2019

TRENCHLESS SANS TRANCHÉE Journal

THE OFFICIAL PUBLICATION OF THE NORTH AMERICAN SOCIETY FOR TRENCHLESS TECHNOLOGY
Great Lakes, St. Lawrence & Atlantic Chapter | Chapitre des Grands-Lacs, du Saint-Laurent et de l'Atlantique

REHABILITATION OF THE BARTON STREET HORSESHOE-SHAPED COMBINED SEWER IN HAMILTON

PM #40065075

- First Annual No-Dig North Recap
- Sampling Strategies in CIPP Quality Assurance Programs

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ON THE COVER: Sewer rehabilitation in Hamilton

TRENCHLESS SANS TRANCHÉE Journal

2019

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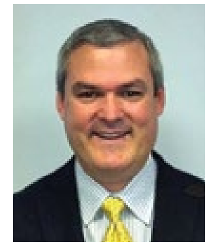
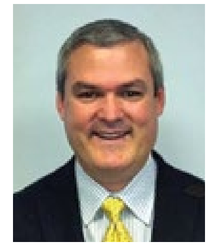


The GLSLA board of directors and member volunteers are continuing to work to provide value to our members through training, publications, and our website. GLSLA also continues to be a proud supporter of NASTT programs, including the silent auction and student scholarships.

In Calgary on October 28, 29, and 30, 2019, the three Canadian chapters of NASTT (Northwest, GLSLA, and BC) were proud to host the first-ever No-Dig North show. The show was an enormous success with 575 attendees, more than 65 booths, more than 60 technical papers presented, and four NASTT training courses with more than 60 people participating. The conference provided a great opportunity for municipalities, utilities, consultants, and contractors to gain knowledge and network with the trenchless industry across Canada and the United States. No-Dig North has now been established as an annual event with the next No-Dig North being held in Vancouver at the Vancouver Convention Centre, October 19 through 21, 2020.

In partnership with NASTT and ACWWA, GLSLA held the NASTT Introduction to Trenchless Rehabilitation course in Halifax on October 9, 2019, after the ACWWA Annual Conference. The course was well attended with more than 20 participants. We would like to thank ACWWA for their partnership in presenting this course and look forward to continuing to promote the trenchless industry in Atlantic Canada with ACWWA. You can stay up to date on training opportunities and other events on our website at *www.glsla.ca.*

We hope you enjoy this latest GLSLA Chapter magazine filled with great project and industry articles. For more information on the GLSLA Chapter, our events, magazine, and our training sessions or to contact us if you wish to publish an article in our magazine, please visit our website at *www.glsla.ca.*



Des partenariats bénéfiques

Le conseil d'administration et les bénévoles de la section Grands Lacs, Saint-Laurent et Atlantique (GLSLA) travaillent sans relâche à valoriser l'appartenance à l'association grâce à des formations, à des publications et au site Web. La GLSLA est fière d'apporter son concours aux programmes de la North American Society for Trenchless Technology (NASTT), notamment la vente aux enchères silencieuse et les bourses d'études.

Les 28, 29 et 30 octobre 2019, à Calgary, les trois sections canadiennes de la NASTT (NordOuest, GLSLA et C.B.) ont fièrement accueilli leurs collègues au tout premier salon NoDig North. Et quel succès : 575 participants, plus de 65 stands, plus de 60 présentations techniques et 4 ateliers de la NASTT qui ont attiré plus de 60 personnes! L'activité a permis aux municipalités, aux entreprises de services publics, aux conseillers et aux entrepreneurs de mieux connaître l'industrie sans tranchée et de réseauter avec des collègues du Canada et des ÉtatsUnis. No-Dig North sera désormais une activité annuelle. La prochaine édition nous réunira au Vancouver Convention Centre de Vancouver du 19 au 21 octobre 2020.

Le 9 octobre 2019, à Halifax, en partenariat avec la NASTT et l'Atlantic Canada Water and Wastewater Association (ACWWA), la GLSLA a donné à plus de 20 personnes le cours de la NASTT sur l'introduction à la remise en état sans tranchée, à la suite du congrès annuel de l'ACWWA. Nous tenons à remercier celleci de sa collaboration. Il nous tarde d'avoir d'autres occasions de promouvoir avec elle l'industrie sans tranchée au Canada atlantique. Pour ne rien manquer des cours ni d'autres activités, consultez notre site Web, à l'adresse *www.glsla.ca.*

Nous sommes heureux de vous présenter ce nouveau numéro du magazine de la GLSLA, qui regorge d'articles sur l'industrie et d'impressionnants projets. Pour en savoir plus sur la GLSLA, nos activités, nos formations et le magazine, ou pour proposer des articles, rendez-vous sur notre site Web, à l'adresse *www.glsla.ca.*


AMERICAN AUGERS
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DitchWitch

Craig Vandaelle, *NASTT Chair*

Celebrating Our Recent Milestones

> Preparations are well under way for our 2020 technical session schedule. We are offering three forum topics in 2020 that you will want to check out.

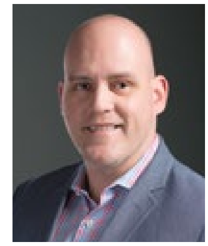
Hello GLSLA members! As the year marches along we're looking forward to the continued growth of the trenchless industry and our Society. We've been busy since the No-Dig Show was held in Chicago back in March and the recent inaugural No-Dig North conference held in Calgary. No-Dig North was an incredible success with nearly 600 attendees and 76 exhibitors. I could not be more pleased with the outcome of this show and the volunteer participation and leadership efforts of our Canadian Chapters.

We are looking forward to another outstanding No-Dig Show next April in Denver and the further development of the No-Dig North Show with the second show to be held in Vancouver, BC in October 2020. Preparations are well under way for our 2020 technical session schedule. We are offering three forum topics in 2020 that you will want to check out. The topics include Service & Lateral Rehabilitation, Cured-in-Place Pipe (CIPP), and Innovative Products. The exhibit hall is also not to be missed as we will have more exhibitors showcasing their industry innovations than we've ever hosted. The NASTT 2020 No-Dig Show is a must-attend event for the trenchless community. Registration is now open, and I hope to see you in Denver.

The No-Dig Show Program Committee members volunteered their time and industry knowledge to peer-review the 2020 abstracts. These committee members ensure that the technical presentations are up to the standards we are known for. A personal "Thank You!" to the GLSLA Chapter members who have volunteered for this important task this year: Brenda Kingsmill, David Crowder, Emilie Alderman, Keivan Rafie, Michael Kleepsies, Mike Davison, and Piero Salvo.

The last time we held the annual conference in Denver was in 2015 and that remains our highest attended conference on record. We expect to beat the record in 2020 and we hope you will join us at this "ground-breaking" conference. 2020 also brings us to NASTT's 30th anniversary! We are excited to celebrate this milestone as we continue with our mission to be the premier resource for trenchless education and training.

Our continued growth relies on the grassroots involvement of our regional Chapter advocates. Thank you again for your support and dedication to NASTT and the trenchless technology industry.



