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BC's Magazine for Trenchless Construction

2023

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Thrust Force Requirements

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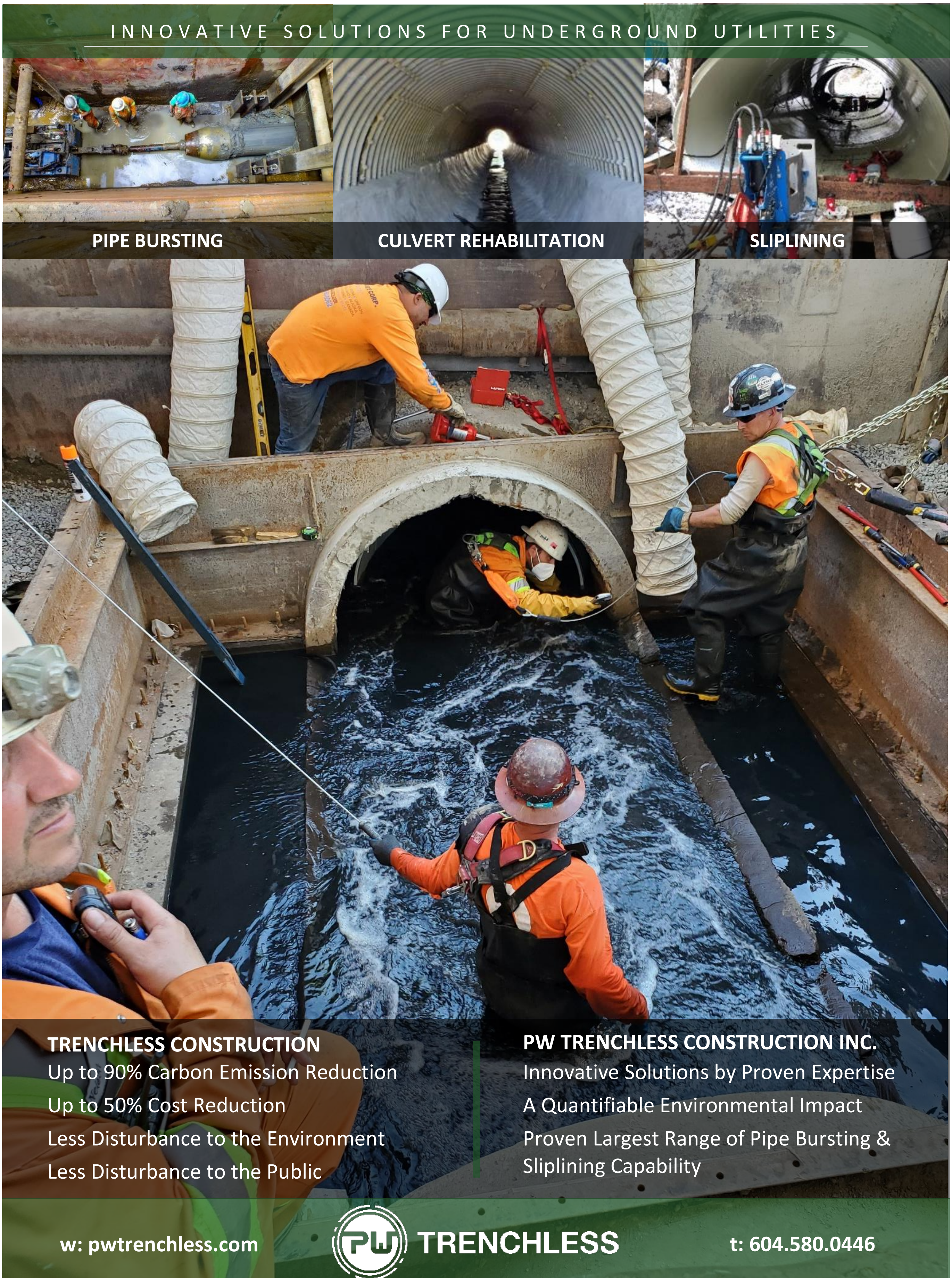
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Printed 07/23 in Canada.

Canada Post Publications
Mail Agreement # 43839013

Return Undeliverable Canadian addresses to: marcomap@shaw.ca

MESSAGE FROM THE NASTT-BC CHAIR

Sam Eichenberger, P.Eng., NASTT-BC Chair

Hello NASTT-BC Chapter Members: As we enter the 2023 summer season, NASTT-BC is proud to report on our recent accomplishments in promoting and advocating for trenchless technologies. Over the past year, we have welcomed new members to the board who bring fresh perspectives and new ideas. We believe that their contributions will strengthen our ability to support the trenchless industry in British Columbia.

One of our recent fun initiatives, was a trenchless technology pub night. This event provided an opportunity for industry professionals to connect and discuss emerging trends and innovations in a relaxed and informal setting. This event also allowed for the promotion of our Cured-in-Place Pipe (CIPP) course for our members. This course provided in-depth knowledge on CIPP, which is a popular trenchless technology used for rehabilitating pipelines. The course was well attended, and we believe will be of great value to our members and will help them stay at the forefront of the industry.

Looking ahead, we are excited to attend the No Dig North conference in Edmonton this fall. This event is an excellent opportunity to network with other industry professionals and learn about the latest advancements in trenchless technologies. The show has been steadily growing since its return after a hiatus through the depths of the pandemic and NASTT-BC along with the other Canadian NASTT chapters are excited to provide such a quality event. The 2023 No-Dig North will feature two full days and four tracks of sessions as well as Good Practice Courses on the first day of the conference. The conference will also include an exhibit hall with over 100 exhibitors. To learn more about the conference please visit **www.nodignorth.ca**, early bird rates apply until September 8th, 2023.

> *We are proud of the progress we have made!*

Overall, we are proud of the progress we have made in promoting and advocating for trenchless technologies in British Columbia. We remain committed to supporting the industry and are confident that our upcoming initiatives will further enhance our ability to do so.

Sincerely,

Sam Eichenberger

Sam Eichenberger, P. Eng.
CHAIR, NASTT-BC

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MESSAGE FROM NASTT CHAIR

Matthew Wallin, PE, NASTT Chair

Hello British Columbia Chapter Members and Associates!

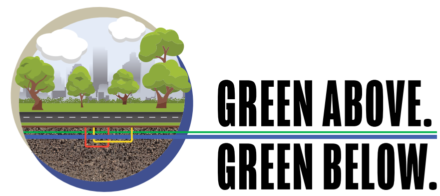
We've just wrapped the NASTT 2023 No-Dig Show held in Portland, Oregon, which was a great success and a wonderful opportunity to see our industry friends and colleagues while we celebrated all things trenchless. And now we are excited to switch gears and head to Edmonton for the 2023 No-Dig North conference, October 23-25! No-Dig North is hosted by the Canadian Chapters of NASTT, and your British Columbia Chapter is a big part of why the trenchless community in this area is thriving. No-Dig North offers three full days of training, education, and networking. This is a must-attend event for everyone in Canada and nearby portions of the US. Please visit **www.nodignorth.ca** for details!

In the coming months we have many additional events planned to bring the underground infrastructure community together. Our ever-popular NASTT Good Practices Courses are being held both virtually and in-person throughout the year. Visit **www.nastt.org/training/events** to find a course that fits your schedule.

We are also already planning for the 2024 No-Dig Show which meets in Providence, Rhode Island next April 14 - 18. Providence is a great central location within the heavily populated northeast corridor, just a short drive from Boston, and within reasonable drive from Philadelphia, New York City, Hartford, and many other cities in between. Our Show motto is ***"Green Above, Green Below"*** and it is important that our industry is a steward of our precious natural resources, so we welcome the opportunity to provide a forum for learning about the latest in innovative trenchless products and services that help us all accomplish that lofty goal. Learn more about all the No-Dig Show has to offer at **www.nodigshow.com**.

