in contact with asbestos.

AC water mains in the City of Richmond have been found to be particularly vulnerable to the local conditions, specifically groundwater and the soil composition. As the City is located essentially at sea level, the phreatic surface is influenced by the tidal cycle and typically ranges from approximately 1.0 to 2.5 metres below ground level. During rainfall events it is not uncommon for the phreatic surface to be at the ground surface.

The City's AC pipelines are eroding from both the inside and outside of the pipe. Water in the past supplied from the Greater Vancouver Water District had a low ph that accelerates leaching of cement mortar from the inside wall of the AC water pipes. Similarly, the high water table and aggressive soil in Richmond accelerates the cement mortar leaching from the outside pipe wall of the AC water mains. These two factors have combined to reduce the effective life of the City's AC pipelines below the anticipated 75-year design life.

Given the reduced life expectancy of AC watermains and the asso-

200mm diameter Ipex Fusible PVC pipe on site awaiting installation

ciated impacts on system reliability, the City has taken a proactive role in this regard by developing an AC watermain replacement program.

MINORU PARK WATER MAIN REPLACEMENT DESIGN

The Minoru Park water main replacement project was designed to facilitate installation of fusible C900 PVC water pipe through Horizontal Directional Drilling. The alternative of completing pipe installation through traditional open-cut methods was not acceptable given the significant impact to Minoru Park landscaping/amenities and the complete inability to satisfactorily restore this showcase park prior to the commencement of the 2010 Olympic Winter Games.

The City had successfully completed directionally drilled watermain projects in the past using continuously "welded" pipe, usually High Density Polyethylene. While C900 PVC pipe has widely been used throughout the City on standard open-cut projects, the City had limited previous experience with Fusible PVC pipe in a directionally drilled application. Fortunately, the use of Fusible PVC pipe had been proven in numerous similar applications throughout North America.

Pipe staging and entry pit looking south

The soil conditions in general in the City represent excellent conditions for trenchless technologies, including horizontal directional drilling. A typical soil profile is generally a thin layer of construction related granular materials at the surface overlying an approximately 2 to 4-metre thick layer of a soft to firm silt mixed with clay. It is within the silt/clay layer where main installation is completed. The City could proceed at this location and others with a great deal of confidence that uniform conditions would exist and that there would be no significant obstacles, i.e., boulders, etc., that would impede progress. Accordingly, the City completed a detailed review of this opportunity and considered the following main items.

Evening operation during sporting event allowing use of facility

Advantages

1. Minimized disruption to park users – Open-cut procedures on the Minoru Park water main replacement project would have considerable impact on the park patrons and residents in general in the vicinity of the work. Specifically, the water main crossing Minoru Park traverses an all weather artificial turf playing field, numerous park related amenities, a cricket field and considerable landscape features. With strategic placement of the three entry/exit pits, horizontal directional drilling would eliminate virtually all park related impacts and allow sports and recreational related activities to proceed unhindered. Installation of fusible PVC pipe in particular through horizontal directional drilling

Ulmer Contracting set-up of drill rig at south entry pit

Vermeer D20x22 drilling rig in operation

could be completed quickly, i.e., over a period of a few days, as compared to a few weeks using conventional open-cut methods.

2. PVC pipe versus High Density Polyethylene pipe – From the City's viewpoint, both PVC and HDPE pipe represent excellent watermain building materials that are well suited to local conditions and facilitate horizontal directional drilling. As the City completes the vast majority of new and replacement watermain construction with PVC pipe, the operations and maintenance program has been geared in this direction accordingly. The use of HDPE pipe would require significant staff training and purchase of relatively expensive equipment. As the PVC pipe would be continuously restrained, seismic properties similar to High Density Polyethylene pipe were anticipated.

3. Sustainable practice – An important measure of success to the City is to be recognized as leaders in sustainable practices. Installation of the watermain through directional drilling would facilitate this success descriptor as the need to import granular bedding materials and various surface restoration requirements including asphalt and concrete would be entirely eliminated and/or reduced.

4. Schedule – Disruption to park users was further minimized as the schedule provided by the contractor for water main installation through horizontal directional drilling allowed for quicker completion as compared to the open-cut method.

Disadvantages

1. Risk associated with a technique new to the City – The City had completed numerous horizontally directionally drilled projects in the past, but had no previous experience using fusible PVC pipe over the distances contemplated on the Minoru Park crossing project. The use of IPEX Fusible PVC C900 DR18 Pressure Pipe was also new to the City, but does comply with the City's standard specifications.