Matière à célébration

Salutations à tous mes collègues de la GLSLA! L'année tire à sa fin et nous gardons le cap sur l'essor de l'industrie de la technologie sans tranchées et de la Société. Nous sommes très occupés depuis le No-Dig Show de Chicago, en mars dernier, et l'inauguration récente du nouveau salon No-Dig North, à Calgary, au succès duquel ont contribué près de 600 participants et 76 exposants. Ce résultat me ravit, tout comme l'apport des bénévoles et le dynamisme de nos sections canadiennes.

Nous voici donc énergisés pour un autre No-Dig Show des plus prometteurs, celui d'avril, à Denver, et pour la deuxième édition du salon No-Dig North, qui aura lieu en octobre à Vancouver, en Colombie-Britannique. Le programme des ateliers techniques de 2020 est déjà en préparation. Nous proposons trois thèmes qui vont vous intéresser au plus haut point : entretien et remise en état par voie latérale, chemisage, et produits innovants. Ne manquez pas non plus le salon des exposants, qui seront plus nombreux que jamais à présenter leurs nouveautés. Le No-Dig Show de 2020 de la North American Society for Trenchless Technology (NASTT) est un incontournable de la communauté du sans-tranchées. Inscrivez-vous dès maintenant. J'espère vous y voir!

Les membres du Comité de programme ont mis gratuitement leur connaissance de l'industrie au service du No-Dig Show pour évaluer les présentations de 2020 et veiller à ce qu'elles répondent en tous points aux normes qui ont fait notre réputation. Je tiens à remercier personnellement les membres de la GLSLA qui ont donné leur temps à cette fin, cette année, nommément Brenda Kingsmill, David Crowder, Emilie Alderman, Keivan Rafie, Michael Kleepsies, Mike Davison et Piero Salvo.

NO-DIG NORTH

« Le programme des ateliers techniques de 2020 est déjà en préparation. Nous proposons trois thèmes qui vont vous intéresser au plus haut point. »

Le congrès annuel de 2015 avait aussi lieu à Denver, et cette édition reste dans les annales pour une participation record. Notre objectif : faire mieux encore en 2020! Nous espérons que vous serez des nôtres pour cette occasion à nulle autre pareille, d'autant que 2020 marque aussi le 30e anniversaire de la NASTT. Nous comptons bien célébrer, notamment en réitérant notre volonté d'être la référence de l'éducation et de la formation en technologie sans tranchées.

Notre croissance dépend de la participation des membres de nos sections régionales. Je vous remercie donc une fois encore de votre appui et de votre dévouement à la NASTT et à notre industrie.

First Annual No-Dig North

The first annual No-Dig North conference was held in Calgary, Alberta from October 28 to 30, 2019. The conference was an overwhelming success with 575 registered attendees, 76 exhibitors, and four well-attended short courses prior to the event.

This conference is sure to become a yearly tradition in Canada with the 2020 show scheduled for October 19 to 21, 2020 in Vancouver, British Columbia. Once again short courses will be offered in 2020 as will Municipal Scholarships, which offer municipal and public utility employees the chance to attend the conference for free. More information on the 2020 No Dig North show including call for abstracts, booth registration, pre-conference course registration, and municipal scholarships will be provided on the No-Dig North website at *www.nodignorth.ca.*

Courtesy of:
North American Society for Trenchless Technology (NASTT)
NASTT's 2019 No-Dig Show
Chicago, Illinois, March 17–20, 2019

ADDRESSING THE SHORTCOMINGS OF A SAMPLING STRATEGY IN CIPP QUALITY ASSURANCE PROGRAMS

Tony Araujo, Paragon Systems Testing, Concord, Ontario
Bruce Yao, Paragon Systems Testing, Concord, Ontario

OVERVIEW

Cured in place pipe (CIPP) has become ubiquitous as a rehabilitation process for underground infrastructure. While the technology has become widely accepted as an effective rehabilitation method, the strategies for ensuring the quality of an installation are still evolving. Research has shown high quality rehabilitations can be achieved with CIPP when it is deployed with sufficient oversight.

The two primary metrics for determining whether a CIPP installation will be effective are the short-term flexural modulus and the installed thickness. Other industry research has shown that even with a rigorous QA process in place, short-term flexural modulus and installed thickness can exhibit significant variability, exposing the Owner to the risk that non-conforming liners are being installed.

This paper identifies the shortcomings of the traditional QC sampling approach used in many heat cured CIPP projects and demonstrates the innovative QA/QC process used by Toronto Water to reduce the risk that non-conforming CIPP liners are installed in their sewer rehabilitation program.

INTRODUCTION

CIPP is being used throughout North America to reduce the necessity of digging up and replacing old sewer infrastructure and replacing it with new pipes. Even though the two technologies (CIPP and new pipe) are fundamentally different, the approach used for quality control by the CIPP industry has tended to mirror the approach taken by the new pipe industry.

New pipes (plastic HDPE/PVC, concrete, or clay) are manufactured in a typical manufacturing arrangement. Ensuring that a quality product emerges from the pipe manufacturing process involves the same basic requirements:

- Acquiring raw materials that meet defined quality standards
- Processing the raw materials into pipes using a defined process controlled by trained employees
- Defining the number of pipes in each lot that will be tested to confirm the required properties
- Testing the sample of pipe(s)
- Accepting, rejecting, or reworking, if possible, the lot of pipes based upon the sample test results

Of course the manufacturing process for new pipes also occurs in an environment which is controlled within the parameters required of the production process.

The path which CIPP liners follow to get to a finished product is not quite the same as a new pipe. The principle difference being that much of the processing of the raw materials into a finished product occurs in the field under variable conditions which cannot be controlled. The intrinsic value of cured in place pipe technology (that we manufacture a new pipe inside of an existing old pipe) is also its most significant process variable.

In a best-case scenario the CIPP installation contractor can control and track the CIPP installation process variables and ensure that a well-trained crew performs the installation. However a CIPP contractor can't control site specific variables such as the weather, the water table depth, the depth of the sewer or the rate of heat loss in the ground surrounding a sewer. Unless the contractor is vertically integrated with their own raw material suppliers, they also cannot control the wet out operation and substrate material used, such as felt, fiberglass, or a blend of both.

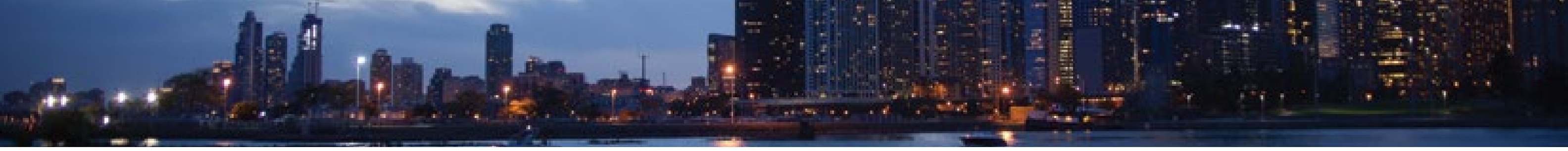
CIPP is effectively manufactured by mobile factories which travel from site to site, setting up and then tearing down their manufacturing equipment for each installation. Given this characteristic of CIPP manufacturing, one would expect to find that the CIPP process produces pipe liners with greater variation in physicals than other pipe materials.