> *Join us in Edmonton for No-Dig North 2023, October 23-25!*

If you have attended an NASTT event (national or regional) you probably left feeling excited and eager to get more involved. I ask that you consider getting engaged in one of the many NASTT committees that focus on a wide variety of topics. Some of our committees that are always looking for fresh ideas and new members are the Training and Publications Committee, the individual topic Good Practices Course Sub-Committees, the Educational Fund Auction Committee, the No-Dig Show and No-Dig North Planning Committees and Technical Program Committees. There are many opportunities for you to consider where



your professional expertise can be put to use through networking with other motivated volunteers. With education as our goal and a strong drive to provide valuable, accessible learning tools to our community, we are proud of our continued growth as both an organization and as an industry. Our volunteers and committee members are what keep us moving in the right direction.

For more information on our organization, committees, and member benefits, visit our website at **www.nastt.org** and please feel free to contact us at info@nastt.org.

We look forward to seeing you at a regional or national conference or training event soon! And we hope you are planning to join us in Edmonton for No-Dig North 2023, October 23-25.

Matthew Wallin

Matthew Wallin, PE
NASTT Chair

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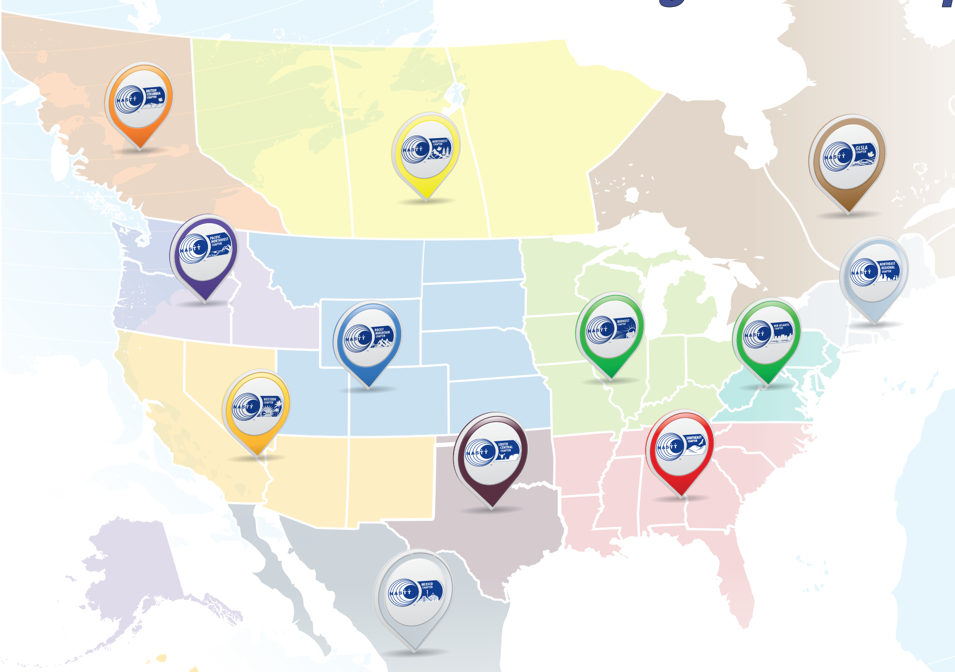

The grassroots of NASTT is a network of 12 Regional Chapters throughout the United States, Canada and Mexico. Regional Chapters network at the local level, share infrastructure challenges and develop new ideas. Regional Chapters hold various events throughout the year, and like NASTT, are dedicated to the advancement of trenchless technologies for the benefit of the public and the environment.

With your NASTT membership you are automatically enrolled not only in the national and international organization, but also in your Regional Chapter. So join today and get to know the “local heroes” that are making their communities better places through the innovative engineering solutions of trenchless technologies.

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Underground Infrastructure Sustainability:

No-Dig North, Edmonton Convention Centre, October 23 – 25, 2023

All three NASTT Canadian Chapters are preparing for another success and looking forward to staging the 4th Annual No-Dig North Show at the Edmonton Convention Centre October 23 – 25, 2023.

As Canada's premier trenchless educational and networking event, the No-Dig North Show has cemented its reputation as one of the foremost underground infrastructure events in Canada. The 4th Annual event in Edmonton promises to again garner significant attention from top infrastructure decision-makers across North America including municipal authorities, utilities, engineers, contractors, suppliers and policy-makers.

Last year's show in Toronto set a new record for attendance demonstrating there is a bright sunny future ahead for trenchless technology in Canada. Be sure to join us for this important event as a delegate, presenter or exhibitor! The excitement and anticipation is building for another record-setting show!


Networking and close personal access to industry expertise is a central feature of the annual No-Dig North show



Delegates have easy access to industry experts and trenchless technology exhibits featuring innovative new technologies

For more details and updates please visit:

www.nodignorth.ca

Pipe Bursting Under Highway 99:

Diameters Upsized in Squamish BC Sewer Main Project

HDPE pipe was fused and staged in a large lay down area on the side of the road

By: Marcelo Nakashima, PW Trenchless Construction Inc.

The crew at PW Trenchless were up in Squamish to replace a sewer main under Highway 99 via the Pipe Bursting method. On November 15, 2022, the first burst replacing 300mm pipe with 450mm pipe, 135 metres long, took place along Mamquam Road towards Highway 99. The exit pit was dug close to the intersection of Mamquam Road and Highway 99.

The site was not suitable for using a pair of trench shoring cages so the removal of the large pipe bursting head was a bit more complicated and required some extra excavation once the burst was completed. The burst went smoothly and the 135m of pipe were inserted via Pipe Bursting in roughly 3.5 hours.

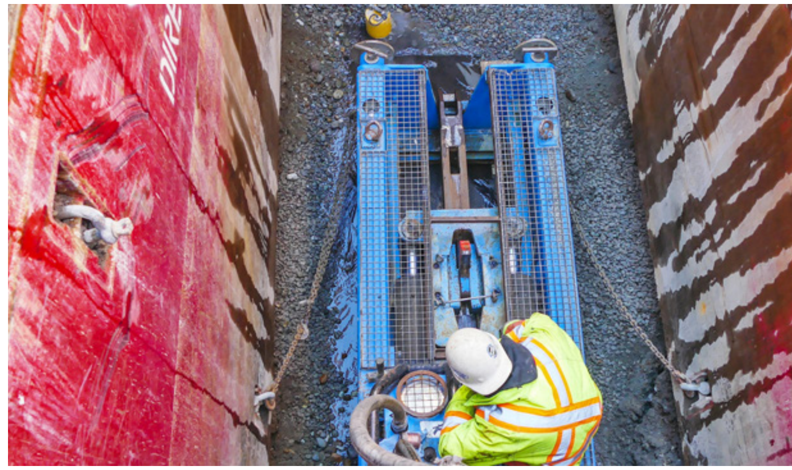
Of course there was quite a bit of set up before the burst was started. For this project, it was decided to excavate around two manholes and jackhammer out the benching and channels of the base of the manholes. This allowed the burst to continue through the two manholes unimpeded, allowing for just one launch of the bursting tool for this 135 metre run. The two manholes had trench shoring cages supporting the excavation as well as a few spots where the existing infrastructure was excavated to make sure the bursting head could pass without causing any problems.

The entrance pit was 4 metres deep so the large diameter 450mm HDPE pipe had to have a long sloped entrance ramp excavated to allow the pipe to enter the host pipe without any grade, allowing the grade of the host pipe to be unaltered.

> *The length and depth of this sewer main made it a perfect candidate for pipe bursting.*

The HDPE pipe was fused together and there was a large lay down area on the side of the road by the golf course that was not

Removal of the large bursting head was complicated and required some extra excavation



Compact exit pit was close to highway intersection

in the way of any vehicles or pedestrians. There was a bypass pump system put in place and various additional pumps were set up to ensure the excavations were kept dry for the duration of the burst. As we had to cross the Provincial highway with the bypass we had to come up with some innovative solutions to install the 250mm bypass pipe.