2. Unknown utility conflicts – Utility conflicts become obvious through open-cut installation methods as the excavation proceeds. The discovery of a direct conflict with an unknown utility(s) would require open cut excavation(s) thereby defeating the purpose and advantage of horizontal directional drilling. The City also had previous experience with other organizations whereby they completed their utility installation, i.e., gas main, through horizontal directional drilling, didn't realize there was a conflict, and installed their pipe through the City's existing

Table 1 - IPEX Fusible PVC Pipe System

Safe Allowable Bend Radius and Pulling Force

Class 150 (DR18)

Nominal Size mm (inch)	Min. Bend Rad. mm (ft)	Straight (no bending) kN (lbs)
100 (4)	6,700 (30.5)	48.9 (11,000)
150 (6)	9,000 (43.9)	100.1 (22,500)
200 (8)	18,000 (57.6)	171.3 (38,500)
250 (10)	25,600 (70.4)	258.4 (58,100)
300 (12)	26,400 (83.8)	364.3 (81,900)

From IPEX Fusible Brute™ Pipe Installation and Handling Guide

sewer pipe.

3. Concerns with reduced PVC pipe structural capabilities

a) The City typically completes PVC watermain construction through conventional open-cut methods and realizes the benefit of engineered backfill, compacted to a minimum of 95% Proctor density. As pipe installation through directional drilling would be completed in native ground, the City would not realize this benefit.

The recommended maximum out of round deflection for PVC pipe is generally considered to be 7.5%. Calculations completed on the construction basis condition (empty pipe with live load conditions) using the Modified Iowa Formula (below) with a Modulus of Soil Reaction value of 500 psi provided for an acceptable result of approximately 0.8% deflection, which was considered to be a minor compromise.

$$\frac{\%\Delta Y}{D} = \frac{(D_L K P + K W')(100)}{\left(0.149 \frac{F}{\Delta Y} + 0.061 E'\right)}$$

b) While PVC pipe may be pulled onto a curved path, the pipe curvature limits the ability to tap the main to install services as part of the construction project and in future installations. Tapping a curved PVC pipe is discouraged by the City of Richmond.

The City reviewed the merits of the advantages and disadvantages and concluded that proceeding with directional drilling of Fusible PVC pipe was warranted and would provide an overall benefit to the City.

DESIGN/CONSTRUCTION

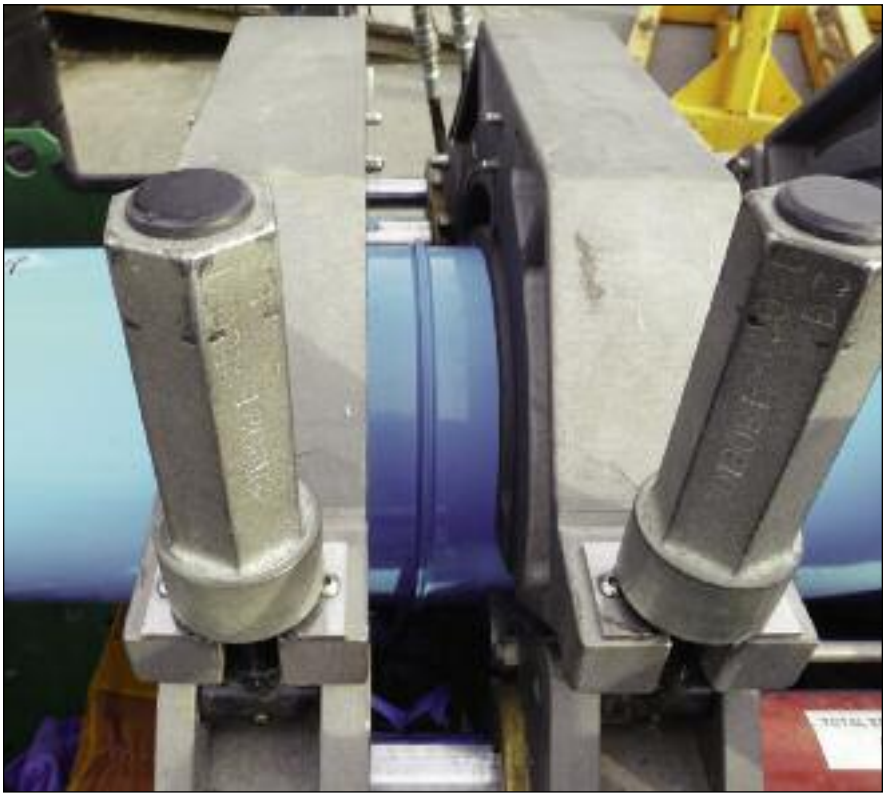
Horizontal directional drilling is one of several trenchless construction methodologies whereby a drilling bit is guided through soil to create a round cavity, which will stay intact for at least several days. The drill head is propelled by adding segments of rod as the head proceeds forward though a start-and-stop procedure. Once a cavity is created, the drill bit is removed and a pulling adaptor is attached to the drilling stem. A significant length of Fusible PVC pressure pipe is affixed to the adaptor and pulled into place. As the adaptor is pulled back to the rig, segments of drill rod are removed.