REVIEW OF WINNIPEG CIPP FLEXURAL MODULUS DATA

The City of Winnipeg in Manitoba, Canada was an early adopter of CIPP for sewer rehabilitation. Their first installation in 1978 was one of the earliest in North America. Being an early adopter of a new technology came with risks which they tried to minimize, in part by performing 100% inspection of each liner for the three most critical properties of a CIPP installation: flexural modulus, flexural strength, and wall thickness. This is a practice which the City follows to the present day. Today, verification of as-installed flexural modulus is routinely used as a quality control tool in CIPP installations.

A paper documenting the flexural modulus data from 15 years of installations in Winnipeg was presented at No-Dig 2012[1]. The data set was described as "… one of the most comprehensive databases of CIPP flexural modulus and strength values ever assembled in North America." The data is representative of "… a large number of contractors, resin types, curing methods (hot water cures versus steam) and some installation related variances (pulled in versus inverted liners)."

The flexural modulus data presented in Figure 1 shows the average flexural moduli obtained for the 15 years of Winnipeg CIPP installations. Data from three types of field samples, restrained pipe, plate and tail end are included.



For the purpose of this paper we're only looking at the data from the restrained pipe samples, since restrained pipe samples are considered as the most representative of the properties of a CIPP installation.

The restrained pipe field samples from the Winnipeg data set exhibited an average flexural modulus of 3,375 MPa and the results varied from a low of 1,000 MPa (145,000 psi) up to a high of 4,600 MPa (670,000 psi), for a range of 3,600 MPa (520,000 psi). The data showed a standard deviation of 675 MPa (98,000 psi).

The data shows that nearly all (96%) of CIPP installations achieved the minimum flexural modulus of 1,724 MPa (250,000 psi) specified in ASTM F1216[2]. The paper did not specify, but one of the authors of the paper did subsequently confirm that the typical flexural modulus design basis for the installations was 2,413 MPa (350,000 psi). This meant that 80% of the results complied with the design basis.

CIPP FLEXURAL MODULUS DATA COMPARED TO PVC PIPE

What can we glean from the City of Winnipeg flexural modulus data? How does it compare to other more commonly deployed engineering materials? The easiest way to answer these questions is to compare it to PVC pipe. PVC is the most widely used pipe material[3] and has been in widespread use in North America since the 1960s (ASTM D1785 – Standard Specification for PVC Plastic Pipe[4] was originally approved in 1960).

The CIPP field samples which we receive for testing are usually molded within a short segment of PVC pipe. These pipe segments are sized to approximate the internal diameter of the sewer which is being lined. Since we have numerous samples of these PVC pipes available after removing the CIPP liners, we decided to perform flexural modulus tests on a random sample of these PVC pipe segments.

Since we had no control over the source of the PVC pipes, it was not possible to determine if these pipes were from a single source or from multiple suppliers and it is possible that the pipes were made by different manufacturers. The pipes ranged from 10" to 16" in diameter.

The flexural modulus test specimens were prepared from full through wall-thickness samples with the outer and inner diameter surfaces left intact. Five specimens were tested for each pipe and the average of the five specimens was reported. The tangent flexural modulus data is shown in Figure 2.

The PVC pipe samples exhibited an average flexural modulus of 2,980 MPa (432,000 psi), and the results varied between 2,850 MPa (413,000 psi) and 3,150 MPa (460,000 psi), for a range of 300 MPa (43,500 psi). The data showed a standard deviation of 78.4 MPa (11,400 psi).

Flexural modulus is not a routinely specified property for PVC pipe, tensile modulus is normally specified instead. However as a plastic material which is in common use, typical flexural modulus values from pipe suppliers are available for us to use as a comparison. One typical industry reference[5] lists a nominal flexural modulus for PVC pipe of 2,482 MPa (360,000 psi).

SAMPLING AS A QUALITY CONTROL STRATEGY

From the author's review of North American owner specifications/requirements for CIPP installations over the past five years, a large percentage of owners either do not require physical testing of the finished CIPP liner, or describe physical testing as an option which may be pursued at the discretion of the owner or contract administrator. Most owners require at least a sample of liners installed to be tested in order to demonstrate compliance with the material standards and/or the liner design. The sampling frequency will typically vary from as few as one sample per contract to one sample per every few hundred feet of liner installed. A minority of owners require 100% testing of all installed liners.

Sampling (or acceptance sampling) of a product from a manufacturing process is a commonly used quality control tool. The practice was popularized in World War II by Harold Dodge and Harry Romig[6]. They reasoned that if every bullet was tested you wouldn't have any bullets left to use; however, if you didn't test any bullets, then some of them wouldn't work when they were needed with catastrophic results.