On the day prior to the burst, the pulling apparatus was put in place and the pulling rods were inserted into the Host Pipe. The pulling cone was installed on the lead end of the HDPE pipe. The morning of the burst it was moved across the road and put in alignment with the host pipe.

The pumps looked after any existing ground water in the excavations, but luckily it was a dry sunny day. The weather was a bit cold and once the Replacement pipe was staged into the entrance pit

Complex project created minimal traffic disruption along busy highway

it was discovered that the swivel that connects the Bursting head to the pull back rods had a small amount of ice in the cavity. The swivel was hung above the exhaust of one of the nearby generators that were powering the bypass pump and the ice was removed.

Once the head, swivel and pull back rods were attached, the crew took a well-deserved coffee break and the burst commenced before 11a.m. The crew was diligent watching the inspection pits to make sure the bursting head and pipe went under the existing infrastructure without damaging any existing pipes.

> *"Pipe Bursting method saved 560 Tonnes or 40 Truck Loads of excavated material compared to open cut replacement."*

The large diameter HDPE pipe had to have a long sloped entrance ramp excavated to allow it to enter the host pipe

ABOUT THE AUTHOR:

Marcelo Nakashima *is a recent strong addition to the PW Trenchless team. A committed and engaged professional with a problem-solving approach and relevant experience supervising and scheduling work force, planning and executing events and projects, logistics, customer relationship, customer service and project management. With more than 10 years of industry experience he holds post-secondary credentials in Business Management, Project Management and Engineering.*

The site was wide and traffic was only stopped a few times while excavators needed to be moved to align the pull back rods when the swivel and head were attached and then to move a generator to all the vacuum truck better access to remove debris from one of the pits.

The length and depth of this sewer main made it a perfect candidate for pipe bursting, and saved approximately 560 Tonnes or 40 Truck Loads of material from being excavated out of a trench for open cut replacement of this pipe. We also discovered some unknown conditions in preparation for this burst affecting the section under the highway. Therefore, that section is under engineering review and will take place in the near future.

Canadian Underground Infrastructure Innovation Centre (CUIIC):

Expanding Research, Education and Innovation in the Underground Sector

By: Alyscia Sutch, CUIIC

The Canadian Underground Infrastructure Innovation Centre (CUIIC) has now been active for just over a year, and in that time has already made an impact on advancing research, education and innovation in the underground sector in Canada. Located at the University of Alberta in Edmonton, CUIIC brings together nearly sixty member organizations from different sectors, including utilities, municipalities, contractors, consultants, manufacturers, suppliers, and non-profit agencies, to tackle the common challenges faced by the underground infrastructure industry. Underground infrastructure spans many different sectors, including water, storm water and waste water, telecommunications, power, energy and transportation. However, these sectors also have overlap in terms of the challenges they face in building and maintaining underground infrastructure. CUIIC includes stakeholders across these areas and offers a variety of opportunities for interaction and collaboration. The mission of CUIIC is three-fold:

(1) Target current and future needs for underground infrastructure and push innovation;

(2) Facilitate research and collaboration among stakeholders from across Canada and beyond, and;

(3) Promote excellence in education and foster engagement among young professionals.

CUIIC is a natural evolution of two organizations that made strong contributions to the underground sector, one in Alberta and another in Ontario. The Consortium of Engineered Trenchless Technologies at the University of Alberta (Dr. Ali Bayat) and the Centre for Advancement of Trenchless Technologies at the University of Waterloo (Dr. Mark Knight) were both active in research and education in trenchless technologies. A group of leaders from both organizations, along with other experts in the underground sector, collaborated to establish a new centre that would foster innovation and research in underground construction, as well as provide educational opportunities for professionals and students across Canada.

With its focus on research, education, and innovation, CUIIC is well-positioned to help the underground sector

This process culminated in receiving official approval for CUIIC to be established as an academic centre at the University of Alberta in March 2022.

CUIIC operates with a democratic governance structure and includes three core committees: the Education and Outreach Committee, the Industry and Membership Committee, and the Research and Innovation Committee, each with a distinct focus. Professionals from different fields volunteer their time and expertise to serve on these committees, which helps to drive the organization's initiatives.

> *CUIIC brings together nearly sixty member organizations from different sectors.*

CUIIC Webinars started in Fall 2022 and have been successful in sparking discussions around topics related to the underground sector. Webinars are held on the third Thursday of each month. To date, topics have included approaching reconciliation as an engineer, the legal aspects of underground construction, machine-learning depiction for underground infrastructure, and how to read a geotechnical report. Additional topics focused on spray-in-place pipe and spray-applied polymer linings, microtechnology for utility installations, subsurface utility engineering, and managing waste from microextraction. Registration for these webinars is free and all webinars are open to anyone interested, whether or not they are CUIIC members. Both professionals and students are welcome, and the webinars and discussion sparked by the presentations provide plenty of learning opportunities for everyone.

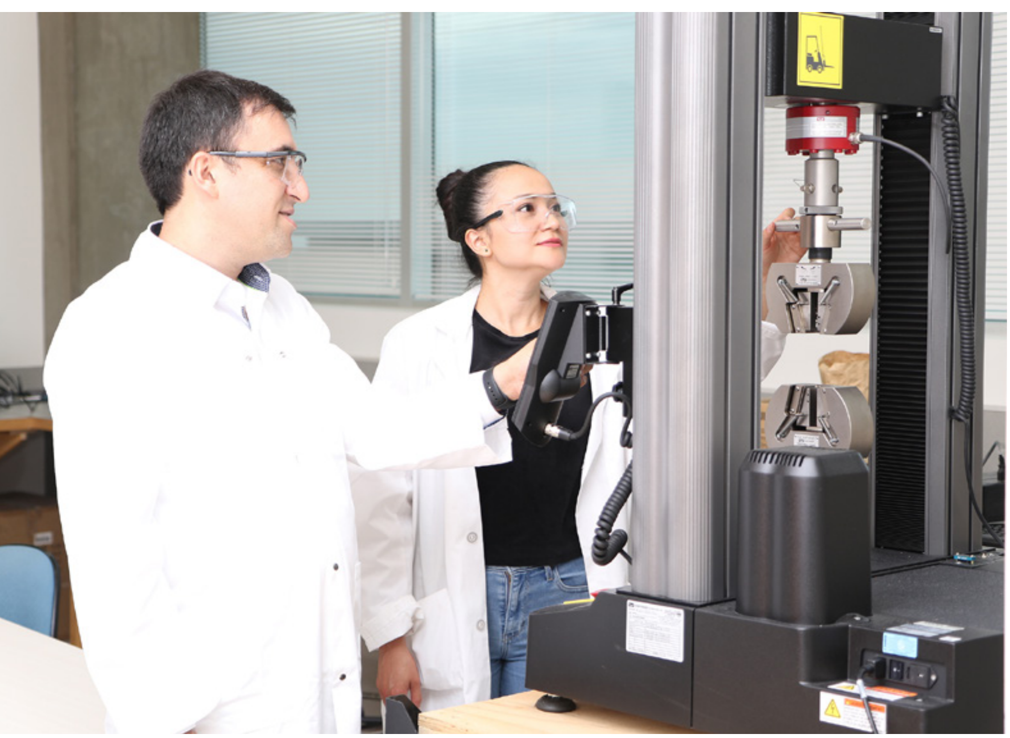
The 2023 Pipeline Rehabilitation Academy was held on March 21-22, 2023 in Mississauga, ON and was a success, with approximately 80 registrants. There was a packed agenda for this event. The first day focused on developing a successful gravity and pressure pipeline rehabilitation program. The second day followed up with topics related to pressure pipe rehabilitation and design, as well as quality assurance and quality control. Speakers included representatives from academia, industry, and municipalities, giving participants a broad perspective of the challenges associated with rehabilitation of gravity and pressure systems. The 2024 Pipeline Rehabilitation Academy is heading to Richmond, BC on March 13-14, 2024. Anyone interested in learning more speaking, sponsoring or registration can visit **www.academy.cuiic.ca** for more information.