Design - The design was completed specifically to accommodate a directionally drilled water main. The possibility of implementing a structural liner was considered, but ruled infeasible given the reduction in pipe hydraulic capacity and the need to keep the existing water main in service at all times. Similarly, the option to complete water main replacement through pipe bursting was infeasible for the same reasons plus the numerous pipe repair couplings on the existing water main that would render pipe bursting impractical.

As with most projects, it was paramount that all existing utility crossings were identified. The proposed alignment was parallel to and in close proximity to the existing 150 mm diameter AC water main, the as-built records for which were very sketchy. As several park amenities are serviced from

South entry pit and pipe pullback in process

Pipe fusing machine and operator with data logger



Pipe fusing

this main, it was not an option to discontinue water supply and therefore it was necessary to determine its exact location through the use of ground penetrating radar. Hydraulic modeling based on the Official Community Plan build-out scenario dictated that the existing 150 mm (6-inch) water main required upsizing to 200 mm (8-inch) to accommodate City Centre growth.

Drilling - The drill rig used by Ulmer Contracting to install the pipe on this project was a Vermeer D20x22, 89 kN (20000 lb) pull. Existing utilities were exposed via a Hydrovac Excavator prior to drilling. Maximum spindle torque was 2980 Nm (2200 ft lbs). A 300 mm (12-inch) diameter wing cutter / back reamer was used to drill the hole. The line was installed in 2 runs, with an average of 10 hours to drill each cavity.

Pullback - This was followed by a compaction reamer ahead on a swivel, which was attached to the pipe to pull in the new IPEX Fusible PVC C900 DR18 Water Pipe. Drilling mud was used as a conservative measure to maintain the drill hole cavity and to reduce friction during the pullback process. Drilling mud is typically not used in Richmond on small diameter water main projects because the soil layer is normally a damp, firm silt mixed with clay. Actual individual pipe string installation (there were two pipe strings in total) took approximately 2 hours each. Maximum pull encountered over the course of the job was 44 kN (10,000 lbs) which was well below the limit of the rig and the maximum allowable for the IPEX Fusible PVC Pipe system (see Table 1).

Pipe Pull Force

Maximum Pulling Forces as shown in the following table were determined from applying a safety factor of 2 to the pipe yield strength tested in tension. (Note, typically the pipe wall itself can withstand much greater axial pull forces; 1.8 to 2.7 times the forces noted in the table for the system.)

Pipe/Joint Assembly

IPEX Fusible BruteTM PVC pressure pipe is manufactured in 12.2-meter (40 feet) lengths to meet the requirements of AWWA C900. Pipe fusing was sub-contracted to Magnum Road Builders Inc., who retained the specialty fusing equipment required for Fusible PVC pipe. The 12.2 meter length Fusible PVC pipe ends were faced and then fused by heating to a range of 400 to 420 degrees Fahrenheit (204 to 215 degrees Celsius) and applying a pressure ranging from 2790 kPa to 2896 kPa (405 to 420 psi). After fusing, the pipe cooled to 38 degrees Celsius (100 degrees Fahrenheit), within 5 minutes. Approximately 30 minutes was required to allow the pipe to sufficiently cool down prior to handling given the ambient temperature ranged from 8 to 13 degrees Celsius (46 to 55 degrees Farenheit). A data logger to record all pertinent technical information was used continuously throughout the fusing process.