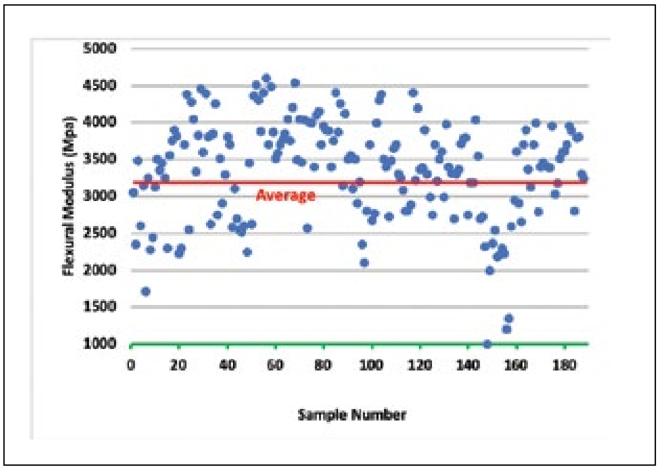


Figure 1. *City of Winnipeg flexural modulus from CIPP pipe installations[1]*

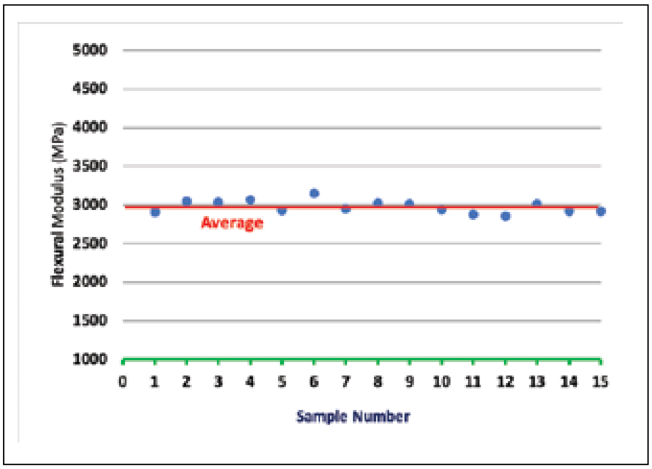
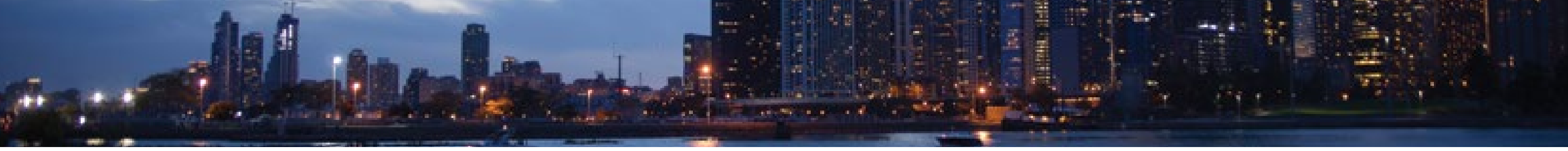


Figure 2. *Tangent flexural modulus measured on PVC pipe samples*



The principle behind sampling is that a sample can be picked at random from a production lot and tested and that a decision whether to accept or reject that production lot can be made with the result. The PVC industry defines a lot as a subdivision of a batch, with a batch being "A defined quantity of a homogeneous material or compound produced under uniform conditions."[6] Sampling data can also be used to improve process control.

PVC pipe quality is controlled with defined sampling plans. A typical PVC industry sampling plan would test pipe stiffness on a minimum of one pipe per production shift[7]. If a failure results from a test, the batch is quarantined and additional samples from the quarantined batch is retested. A predetermined acceptable quality level (AQL) must result from these retests for the batch to be considered acceptable, otherwise the batch is rejected. A rejected batch can only be released after 100% testing with only those pipes found compliant released to the client.

It is evident from the PVC test data that sampling as a quality control tool is effective at producing pipe which consistently meets specified requirements. The average flexural modulus which we measured for these PVC pipes compares favorably with the reference and all of the pipes conformed to the reference value. PVC is manufactured under "uniform conditions."

Similar to PVC pipe, CIPP raw materials like resins or felts can be produced under uniform conditions and their quality controlled with sampling plans. CIPP liner manufacturing in the field, however, is inherently non-uniform since the field conditions under which a liner must be installed are variables outside the control of the installer and the manufacturing facility is effectively set-up and disassembled for each liner. Sampling, as the term is defined by the quality profession, of a batch of field cured CIPP liners is not possible, since each liner is manufactured under unique conditions.

This is evident when the Winnipeg CIPP data and the PVC pipe data are compared (Figure 3). The random sampling of PVC pipe's exhibited a standard deviation of 78.4 MPa (11,400 psi), while the CIPP liner data exhibited a standard deviation of 675 MPa (97,900 psi) or nearly an order of magnitude greater than the PVC. Additionally 4% of CIPP liners failed to comply with ASTM F1216 minimum modulus and 20% of the results fell below the design modulus. All of the PVC pipe flexural modulus conformed to the reference modulus for PVC pipe.

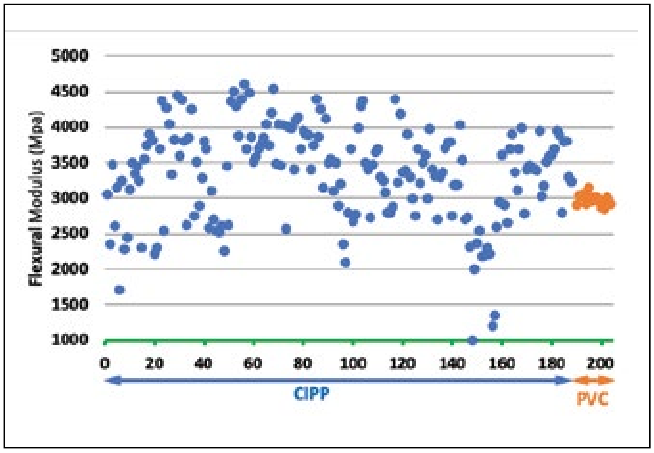


Figure 3. *Flexural modulus of Winnipeg CIPP pipe samples compared to PVC pipe samples*

In PVC quality control where a product variable can be expected to be normally distributed in the batch/lot, sampling is used to infer a statistical basis for the measured property will be present, with a certain probability, in the batch/lot which was sampled. A decision can then be made with this data either to accept or reject the entire lot.

Given the unique manufacturing conditions of CIPP and the demonstrated variability of the flexural modulus data derived for the City of Winnipeg, the same statistical inference cannot be made if sampling was to be used. Each liner's flexural modulus is a creation of the unique installation conditions for that liner. An acceptable result in one liner cannot be used to determine the probability of any other acceptable liners being installed. Similarly a failed test result in one liner cannot be used to reject any other liners in a project.

Because of the nature of its manufacturing process, a sampling quality control strategy for PVC pipe ensures, with a high probability, that nearly all, or all of the pipe installed meets the required specification. But a sampling strategy for CIPP installations does not ensure the same outcome.

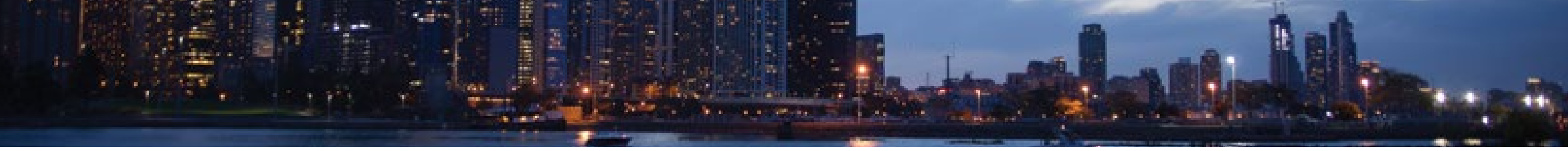
Sampling of CIPP installations for quality control ensures that non-conforming liners will be installed and not identified and rectified. The Winnipeg experience demonstrates that even with rigorous controls in place, a significant proportion of installed liners will not be compliant with specification or design requirements.

COMPREHENSIVE QUALITY CONTROL TESTING FOR A CIPP PROJECT

The City of Toronto began a CIPP rehabilitation program in 2016. The owner, Toronto Water, contracted with a consulting engineering firm to provide contract administration. CIPP installations were required to comply with Toronto Water specification TS 4.10 Specification for the Cured-In-Place Pipe Lining of Sewers. The specification requires that all liners be sampled and tested for flexural modulus and wall thickness in accordance with ASTM F1216.

TS4.10 requires that the flexural test results for each installation comply with the ASTM F1216 minimums. Liners failing to meet F1216 minimums are considered deficient. The specification permits the installation contractor to design liners using flexural properties higher than these minimums. In these cases, the specification also requires that the flexural modulus and wall thickness comply with the design values.