The Canadian Underground Infrastructure Innovation Centre will also be exhibiting at No-Dig North 2023 in Booth #222 October 23-25, 2023 in Edmonton. Stop by to learn how CUIIC provides stakeholders across all sectors with opportunities to collaborate on research and training opportunities in underground infrastructure.

CUIIC Academy will be hosting the 2023 Safety Academy, to be held on November 29-30, 2023 in Edmonton, AB. Planned by the CUIIC Safety Committed, experts have developed an agenda that will equip attendees with knowledge on a wide range of underground construction safety

Held at the University of Alberta, the first annual CUIIC Innovation Forum and AGM brought together 80 attendees to learn about the latest in underground construction

The CUIIC Innovation Forum and AGM included a tour of the University of Alberta laboratory facilities



CUIIC fosters innovation and research in underground construction

topics, particularly the safety issues and regulations specific to underground construction. Registration for this event is now open and anyone looking to learn more can visit **www.academy.cuiic.ca** for more information.

Since fall 2022, CUIIC has spearheaded proposal development for several research programs, including several Natural Sciences and Research Council of Canada (NSERC) Alliance grants. CUIIC greatly values the time and expertise of the academics from more than half a dozen universities across Canada (from the University of Alberta, Concordia University, University of Waterloo, University of Toronto, University of Birmingham in the UK and University of Twente in the Netherlands) who have provided input into the development of these proposals. These research initiatives actively involve diverse stakeholders and well over 20 research partners have committed in-kind support for strategic research areas. Currently, this includes lowering risk in underground construction, the use of data to enhance efficiency in underground construction, lowering greenhouse gas emissions through adoption of clean technologies, and addressing climate change and resiliency in the construction, rehabilitation and maintenance of underground utilities.

The challenges facing the underground infrastructure industry in Canada are significant, ranging from aging infrastructure to the unpredictability of climate change.

> *The 2024 Pipeline Rehabilitation Academy is heading to Richmond, BC March 13-14, 2024.*

However, CUIIC's efforts to promote collaboration and innovation among stakeholders from different sectors are already yielding positive results. With its focus on research, education, and innovation, CUIIC is well-positioned to help the underground sector to meet the challenges of the future.

ABOUT THE AUTHOR:

Alyscia Sutch *is the Research Marketing and Communications Coordinator at the Canadian Underground Infrastructure Innovation Centre (CUIIC) located at the University of Alberta. She has over 14 years of experience working in the underground construction industry.*

CUIIC Innovation Forum and AGM

The first annual CUIIC Innovation Forum and AGM was held on May 25, 2023 at the University of Alberta. This event focused on the latest research in underground construction, while also providing networking opportunities and the annual general meeting.

This yearly event brought together 80 attendees to learn about cutting-edge solutions and major trends in underground infrastructure and tour the University of Alberta laboratory facilities.

The forum highlighted informative presentations by guest speakers including Matina Kalcounis-Rueppell, College Dean and Vice Provost at the University of Alberta, Abhishek Bhargava, Senior Manager, Drainage Engineering at EPCOR, Greg Caldwell, Director, Utility Hydrogen at ATCO, Ali Bayat, Director of CUIIC at the University of Alberta and Kevin Jolly, Business Development Manager along with Rob Petruk, Digital Offerings and Innovations at Dura-Line.

CUIIC would like to thank all of the speakers, attendees and University of Alberta staff who facilitated the lab tours. The event was very well received and we look forward to hosting the Innovation Forum again next year.

Thrust Force Requirements During Direct Steerable Pipeline Thrusting (DSPT):

Friction or Fiction?

By: Stefan Goerz, M.Sc., P.Eng., PE., CCI Group of Companies

1.0 INTRODUCTION

Pipe thrusting in the pipeline industry has become a very common technique for trenchless crossing installation. The most common technique is Direct Steerable Pipe Thrusting (DSPT); however the pipe thruster has also been commonly used in other applications such as casing installation or retraction, and support for other trenchless techniques. The focus of this article is to review the pipe thrusting requirements for small overcut (or annulus) applications. Since the overcut is generally smaller than that of horizontal directional drilling (HDD) there is a concern of friction dominating the total thrust force required for installation or retraction. As in traditional microtunnel applications with limited vertical geometry, such as curves, the friction generally dominates the jacking or thrusting force requirements. Traditional microtunneling is predominantly used for larger diameter applications than what is seen for pipeline applications in the oil and gas industry.

The topic of frictional contribution and its impact on the pipe thrusting activity is very important to advance design to a stage that can help assess contractor plans with a known degree of accuracy. Conservatism isn't an adequate method for design, especially when working with a contractor to optimize equipment due to availability, construction workspace or worksite layout.

2.0 BACKGROUND

Direct Steerable Pipe Thrusting (DSPT) is continuing to gain popularity in the oil and gas, as well as municipal sectors, as a trenchless tool to execute complex crossings. The purpose of this section is to review the components of friction as they relate to this technology and to understand how designers are able to make the frictional resistance calculations more representative.

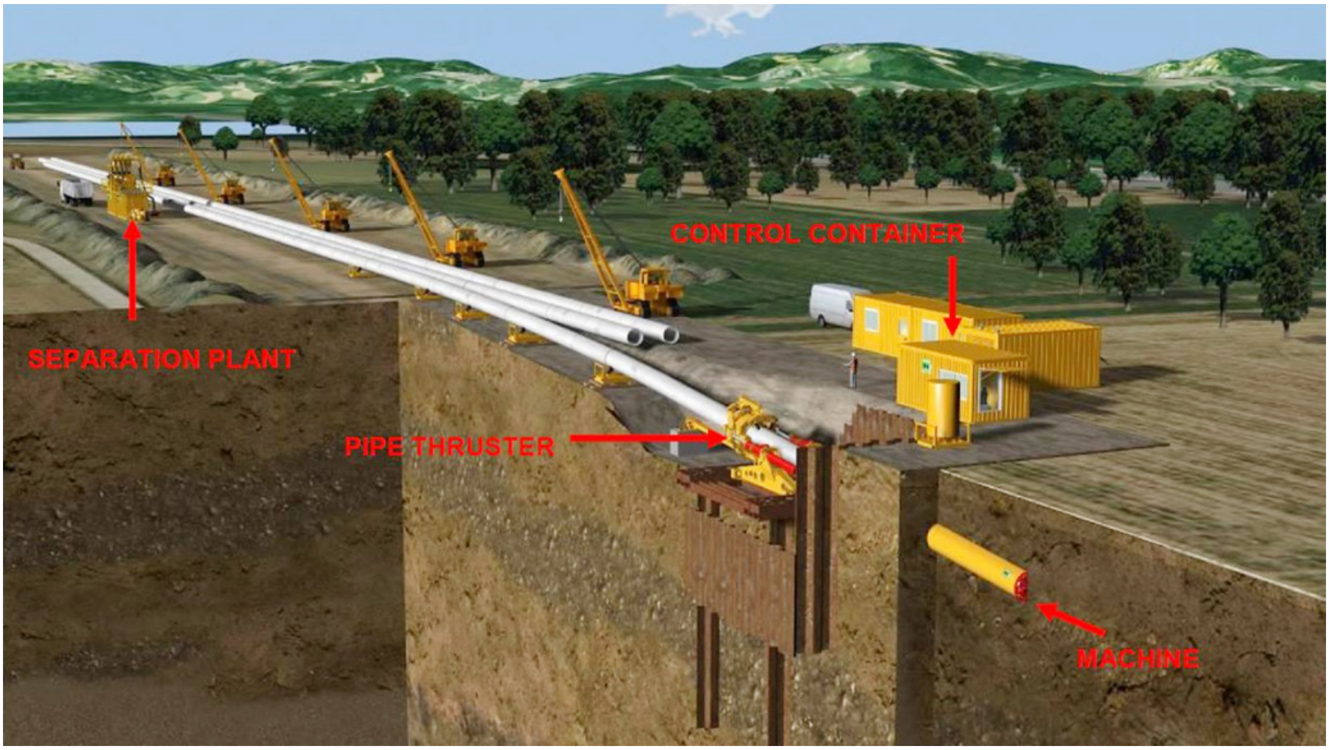


Figure 1. Typical DSPT worksite showing equipment at the launch area (Pfeff D., 2013)

2.1 Construction Application

As noted, pipeline thrusting is generally utilized for installation or removal of pipeline through the DSPT methods. DSPT is a method of installing steel pipeline crossings, ranging in diameter from 914.4 mm to 1524 mm (36 to 60 inches), by thrusting a guidable, slurry supported MTBM along a pre-determined path (Pfeff D., 2013). An illustration of a typical DSPT launch area is shown in Figure 1.