CONCLUSION

Trenchless construction methods are being used more commonly in British Columbia, especially Horizontal Directional Drilling as described above. Residents gain the added benefits of less traffic disruption/congestion, reduced dust and site debris, minimal restoration of properties, and participation in a more sustainable community. All these attributes were realized on this City of Richmond project including reduced costs. These hidden/intangible advantages to the municipalities are recognized by industry as opportunities for future works.

References

1. Asbestos Cement (AC) Class 150 Watermain Piping Phase IX – 2006 Condition Evaluation Program Summary Report 1, Levelton Consultants Ltd., G.W. Stark, E.I.T. and R.S. Charlton, P. Eng., June 29, 2006.

2. Asbestos Cement Watermain Time to Failure, Lloyd Bie, P. Eng., January 20, 2005.

About the Authors

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Alternative Fusible PVC™ Pipe Improves Water Quality And Cuts Cost for Rural Québec Municipality

When the small agricultural municipality of Saint Paulin, Québec needed to connect several residents to the town's sewer and drinking water systems for improved water quality, they wanted to ensure that it was done properly, quickly and cost effectively. Located in the historical Trois-Rivières area between the cities of Montréal and Québec, the municipality was also faced with the challenge of running the new sewer and water pipe system under the Rivière du Loup. Ultimately, the town needed to decide between using traditional HDPE (high-density polyethylene) pipe or alternative Fusible PVC (polyvinyl chloride).

An Improved Alternative Choice

Recent water quality testing completed on the wells of several residents not connected to Saint Paulin's existing sewer and water distribution system showed water contamination in the drinking water. The source of the contamination was thought to be caused by the traditional septic systems used in this area of the municipality.

Following the testing, the Ministère des Affaires Municipales Québec required Saint Paulin to extend the water distribution and sewer system to those residents experiencing water quality problems. With 80% funding provided under programs overseen by the Ministère des Affaires Municipales, Saint Paulin set out to deploy the new system. The town first needed to decide between using traditional HDPE pipe, which has long been installed in trenchless applications, or PVC, which has grown steadily in popularity throughout North America and is fast becoming the most widely installed material in water systems today.

Municipalities who have been used to using HDPE in trenchless applications for several decades are not always fast to change, and Saint Paulin was no exception. Fortunately, IPEX has introduced CIOD (cast-iron outside diameter) Fusible Brute™ PVC pipe that enables fully restrained joints with a tensile strength equal to that of the pipe. By combining the mechanical properties of PVC with an innovative patent-pending butt fusion process (in Canada, patented in the US), Fusible Brute PVC pipe is capable of being installed in long continuous trenchless applications.

"At first, the municipality was hesitant to use PVC in the trenchless application. We met with the engineering consultant, explained the differences between PVC and HDPE, showed him the testing and specification information and demonstrated how Fusible PVC could ultimately offer more cost-effective installation and long-term maintenance," recalls Alain Charky, manufacturer representative for IPEX.

With HDPE, Saint Paulin would have to special order the pipe and use expensive transition fittings due to its nonstandard outer and inner diameter that didn't match the town's existing PVC water system. In addition, HDPE's overall weight and material for the given pressure class would have resulted in a higher material and installation cost.

On the other hand, Fusible PVC would allow for easy connections to Saint Paulin's existing PVC water distribution and sewer system via simple standard fittings, providing material consistency across the entire municipality. PVC's reduced wall thickness also requires less material and yields better flow.

In addition to ensuring reduced initial deployment costs, the total cost of ownership was also a concern for a small municipality like Saint Paulin. CIOD Fusible PVC pipe is easy to maintain over the life of the system because all the accessories are readily available and can be deployed by the town's public works employees. The Fusible PVC's gasket-free joints and excellent abrasion and scratch-resistant properties also ensure long-term reliability and reduced maintenance of the system.

"When the consultant took everything into consideration, from the installation to the life of the system, they clearly saw that Fusible PVC was the better choice for the municipality," says Charky. "It was a win-win situation."

The town of Saint Paulin Quebec selected IPEX Fusible HDD pipe to connect its rural residents to the town's sewer and drinking water systems.