Where the modulus or thickness do not meet or exceed the design values, the specification requires that the installation to be reconciled. For reconciliation to successfully address this situation it is necessary that additional modulus or thickness over and above the design requirement is achieved in the field sample test results, such that when the design is recalculated with the actual test results, instead of the nominal design values, sufficient thickness will be seen to have been installed. After reconciliation each liner is categorized as deficient or not deficient. Deficient liners are



> **Examining all three graphs together illustrates the quite different capability of each contractor to provide a consistent flexural modulus from each installation.”**

then dealt with individually by the contact administrator with the installation contractor.

Three installation contractors installed liners in the 2016–2017 season for Toronto Water. Each contractor used a unique liner system and used that same liner system throughout the contract. Field samples were taken from each liner installation, tagged by an inspector, and transferred to the laboratory with chain of custody documentation where they were sampled and tested for ASTM D790 tangent flexural modulus, flexural strength, and wall thickness in accordance with ASTM D5813.

A summary of the flexural modulus test results are shown in Figures 4 to 6. In order to anonymize the test results we have taken two steps in the presentation of this data. Since each contractor used a unique design modulus and we could not reveal what that specific modulus was, we presented each contractors flexural modulus test results as a percentage of the design modulus. Additionally, since not all contractors installed the same quantity of liners, we chose to present a smaller sub-set of the data, one set each from the start and end of the contract, for each contractor.

Examining all three graphs together illustrates the quite different capability of each contractor to provide a consistent flexural modulus from each installation. Contractor A’s cured liners achieved from a high of almost 120% more than design modulus to a low of nearly -20% with only two liners failing to meet the design modulus. Contractor B achieved a much narrower range of modulus but 16 liners failed to meet the design modulus. Contractor C appears to be able to produce a similar narrow range of modulus as Contractor B but only at the start of the contract. All of Contractor C’s results exceed the design modulus at the start of the contract; however, by the end of the contract Contractor C’s flexural modulus shows a noticeable downward trend with many of the last liners they install falling below the design modulus.

Since we presented the flexural modulus as a percentage of the design for each liner, we also calculated the standard deviation for this data as a percentage of the design for each of the contractors. To permit a direct a comparison to the Winnipeg data, we performed the same calculation for the complete Winnipeg data set as well. These standard deviation data are shown in Table 1. The number of PVC pipes we tested was insufficient for us to calculate a valid standard deviation for this data set; however, the data does show that PVC pipe manufacturing is much more consistent process than CIPP installations.

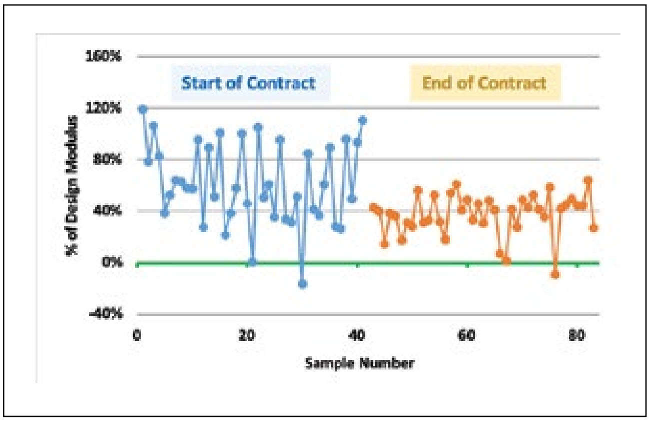


Figure 4. *Flexural modulus data for Toronto Contractor A. 0% represents design modulus*

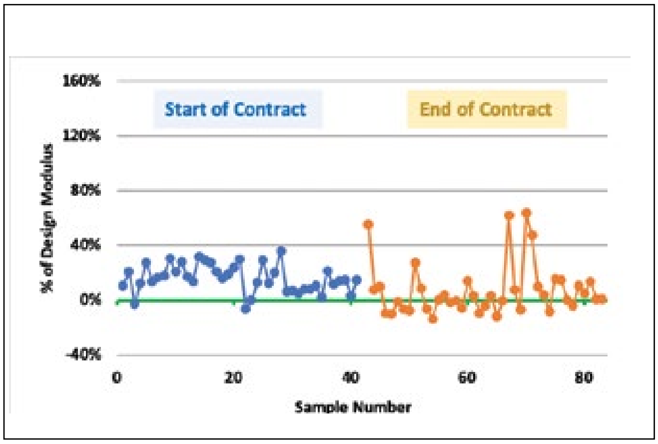


Figure 5. *Flexural modulus data for Toronto Contractor B. 0% represents design modulus*

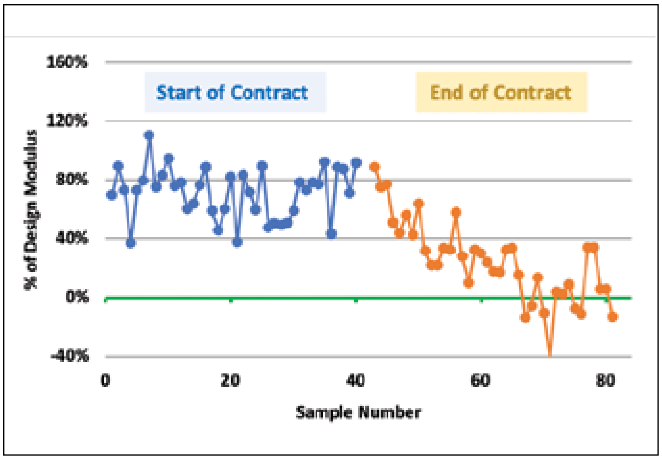


Figure 6*. Flexural modulus data for Toronto Contractor C. 0% represents design modulus*

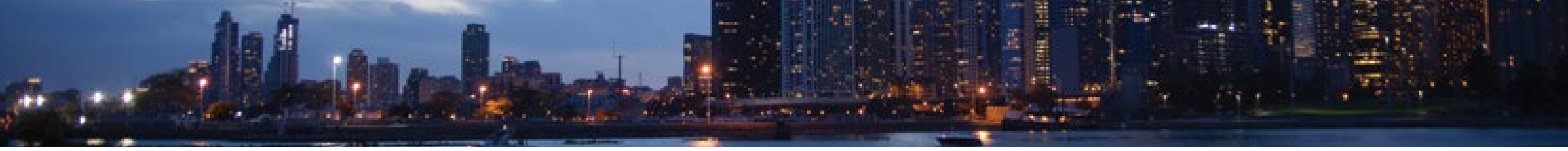


Table 1 summarizes the difficulty which today's CIPP contractors have in producing a consistent installed flexural modulus in the field. The historical Winnipeg data may be skewed somewhat by early installations where installers were still gaining experience in the early years of CIPP technology, but a similar range of scatter can still be seen in Toronto 38 years after CIPP was first installed in Winnipeg.