The product pipeline section is prepared, welded to the proper length, and laid on the surface. The MTBM is connected to the front of the pipeline section. The MTBM is typically 25 mm larger, radially, than the product pipeline, creating an overcut. A stationary thruster is situated at a launch location where the MTBM and pipeline are threaded through the clamping inserts of the thruster at the design angle. The vulcanized rubber clamping inserts grab the outer surface of the pipeline and push the MTBM and pipeline section forward. Additionally, the DSPT system uses a bentonite fluid injected within the annular space created by the overcut. The bentonitic fluid is under pressure, intended to support the soil along the borehole wall and provide lubrication during tunnelling operations.

The importance of estimating thrust forces during Direct Steerable Pipeline Thrusting (DSPT) techniques cannot be understated.

2.2 Soil Mechanics

The soil mechanics of sliding the pipeline through the ground is a complex problem, especially considering the variability of the natural soils in combination with the bentonite lubrication fluid injected into the overcut during installation. Influential soil properties are the peak and residual angle of internal friction (friction angle) and adhesion or cohesion. For this article, friction angle will be examined in depth and cohesion or adhesion will be considered negligible in short term or dynamic applications. Cohesion or adhesion properties become much more significant during longer term standstills and long periods without movement which is considered another important subject for research. Interface friction is the amount of frictional resistance between two surfaces of different materials.

The peak angle of internal friction, associated with the Mohr-Coulomb failure envelope, is a very common property in soil mechanics and helps determine the soil shear strength. Conceptually, it is an estimate of the frictional resistance between the soil particles – a soil to soil interface friction. The residual friction angle is associated with movement, after a shear failure plane develops, and represents the minimum (lowest frictional strength). Generally, clay soils have lower friction angles, and sands/gravels heave greater friction angles. Typical values for angle of internal soil friction are shown in Table 1.

Organic soils as shown in Table 1 often have extremely high moisture content and could be analogous to a bentonite mixture near its liquid limit. Gleason (1997) completed a series of direct shear tests on hydrated and remolded bentonite and determined the friction angle was ~10 degrees for these samples.

3.0 LITERATURE REVIEW

3.1 DSPT Thrust Force

Pruiksma, Pfeff, & Kruse (2012) investigated the thrust force in DPI using ABAQUS finite element software package. The authors found that, according to the software, the five (5) mechanisms that contribute to the thrust force are as follows:

1. Friction behind the thruster on rollers,
2. Friction between the pipeline and lubricant fluid,
3. Front force at the MTBM face,
4. Friction between the pipeline and tunnel wall, and
5. Friction due to pipe buckling.

The method described by Pruiksma, Pfeff, & Kruse (2012), is herein referred to as the "***current state of practice***". This article focuses on mechanisms 2 and 4.

Table 1. Average drained friction angles of various soils (Praetorius and Schoser, 2017)

Soil Type	Angle of Internal Friction (degrees)
Sand, loosely compacted	30 to 32.5
Sand, densely compacted	32.5 to 35
Sand and Gravel, loosely compacted	30 to 35
Sand and Gravel, densely compacted	35 to 40
Broken stone / ballast mixes	35 to 45
Weakly cohesive soils	25 to 27.5
Highly cohesive soils	15 to 25
Organic Soils	5 to 15

3.2 Effect of Soil to Pipeline Interface Friction

The frictional forces that develop along the length of the casing or pipeline alignment are dependent on many factors. The magnitudes of frictional forces are mostly dependent on the interface shear of the pipe material, and the soil type along the tunnel sidewall. Many works of literature have examined the pipe to soil interface shear characteristics including Staheli 2006, Iscimen 2004, and Uesugi & Kishida, 1986. It is suggested to refer to the source literature to gain further understanding, as these works of literature go into much greater depth than this article. The research provides evidence that surface roughness of pipe material has a large influence on the amount of frictional resistance for pipe to soil contact.

Additionally, a "bi-linear" friction envelope appears to be present where the interface friction is unable to increase past the internal friction angle of the soil with which the material is in contact, providing insight into maximum frictional resistance in unlubricated sections of DSPT alignments. The relationship is shown on the illustration in Figure 2.

The concept that is shown from Figure 2 is that the maximum interface friction possible is the angle of internal friction of the soil in contact with the interface.

Table 2. The Coefficient of Friction at Various Pipe-Ottawa 20/30 Sand Interfaces (Iscimen, 2004)

Pipe Type	Coefficient of Friction					
	N = 40 kPa		N = 80 kPa		N = 120 kPa	
	peak	residual	peak	residual	peak	Residual
Hobas™ FRP	0.51	0.43	0.50	0.44	0.48	0.42
Polycrete	0.50	0.42	0.49	0.43	0.47	0.43
Steel	0.68	0.49	0.62	0.44	0.62	0.47
Wet-cast Con.	0.68	0.49	0.65	0.48	0.63	0.45
Vitrified Clay	0.71	0.50	0.63	0.48	0.65	0.49
Packerhead™ Con.	0.81	0.54	0.73	0.53	0.73	0.52
Sandpaper No.60	0.80	0.60	0.77	0.55	0.75	0.55
Sandpaper No.36	0.82	0.61	0.76	0.56	0.74	0.54

This is because at that point of critical roughness, the shearing plane changes from the interface, to a point within the soil mass.

The residual friction angle to be used in the jacking or thrust force calculations for the soil which contacts the pipe is recommended by Bennett and Cording (2000) and Staheli (2006).

Iscimen 2004 determined frictional interface values of curved interfaces from research. The interface friction values obtained at various normal stresses is summarized in Table 2.

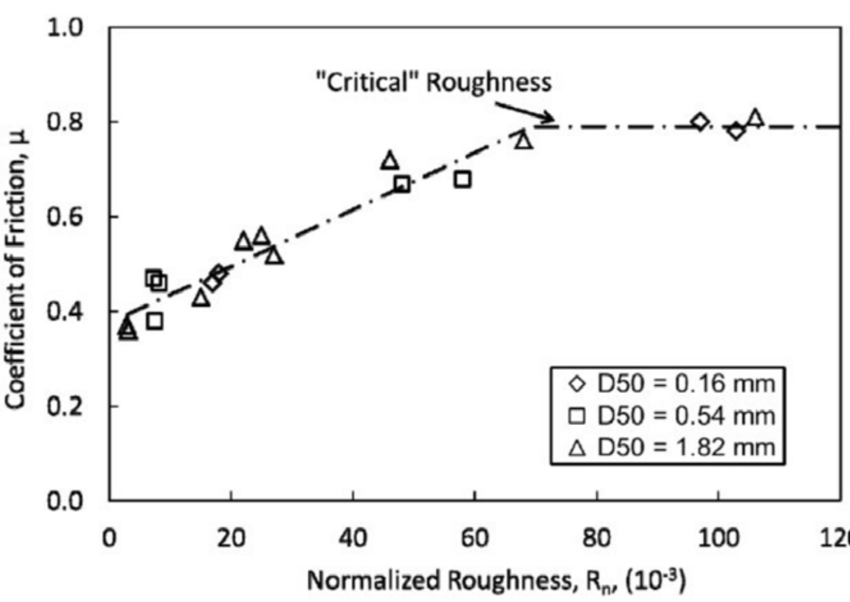


Figure 2. Illustration of the Bi-Linear relationship between coefficient of friction and surface roughness (Uesugi & Kishida, 1986)