An Innovative Fusion Process

For the forced sewer system, Saint Paulin used a total of 2,208 meters of 100mm (4 inch) pressure-rated 165 psi (cast-iron outside diameter) CIOD Fusible Brute PVC pipe (DR25). For the potable drinking water system, they used a total of 2,611 meters of 150 mm (6 inch) pressure-rated 235 psi CIOD Fusible Brute PVC pipe (DR18). The Fusible Brute PVC pipe meets CSA B137.3, AWWA C900, AWWA C905, NSF-61, NQ 3660-950 and ASTM cell classification 12454. For the majority of the system, the two pipes run side by side, separated by approximately one meter (3.3 feet).

The Fusible Brute PVC pipe is available in 12.2-meter lengths. To create longer pipe lengths for the installation, the patent-pending fusion process for the Fusible Brute PVC incorporates a proprietary PVC formulation and a unique combination of heat, pressure, and time, using slightly modified standard industry fusion machines. The fusion process is carried out by trained and licensed individuals to ensure consistent, reliable fusion that creates piping systems of unparalleled strength.

Fusion time with Fusible Brute PVC is comparable to other thermoplastic materials. The overall fusion of the Saint Paulin system was accomplished at an average of 19 joints per day, which took place at the

The shelter of a tent combined with the heat from the fusion machine was enough to keep the pipe ends at the required temperature for fusing.

end of October 2009 and was complete by 10 November 2009. Fusion also can be performed under any temperature, as long as the pipe ends are maintained at a temperature above 4°C and both the pipe ends and fusion machinery are sheltered from the elements.

For the Saint Paulin system, a remote field was used as the staging area and a tent was set up to shelter the fusion process from the elements. Under the tent, heat from the fusion machinery itself was enough to keep the pipe ends above 4°C. Once the fusion was complete, the lightweight, flexible lengths of pipe were then simply dragged from the staging area to the installation site.

A Cost-Effective, Greener Deployment

For maximum cost-effectiveness and limited disturbance for residents, Saint Paulin specified a trenchless application using horizontal directional drilling (HDD) methods. HDD offers several key benefits, including faster installation, ability to place pipe under natural and man-made obstacles and a greener more environmentally-friendly approach. The use of HDD eliminates the need to excavate a trench, which often requires tearing up asphalt and disturbing roadways, destroying the surrounding natural environment, and risking damage to other underground systems. These can require significant repair costs after the pipe is installed.

It wasn't just cost concerns that had Saint Paulin specifying HDD methods. In 1988, the village of Saint Paulin merged with the township of Hunterstown. This increased the number of residents to approximately 1,600. Today, Saint Paulin encompasses more than forty farms and 90 small and medium-sized businesses. The urban section of the original Hunterstown area is crossed by the Rivière du Loup, and it was under this river that the new water system needed to traverse to reach residents on the other side. Only HDD could be used for this 84 meter (276 feet) section of the new water system.

"HDD equipment bored one path for the sewer and water pipes under the river, and when the drilling head reached the other side, it was replaced with pulling equipment that pulled both lines of the pre-fused lengths of Fusible Brute PVC pipe side-by-side under the river," explains Charky. In addition to the 84-meter pull under the river, the entire Saint Paulin project consisted of approximately another 25 pulls, with the longest pull being 207 meters.

The full-strength butt fusion joints of the Fusible Brute PVC pipe offered Saint Paulin a greater pull force rating than they would have had with HDPE and other restrained PVC systems. A greater pull force offers safer installation in tough conditions for HDD trenchless applications. In addition, the smaller outside diameter of the Fusible PVC pipe means that the drilling equipment can make smaller bore holes. A smaller bore hole makes for an easier, faster drilling process and reduces the amount of drilling fluid required. In turn, using less drilling fluid reduces the amount of fluid waste that has to be disposed of, making the project even more environmentally friendly.

A Better System in Place

After the new Saint Paulin system was installed, a one hour 125 psi pressure test was completed in accordance with ASTM D-638 methods on 1800 meters of the 150mm (6 inch) pressure-rated 235 psi CIOD Fusible Brute PVC pipe (DR18) used for the drinking water distribution system. The pipe passed with no make-up water required, indicating absolutely no leakage in the system.

The water distribution system located south of Rivière du Loup, which makes up most of the project, is currently in service. The forced sewer system and remaining water distribution system will be up and running by mid 2010. Thanks to innovative Fusible Brute PVC pipe from IPEX, the small rural municipality of Saint Paulin, Québec has a reliable system that will solve its water quality issues. At the same time, they achieved a more environmentally-friendly deployment and ensured an overall lower cost of ownership through easier installation, stronger fused joints and reduced maintenance. ●