Each of the flexural modulus results which fall below the design must be reconciled and demonstrated not deficient in order to be accepted by the owner. This requires that sufficient additional liner thickness be present in each of these installations. Since liners don't come in an infinite range of thicknesses, contractors will usually install the next larger thickness of liner which is needed to meet the design for the sewer. It follows then that liners should always be as thick as or thicker than the design in nearly all installations, thus ensuring that a low modulus test result can simply be reconciled by a thicker installed liner. Unfortunately this isn't necessarily the case and the Toronto data demonstrates the problem with this assumption.

Figure 7 summarizes the range of liner thicknesses for the liners installed in the Toronto contracts. The data illustrates the expected result of using standard liner thicknesses. Most liners are much thicker that required to meet the design thickness. However a significant proportion of liners which were thinner than the liner design were also installed. Where these thin liner thicknesses intersect with a flexural modulus which is also less than the design, the liner is deemed deficient and either further detailed reconciliation is needed or corrective action on the part of the contractor may be required.

SUMMARY

Toronto Water uses CIPP as an effective sewer rehabilitation technology and appears likely to continue to do so in the future. Their quality assurance program ensures that CIPP liners comply with their specifications.

The results which we have reported describe the variability that can be expected from a very well run CIPP installation program utilizing a thorough quality assurance process which recognizes

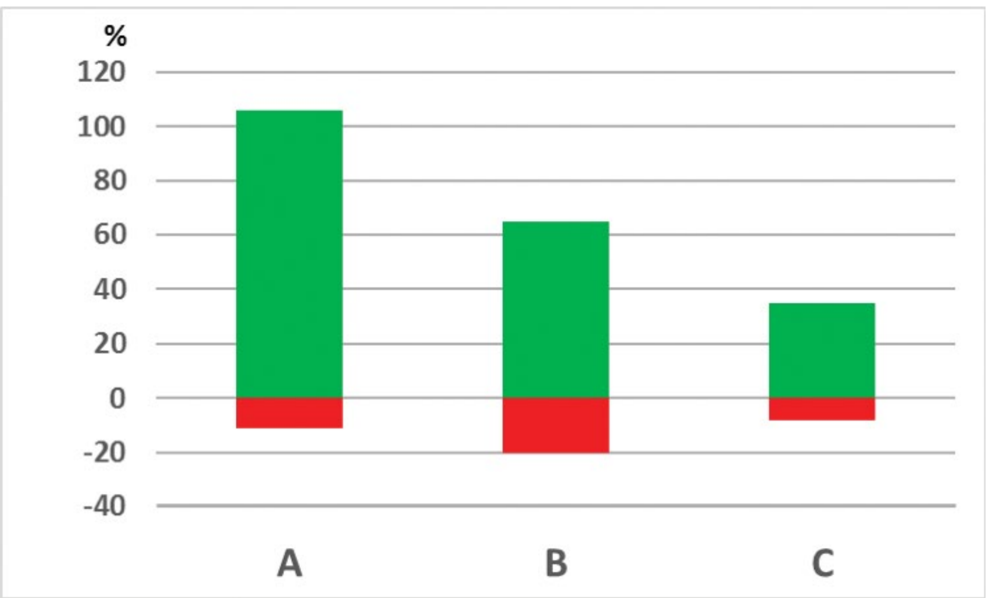
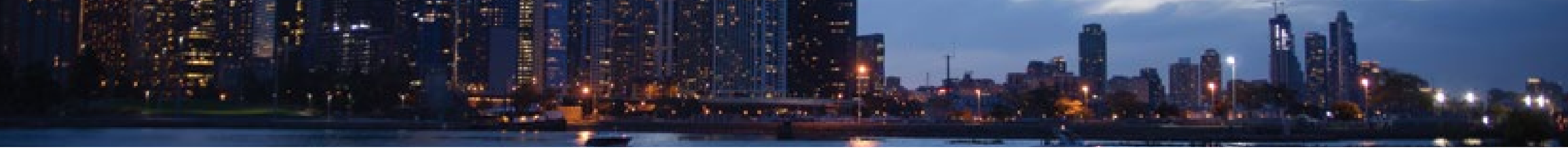


Figure 7. *Toronto installed liner thickness expressed as a percentage of design thickness. Contractors A, B, and C.*

	Winnipeg	Toronto Contractor A	Toronto Contractor B	Toronto Contractor C
Start of Contract	28	32	10	17
End of Contract		16	19	28

Table 1. *Flexural modulus standard deviation % of design modulus*



that a sampling approach cannot address the inherent variability of CIPP installations. While CIPP technologies have improved, the ability of contractors to obtain more consistent quality installations has not yet been demonstrated.

100% inspection reveals, that even with a very rigorous quality control regime, a significant percentage of CIPP liners will fail to meet specification requirements. A sampling QC testing strategy will not identify these liners. A large percentage of CIPP liners installed in North America today undergo little or no testing for flexural modulus and simply rely on a video inspection after installation to ensure that a smooth liner has been installed and that all of the laterals have been opened.

Owners across North America are using CIPP in place of more traditional dig and replace technologies like PVC pipe. It is unlikely that these owners would permit a sewer contractor to install new PVC pipe in a dig and replace installation where they knew that 20% of the PVC pipes were likely to not have the required physical properties. It's even less likely that these same owners, if they did allow a contractor to install these deficient pipes, would then pay the contractor full price for brand new deficient pipes. Yet this is precisely what many water and sewer utility owners are doing today when they require little or no physical testing of their CIPP installations.

RECOMENDATIONS

Physical testing for installed flexural and thickness properties of each unique CIPP installation should be considered a mandatory requirement for all CIPP installations.

1. Testing results should be compared to the design for each installation.
2. Testing results which do not comply with a design must be reconciled to determine acceptance or rework requirements.
3. Test data should be reviewed on a regular basis to identify unusual trends.

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Call for Submissions

If you would like to submit your project paper, case study, or other content and photos for an upcoming issue of this GLSLA Chapter magazine, please contact Joe Linseman, the Trenchless Journal Coordinator, at *jlinseman@rcii.com*.

Editorial submissions are welcome, and are due for the next publication by October 2020.

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North American Society for Trenchless Technology (NASTT)
NASTT's 2019 No-Dig Show
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REHABILITATION OF THE BARTON STREET HORSESHOE-SHAPED COMBINED SEWER IN HAMILTON

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Julia Noble, Pipeflo Contracting Corp.

ABSTRACT

The City of Hamilton (City) owns, operates and maintains a large network of aging, large diameter sewers. Maintaining this network is an ongoing task for the City. A large diameter sewer inspection program has been in place for several years and has been effective at identifying sewers that are at risk of future failure.

One of the identified sewers, a 1,200 mm by 1,350 mm horseshoe-shaped combined overflow sewer located 7.5 m below Barton Street, was found to be in critical condition. This 94-year concrete sewer was constructed by tunneling through a mixture of soil and shale. During a CCTV inspection and a secondary man-entry inspection it was confirmed that this sewer had significant longitudinal cracking at the 3 o'clock and 9 o'clock locations, extending extensively along the sewer. Additionally, a 7 m long portion had already partially collapsed along the crown of the pipe leaving a void to the ground above. The City identified the Barton Street sewer for a full rehabilitation.