3.3 Effect of Lubrication Bentonite

During installation of casings or pipelines by pipe thrusting, the bentonite lubrication would be expected to remain within the overcut in most soils. Therefore, the soil to pipeline contact may be limited. Marshall (1998) suggests that, depending on its stability, lubrication introduced in cohesive soil can work its way over the whole pipe surface, resulting in reduced friction along the entire length. The findings indicate that the average frictional resistance drops rapidly once bentonite lubrication is introduced; the decrease was found to be between 44 and 90 percent in Marshall's research. Additionally, this research showed that in soil with peak friction angles of 37.5 to 38 degrees, the interface friction angle fell to 14 degrees once bentonite fluid was injected. This bentonite was introduced when jacking forces became excessive, which is known as partial lubrication. When using mass lubrication, where bentonite fluid is injected into the overcut continuously, the results of Marshalls research show friction angles may approach zero. Staheli (2006) reproduces similar findings in a portion of her Ph.D. thesis. She provides evidence in various case studies that there is marked difference in frictional resistance for lubricated versus non-lubricated intervals. Review of the

> *Research provides evidence that surface roughness of pipe material largely influences the amount of frictional resistance.*

case study information revealed that by applying mass lubrication, a 90 percent reduction in jacking forces was observed in sandy soils. The information from case studies reviewed by both Marshall (1998) and Staheli (2006) reveal that mass lubrication techniques used in most pipe thrusting installation methods are likely to reduce significantly the amount of pipe to soil interface frictional resistance.

Furthermore, the impact of the magnitude of fluidic pressure within the overcut on the frictional resistance is an interesting concept. A drop in fluidic pressure within the overcut indicates a potential loss of fluid to the formation, and it is uncertain if this severely impacts the bentonite's performance. The effect of lubrication pressure was examined by Namli & Guler (2017), and their work suggests that the benefits of bentonite application under constant pressure can be achieved with minimal injection pressures. Namli & Guler suggest that it is not the amount of pressure that reduces pipe-soil friction to 10 percent of its original value; but the mere presence of pressure ensures that bentonite is coating the entire pipe surface area. If pressure is present in lubrication chamber, it is likely that the entire surface area is coated in this lubrication, and the interface friction could be comprised entirely of pipe-bentonite contact, rather than pipe-soil (Namli & Guler, 2017).

Consideration needs to be given to potential deterioration of bentonite lubrication during longer drives. Unlike in conventional microtunnelling where lubrication ports may be installed throughout the drive, during DSPT there are only bentonite injection ports at the front end near the MTBM during installation. This makes targeted injection of the bentonite impossible in the case of deteriorating bentonite. Deteriorating, or non-performing lubrication will significantly affect the thrusting requirements. An added function of the bentonite lubrication is to support the soil surrounding the pipe being thrusted. Consideration needs to be given to the specific gravity and particle size of the soil being supported. If high specific gravity soil particles are present, there is a higher probability that over the duration of pipe thrusting, more soil will be in contact with the pipeline and negate the effect of the lubrication bentonite.

4.0 PLANE OF SHEAR

The plane on which the sliding occurs would determine the interface friction properties during pipe thrusting. The frictional resistance develops due to interface friction between the various materials along the length of the pipeline. The possible interfaces that may impact the overall frictional resistance of the pipeline thrusting may include:

1. Pipeline to Bentonite Lubrication
2. Pipeline to Natural Soil
3. Bentonite Lubrication to Natural Soil

In addition, the angle of internal friction between the same soil materials may be the plane on which shearing takes place.

1. Bentonite to Bentonite
2. Natural soil to natural soil

Figure 3 shows the layers where shear may occur in the annulus and just adjacent to the annulus of the pipeline installation.

Shear would be expected to occur along the interface or material with the lowest frictional coefficient. This is similar to the concept of critical roughness described by Uesugi & Kishida in 1986.

Shear stress is a function of normal stress and the frictional coefficient of the materials in contact along the plane of shear. In order to determine feasible

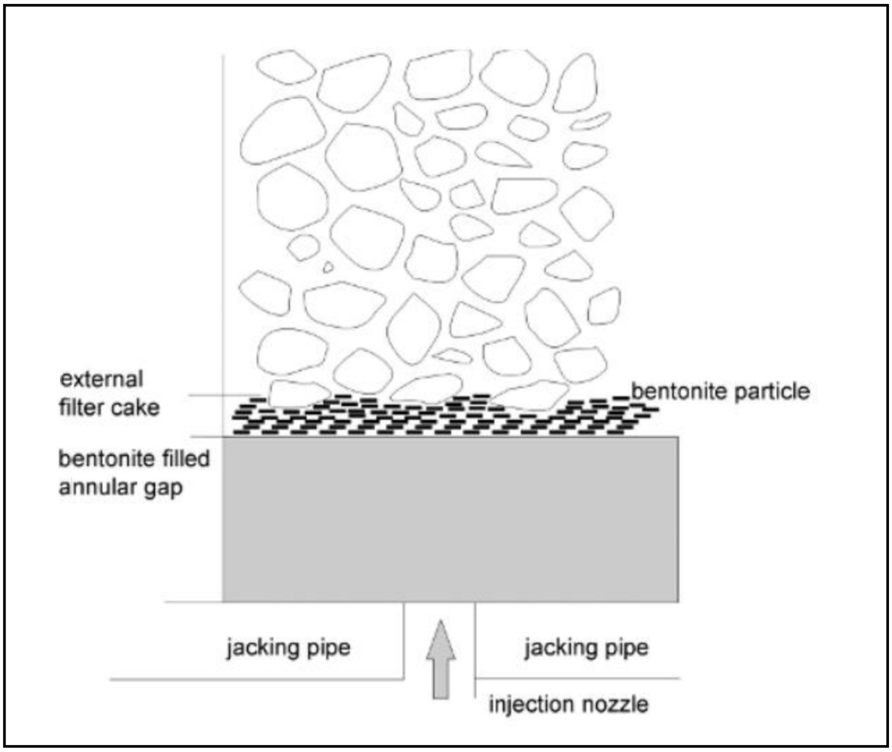


Figure 3. Layers of potential frictional resistance (Praetorius and Schoser, 2017)

Table 3. Back Calculated Friction Coefficients from Case Studies

Case Study	Lubrication Friction Coefficient (N/m^2)	Soil Friction Coefficient ([]) *
Case Study 1	65	N/A
Case Study 3	45	N/A
Case Study 4	7	0.045

* Only Case study 4 had data that was suitable to assess the soil frictional coefficient.

mechanisms for failure of each failure plane there are important considerations such as normal stress, soil hydraulic conductivity as well as lubrication fluid yield point and stability. Deteriorating bentonite fluid could allow additional soil to come into contact with the thrusted pipeline and cause additional friction.

5.0 PREVIOUS CASE STUDY RESULTS

Thrust force during DSPT was evaluated by using case studies and comparing the data obtained to the current ***state of practice calculation method*** (Goerz, 2019). The frictional resistance coefficients embedded within the state of practice calculation method were modified and normalized to best fit the case study data for specific intervals of the drives. It should be noted that this data was mainly obtained for drives through clayey soils. The lubrication friction coefficient and the soil to pipeline interface frictional coefficient are reported in Table 3.

As shown in Table 3, the Case Study 1, Case Study 3, and Case Study 4 lubrication friction coefficients range from 7.0 N/m2 to 65.0 N/m2, which agree well with the recommended value of 50 N/m2 (Pruiksma, Pfeff, & Kruse, 2012).

The soil to pipeline interface friction value was measured through the analysis of Case Study 4. The value obtained was 0.045, which is substantially smaller than the recommended value of 0.2 (Pruiksma, Pfeff, & Kruse, 2012). Although the value is very small, considering that the clayey soil conditions provide a stable tunnel wall, this may be a frictional value more representative of a bentonite lubrication-coated clay wall (or no pipe-soil interaction). The coefficient of friction value determined from the Case Study 4 Data results in an interface friction angle of ~2.5 degrees, which isn't unrealistic for a hydrated bentonite.

6.0 OPPORTUNITIES

When designers use the ***state of practice calculation method*** for determining thrusting requirements there are opportunities to improve the frictional assessment.

Currently the ***state of practice calculation method*** considers both bentonite lubrication-to-pipe and soil-to-pipe interface friction acting through the entirety of the drive. There could be consideration to use three cases when evaluating the frictional resistance to develop risk profile for various unanticipated construction events. The first case could consider the case that the lubricating bentonite or bentonite coated soil (stable sidewall) is the only interface friction during construction. This calculation would utilize the lubrication bentonite frictional coefficient for the entire drive. A second case would assess the potential areas of a specific drive where the bentonite lubrication may deteriorate and added soil to pipe interface friction becomes more apparent. These locations would be areas of coarse granular soils in the drive, or depending on the schedule of the construction, these could be areas near the beginning of the drive where the lubrication has been in use for significant time. A third case could consider a "Worst Case" scenario to assess a collapse of soil onto the pipeline for a significant section if likely, or worse, soil-to-pipeline interface friction for the entirety of the drive.

Another very important consideration which wasn't as much of a focus in this article is the magnitude of normal force the pipeline exerts on the tunnel sidewall. More research is needed in this area, however at the vertical curves or build sections of the design, a normal force may be significant enough to cause "plowing" or a case where the bentonite lubrication is scraped off the wall and a shear plane within the soil mass develops. In this case the soil internal angle of friction would be considered and, as one could imagine, would significantly increase the amount of resistance.

7.0 CONCLUSIONS

Conclusions of this research are:

1. The importance of understanding the soil mechanics and frictional properties of the soil through which the tunnel is constructed is imperative. These properties can significantly affect the analysis.
2. Assessment of the various cases during pipe thrusting is imperative to assist in determining the risk profile for specific crossings.
3. Assessment of normal force should be re-examined to assist with estimating the frictional forces in build sections of the DSPT profile.
4. Additional research is warranted to determine the shear strength properties of bentonite lubrication, as well as shearing angles of resistance. This would not only assist with frictional resistance estimation but would also assist in determining potential hydraulic pressures developing within the overcut.

> *DSPT is continuing to gain popularity as a trenchless tool to execute complex crossings.*

8.0 REFERENCES

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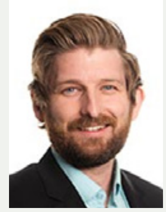
ABOUT THE AUTHOR:



***Mr. Stefan Goerz, M.Sc., P.Eng., P.E.** is the Geotechnical Manager for CCI Inc. and CCI & Associates Inc., a Canadian and US Engineering Firm, respectively, specializing in pipeline engineering including trenchless methods. He has over 11 years of directly related experience in projects related to trenchless pipeline construction, geotechnical investigation and assessment for pipeline and trenchless design, geotechnics for tunnel/microtunnel design as well as geohazard assessment for linear infrastructure projects. Stefan completed his Bachelors Degree (2013) and Thesis based Masters Degree (2019) specializing in Geotechnical Engineering at the University of Alberta. In 2020, Stefan became registered in the USA as a Professional Engineer completing both the Fundamentals of Engineering (FE) and the Practice of Engineering (PE) exams.*

PORT MOODY CIPP:

Old Orchard Park Shoreline Trail Sanitary Sewer Upgrades

Old Orchard Park (foreground) runs along Port Moody inlet

By: Marcelo Nakashima, PW Trenchless Construction Inc.

PW TRENCHLESS WORK: PROJECT PREPARATION

While this article is mainly about the CIPP work completed by Insituform the main work was completed by PW Trenchless Construction (PWT) before and after the CIPP work.

PWT started this project months earlier with an extensive study of the bypassing requirements. No work on the line could take place until all the existing flows had been completely and safely bypassed. Considering that this pipe is within meters of the foreshore of the Port Moody inlet any kind of a spill could not be tolerated. Thus, the bypassing system had to be bullet-proof and have redundancy. There were 4 main inputs from gravity and or pump-stations that had to be controlled and handled. Two overland force mains were set up and the flows re-directed into these temporary force mains.

The site was then set up ready for the CIPP crews to arrive. As there were no manholes on this line the insertion pits were placed at points where:

1) the inputs mentioned above occurred;
2) major changes in alignment, like creeks, or;
3) after sufficient length.

This meant that we had to cut into the existing pipe and prepare it for cleaning and pigging. We then had to prepare the existing pipe ends so that Insituform could install the CIPP, and that we then could attach the new branch fittings and flow control systems.

INSITUFORM WORK: SEPTEMBER 12, 2022

On September 12, 2022, Insituform started to line the existing gravity sanitary sewer lines that run through the Old Orchard Park in Port Moody. Insituform® CIPP is a cured in place pipe (CIPP) liner that is installed via air pressure. This is not a new experimental process as it has has been used for over five decades. To date the life of 25,000 miles of pipe worldwide has been extended via Insituform® CIPP lining.

The starting date for the Edmonton-based Insituform crew, was a dry sunny day that had followed an unusually long dry period for the Lower Mainland area of British Columbia.

PWT started earlier for the preparation and bypass of the forcemain pipe, not for the gravity main portion that is described in this section.

As an ecologically sensitive shoreline park, any kind of spill from the bypass pumping could not be tolerated

After almost 6 hours the pipe was fully set up and ready for use.

The crew showed up and the first process, after the obligatory wheel washing process to ensure there was no contamination brought into the parks eco-system, the Insituform crew did a camera inspection of the line and sent up a cleaning wand as needed. Once inspected, the truck which controls the system was put in place by the entry point at an existing manhole. At both the entry point manhole and the exit point manhole, a pipe testing plug was installed into both ends of the pipes entering the manhole that were not part of the lining process that day. This ensured that no stray debris entered the host pipe which was going to be lined.

The truck holding the liner was then set up in place. The liner had already been "wetted out" with epoxy resin and needed to be kept cool with bags of ice surrounding the liner. The liner is a poly sleeve with a felt inner membrane that is impregnated with a fiberglass type resin and pulled through a series of pinch rollers calibrated to a specific height to ensure the even distribution and thickness of resin within the entire membrane and throughout the complete length of the liner.

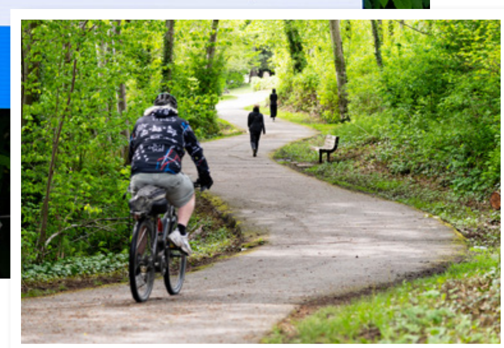
A pipe liner inverter was then set up over the entrance manhole and the liner fed through the inverter with the liner end inverted and held in place with steel bands. High pressure air was directed through the plenum of the inverter to force the liner downwards into the entrance manhole where it was redirected by a wedge in the invert of the manhole. This pushed the liner towards the pipe to be lined.

While high pressure air was being forced through the inverter, a liquid lubricant was applied to allow the new liner to be installed with minimal friction and no damage to the liner. While the lubricant was added a poly tub was placed on the ground to capture any dripping liquid so it would not impregnate the ground of the park. As the liner was inverted into the host pipe, the resin soaked felt inner part of the liner was forced by the air pressure to bond tightly against the inside of the host pipe.

Once the liner was installed through the host pipe, a PVC pipe sleeve of the same diameter as the host pipe was placed around the excess liner laying on the ground outside the exit manhole. This was marked with the date and batch number of both the liner material and the resin in order to provide a test sample of the liner.