The rehabilitation of the sewer involved the construction of a new access shaft to facilitate a grouted-in-place GRP (Glass Reinforced Plastic) liner. The construction shaft was converted to a permanent manhole structure to provide provisions for future maintenance and inspection.

This paper provides an overview of the inspection, design and rehabilitation for this combine sewer.

INTRODUCTION

The City of Hamilton (City), located 70 kms west of Toronto, owns, operates, and maintains several hundred kilometers of large diameter storm and sanitary sewers. Several of the City's sewer systems are more than100 years old, while the average age is around 65 years. Hamilton also has a group of non-circular shaped large diameter sewers, including horseshoe, egg, horizontal, and vertical box shapes. The majority of the City's interceptors and sub-trunk sewers run under heavily populated areas and/or crosses under or run adjacent to highly sensitive, environmentally protective river valleys.

The City's asset management group, with a mandate to carry out sewer inspections, determine rehabilitation needs, and manage the entire sewer system, has deemed that large diameter combined trunk sewers, as "critical assets," have a zero tolerance for failure.

In order to effectively manage these critical sewers with zero tolerance of failure, detailed and accurate sewer inspections are essential. Currently, City through its large diameter inspection program, carries out inspections with a local CCTV contractor who deploys modified, CCTV camera robots with enhanced lighting

Figure 1. *Project location map*

into these large diameter sewers across Hamilton each year.

One sewer that was inspected and identified as high risk was the Barton Street sanitary overflow sewer. This is a 94-year-old, 1,200 mm by 1,350 mm diameter concrete arch-shaped sewer, constructed in a tunnel that runs under Barton Street at an average depth of 7.5 m.

The Barton Street sewer flows in a North East direction from an existing manhole, located within the intersection of Barton Street and Weir Street. This sewer then turns East through a radius section where it continues under Barton Street for 250 m towards Strathearne Avenue, where it outlets directly into the 2,100 mm by 2,250 mm diameter Strathearne Avenue Sanitary Interceptor. Figure 1 below shows the location of the Barton Street sewer.

The goal of this paper is to review in detail the proactive approach the City's Asset Management group has taken to inspect and rehabilitate this 270 m long segment within the Barton Street Combined Sewer.

BACKGROUND

City's Asset Management Group has identified the need for more accurate and reliable data from their large diameter sewer inspections, which will allow them to make more informed decisions regarding maintenance and rehabilitation planning for their aging trunk sewers.

The City of Hamilton retained R.V. Anderson Associates Limited (RVA) to assist the City in undertaking a detailed man-entry inspection inside the Barton Street Sewer between Weir Street and Strathearne Avenue to verify the observations from the initial CCTV inspection and to help the City determine the best trenchless method available to rehabilitate this sewer.

MAN-ENTRY INSPECTION

Man-entry inspections are not commonly carried out for large diameter sanitary sewers due to the confined space entry issues and the ongoing danger of working in high sewage flows. However, this 270 m long segment is a combined sanitary overflow sewer, which is controlled by a weir in the Barton/Weir intersection manhole, so little to no flow is present during none storm periods.

A man-entry inspection was carried out with RVA staff and the City's large diameter inspection contractor Pipeflo Contracting Corp. (Pipeflo). Pipeflo's crews provided the confined space entry support, temporary traffic control, and spray wall cleaning.

Significant safety planning and precautions were required for the November 24, 2016, confined space entry inspection including the following:

- Tripod hoist and full body harness for ingress and egress safety
- Constant air quality monitoring including oxygen, lower explosive limits, and hydrogen sulfide
- Comminutions including the use of handheld radios and a small CCTV robot with enhanced LED lighting which followed the team in the tunnel

To confirm the extent of the deterioration to the concrete sewer tunnel, it was decided that Pipeflo crews would first use the high-pressure water with a portable hand wand, to clean sewer walls from the slime and remove the encrustation as much as possible off the walls and the invert of the pipe, where possible. See Figures 2 and 3 below.

The sewer inspection was carried out in three separate set-ups:

- Intersection of Barton/Weir downstream (east) to the existing hole in the obvert, 90 Lm
- Intersection of Barton/Fairfield upstream (west) to the existing hole in the obvert, 30 Lm
- Intersection of Barton/Fairfield downstream to outlet at Strathearne Avenue, 50 Lm

The reason for three separate set-ups was to minimize the inspection length down the sewer due to its size (1,200 mm by 1,350 mm diameter). This is an awkward size for a man-entry inspection. To overcome this challenge, both technicians wore knee pads and carried a small bucket which held various inspections tools including:

- Digital camera
- Handheld 5 m measuring tape
- 30 m long measuring tape
- Chisel
- Hammer
- Schmidt hammer
- Field book for written notes
- Portable whiteboard with a marker
- Water

The CCTV crawler was used here to gather additional detailed information during the three inspections.

A portable whiteboard was used to communicate with the safety team and the CCTV operator during the inspections, as radios do not work once you travel down through a radius section of sewer. The technicians would write instructions on the whiteboard and point into the CCTV camera requesting additional video to be taken in different areas.

General conditions of the pipe, including longitudinal and circumferential cracks, were observed, measured, and noted during the inspection. Measurements were also taken along the sewer for both the width and height in 5 m intervals. The sewer width dimensions were very consistent. However, the vertical measurements varied from 1,350 mm up to 1,450 mm± towards the downstream outlet. Digital photos were also taken.

Upon completion of the inspection, the sewer tunnel was determined to be in poor condition with a 7 m long section which

Figure 2. *Pipeflo technician spray wall cleaning*

Figure 3. *Pipeflo technician measuring the width of the sewer*

had failed. An 80 m long section of longitudinal open cracks located at the three o'clock and nine o'clock position was also a major concern. Several other locations along the tunnel showed areas where the concrete wall sections were deteriorating heavily. Figure 4 shows the existing hole and void in the crown of the pipe.

The Barton man-entry inspection revealed that the following immediate and short-term actions needed to be implemented including:

- Set up an ongoing monthly CCTV monitoring program to inspect the 7 m long section where the crown of the sewer had failed, for the City to take emergency action if this pipe section collapsed;
- Determine the best rehabilitation options available to extend the life of the important sewer assets; and
- Design and tender out rehab specifications to repair this sewer.

Figure 4. *Looking at the hole in the obvert of the sewer*

LINER DESIGN CONSIDERATIONS

Based on the observed conditions of the existing sewer, a new liner was required to restore the structural adequacy of the pipe. The non-circular horseshoe shaped pipe presented several challenges for the relining operations. The existing sewer acted as a CSO and needed to maximize its cross-sectional area to minimize the risk of causing upstream issues during large storm events. In order to accomplish this, a non-circular Glass Reinforced Plastic (GRP) liner was selected to best match the existing geometry of the sewer and minimize the wasted space occupied by the annular grout.