The end of the installed liner was tied off and a small hole was drilled into the liner. A steel manifold pipe was then inserted

Strong public engagement on the project was very important for this popular local park



into the hole as a port allowing the pressurised air to escape. This steel pipe had a pressure gauge and valve to maintain a constant air pressure to keep the liner mated closely with the host pipe. Once pressurized, steam was introduced to start the curing process. Temperature probes were carefully monitored to ensure constant even curing times and temperatures, which were critically important.

After a predetermined time, calculated by the length and diameter of the project liner, with a considerable safety margin, the steam was replaced by air, the pipe was cooled and pressure removed. The ends of the pipe were cut off and removed in sections to allow access to the manholes. After accessing the manholes the ends of the liners were carefully cut to the correct shape of the host pipe as it entered the manhole.

Cleanup and removal of the excess liner was fast and done carefully, with all necessary means used to ensure no damage to the surrounding area or manholes.

Steel manifold used in the steam curing process

Set up for the UV light curing process

Park is also home to important heron nesting habitat. The Herons bred successfully in the trees above us

INSITUFORM WORK: SEPTEMBER 28, 2022

On September 28, 2022, Insituform started to line the existing sanitary sewer lines that go through the Old Orchard Park. Insituform® CIPP is a cured in place pipe liner that is installed by pulling through the existing, or "Host" pipe. The sanitary sections of the sewer were installed using the iPlus® Glass process. According to the Instituform website, the iPlus® Glass liner is reinforced with glass fiber and can be cured using an ultraviolet (UV) method. This trenchless CIPP solution is a jointless, seamless, pipe-within-a-pipe. It can be used to rehabilitate pipes ranging in diameter from 150mm to 1200mm (6 to 48 inches).

Unlike the CIPP method used on the ***gravity sanitary sewers*** in the park earlier in the month, there was quite a bit of preparation work necessary to complete these projects. Along with the bypass pumps and piping installed for the sanitary sewer, entrance and exit pits needed to be excavated and shored with trench shoring cages. The sanitary sewer was a forced main and as such did not have open manholes to install liners through. The entrance and exit pits were placed at predetermined lengths of the pipe main, and were sensitive to the surrounding trees in the park.

The pits were all excavated and shored by PWT crews during the months preceding the relining operations. The ends of the pipe to be lined were cut perfectly square on the day of the lining and a strong section of C-900 Waterman PVC pipe was attached with a flexible coupling. This allowed for ratchet straps to hold the liner securely in place without fear of cracking the host pipe.

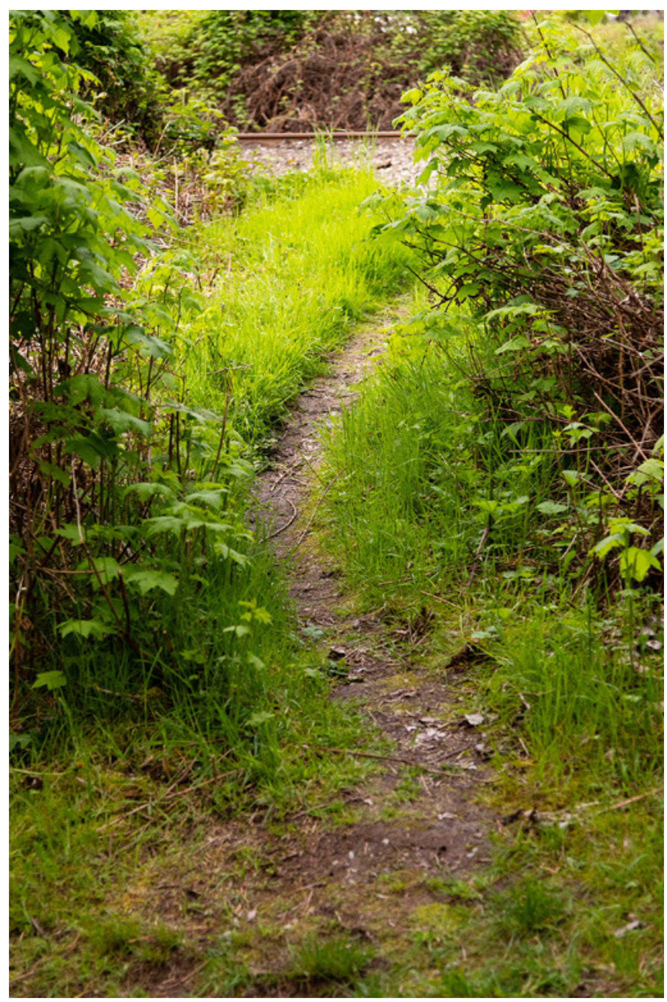
The iPlus® Glass installation process was much different than the Insituform® CIPP installation used on the Port Moody Gravity Sewer mains earlier in the month. While the camera was sent up the host pipe for the initial pre-lining inspection the morning of the lining, a plastic liner was attached to the camera rig and pulled back through the host pipe, along with a pull rope for installing the winch cable. This plastic liner helped reduce friction, and the possibility of damage to either the liner or host pipe.

Lining completed and ready for the PWT crews to finish the connection

"And the Herons bred successfully in the trees above us."

To help keep the liner stably in place, a portion of the liner was sent up the unused portion of the host pipe on the opposite end of the excavated entry pit. A sewer test plug was inserted and inflated which did a good job keeping the plastic liner from being dragged along with the liner as it was installed. The winch cable was pulled through and attached to the liner end, ready for pull back. A plywood deck was placed on an angle and the crate with the liner set on top with the liner end attached to the winch cable. The liner was then installed into the host pipe by pulling it through.

Once the liner was installed, at the other end, in the exit pit where the winch was located, a steel flange was attached to the end pipe and secured with ratcheting straps. This enabled air and the control cables utilized for the inflation and curing of the pipe liner to be inserted. In the entrance pit the UV light apparatus was placed in the pipe and a similar steel flange was attached and held



in place with ratcheting straps. The protruding portion of the plastic liner was also pulled over the end and held in place with tape and straps. The lighting apparatus is installed in to the bag and the end is tied off. Air was forced in from the far exit end to inflate the liner and the clear plastic bag around the entrance pit end.

After the liner was partially inflated, a slit was cut in the plastic and the control and power cords were attached to the UV lighting apparatus. The lights were then placed inside the liner and the end was sealed with a special flange that allows the control and power cords to run through the flange under full pressure. The lights were pulled through the pipe all the way to the exit pit and air pressure and heat were applied until the proper settings were reached. The lighting rig has numerous lights that cure the fiberglass resin impregnated liner until it is as durable as PVC pipe.

After almost 6 hours for the September 28, 2022 lining job, the pipe was fully set up and ready for use. Over the next several weeks, a number of other continuous segments of the pipe were lined in a similar fashion. After a few weeks of work all the liners were installed, and strangely for the Lower Mainland area, the job was completed prior to the rains starting to fall.

> *Cleanup and removal of the excess liner was fast and done carefully, ensuring no damage to the surrounding area.*

PW TRENCHLESS WORK: PROJECT COMPLETION

At this point the PWT crews came back onsite and began joining up the newly lined and tested segments of pipe. Once these CIPP pipes were connected to each other forming a continuous pipe line and connected to the various sewers coming down the mountain the PWT crews were able to backfill the insertion pits, and most importantly, put the new pipe back on line as quickly as possible.

The temporary bypass was then flushed and cleaned out, before its removal and readiness for the next project. A very successful project completed by all and the Herons bred successfully in the trees above us.

ABOUT THE AUTHOR:

PW Trenchless Construction Inc. is an experienced General Contractor established in January 2000, specializing in both trenchless and traditional open cut utility construction methodologies. The company has pioneered trenchless technologies in BC throughout its history and stands apart from other trenchless contractors in the local marketplace by completing all civil works for trenchless projects in-house, using own equipment and forces.

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