RVA conducted the preliminary design of the GRP liner utilizing a range of expected earth, groundwater, and surcharge pressures. The pressures were applied to the as-built geometry of the liner to estimate the stresses on the new liner. A series of hand

calculations were done to estimate the stresses in both the circular portion (crown) and non-circular (invert) portion of the liner. A Finite Element Analysis (FEA) model of the sewer lining was also created to further validate the preliminary design. As expected, the results of the stress analysis indicated that high stress concentrations would develop in the corners of the box-shaped invert and in the straight sections of the pipe profile.

These peak stresses were used to estimate the required GRP liner thickness.

The estimated liner thickness was used to evaluate the hydraulic capacity of the remaining sewer cross-section. The total capacity of the sewer was moderately reduced but was found to be sufficient to proceed with this approach for rehabilitation. See FEA model below.

DETAILED DESIGN AND TENDERING

The Barton sewer posed its own unique constructions challenges including:

- Limited access
- Average depth of 7.5 m
- Complex horizontal and vertical pipe geometry
- Non-circular pipe
- Located underneath a busy arterial roadway

To overcome the limited access issue, a decision was made to design an access shaft directly overtop of the sewer where the crown of the pipe had failed. This access shaft would benefit the City in several ways:

GRP panels could be pushed from this one shaft in both directions without the need to enlarge the existing manhole in the Barton/Weir intersection

After the GRP panel installation, a new manhole would be installed in this shaft location which would give the City future access for inspection and maintenance

To support the location of this new launch shaft, a level "B" subsurface utility investigation was carried out by T2 Utility Engineers Inc. in order to confirm the locations of the existing buried watermains, hydro duct, gas main, and other utilities. As a result of this investigations, it was determined that an access shaft could be constructed in this location with only minimal utility support required.

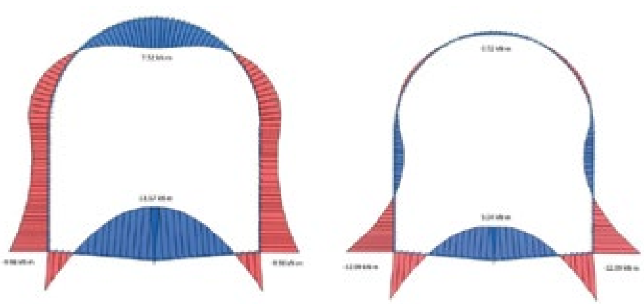

Figure 5. *Bending moments for range of ground conditions considered (preliminary design)*

DETAILED LINER DESIGN

The WRCSRM Type II design methods for non-circular sewers are limited to egg shape and oval sewers. Direct guidance on other shapes, such as the horseshoe shaped profile required for this project, are not provided. The approach taken for egg and oval shaped sewers in the WRCSRM Type II design method is to assess the "critical length" of the straight, or nearly straight portion of the profile. These straight portions of the profile represent the portions of the pipe the behaves "non-circular," and they tend to laterally deform the increase in stress and deformation caused by the non-circular portions of the pipe over what the typical stress of a circular pipe wall.

To account for the horseshoe shaped profile, the two separate critical lengths were evaluated: one for the side walls, and one for the invert. The required thickness was solved for each critical length and it was found that the invert critical length governed the design for this specific horseshoe shaped geometry. A safety factor of two was also introduced into the analysis to account for the extension of the WRCSRM Type II design method to fully deteriorated condition. In addition to the SUE investigation, a geotechnical investigation was also completed with one bore hole drilled in the location of the proposed shaft.

TENDER SPECIFICATIONS

Specifications for the GRP liner were developed and included in the tender documents. The detailed design of the GRP liner was specified to be completed by the contractor to allow to optimize their design, based on the selected GRP supplier, their installation methods, and desired grouting techniques.

RVA staff assisted the City in preparing a comprehensive trenchless rehabilitation tender for the Barton Street Sewer.

Included within this tender document was a contractor evaluation which included some of the following sections including:

- Ability to perform the work
- Experience with similar projects
- Staff experience
- Materials and installation
- Deep shaft construction

The specification criteria helped the City to ensure that only an experienced contractor could bid on this project. Tender closed in the fall of 2017 and a local contractor Pipeflo was the successful bidder.

SEWER REHABILITATION

Sewer rehabilitation work commenced during the winter of 2018 and was completed in late December. The work was broken down into six main phases including:

- Preliminary CCTV inspection review
- Cleaning and preparation of the sewer for rehabilitation
- Construction of 8 m deep access shaft to remove a collapsed section of pipe, which is be used as an access shaft for the installation of the GRP panels
- Installation of WRC Sewerage Rehabilitation Manual SRM Type II Liner, grouted-in-place GRP System along the 275 m long sewer
- Reinstatement of three branch sewer connections
- Post-rehabilitation CCTV inspection of the completed installation

PHASE 1 AND 2 – SEWER CLEANING AND V1 CCTV INSPECTION

Following the award of the project, Pipeflo commenced with sewer cleaning operations. Initially, this involved a man-entry team entering the sewer from the Barton/Weir access manhole, moving down the pipe and physically removing accumulated heavy debris from the invert of the sewer. Removed debris included sand, silt, steel sections of old ladder rungs and safety platforms. Crews also used portable pneumatic air tools to remove the hardened encrustation from both the pipe walls and invert where it was excessive. This was required in order to ensure that the original cross-sectional geometry of this horseshoe sewer was in place.

Pipeflo hired Monteith & Sutherland Ltd., a land surveyor, to undertake an internal LIDAR Survey throughout the entire length of the sewer. This survey was performed to confirm the actual internal dimensions for this non-circular horseshoe shaped sewer. The sewer was not a straight sewer, because it has two major horizontal bends, as well as a vertical bend.

Pipeflo retained Channeline International Ltd. to manufacture the GRP panels for this project. After the LIDAR Survey was reviewed and GRP Liner section was designed by Channeline, proposed dimensions were sent to Pipeflo. Pipeflo crews constructed a template (mandrel), which was fabricated to the dimensions and length of the GRP panel. This mandrel was assembled inside the sewer and crews successfully transported through the sewer. Once confirmed by Pipeflo, the final dimensions were forwarded to Channeline for the execution of shop drawings and liner thickness calculations.

Pipeflo retained Mr. Ian Doherty of Trenchless Design Engineering Ltd. to complete the detailed design of the GRP liner. The design utilized a modified version of the WRC Sewerage Rehabilitation Manual (SRM) Type II design method.

The final design thickness was in close agreement with the preliminary design thickness estimated prior to tendering. The cross-section of the new liner also introduced more rounded corners at the invert and side-wall junction than the original sewer geometry. These rounded corners were used to limit the stress concentrations that would occur at a sharpen corner. An order was submitted by Pipeflo to Channeline to construct the required GRP panels. The first group of panels were delivered in August of 2018.

A QA/QC site meeting was held with RVA, Pipeflo, and City staff to review the GRP panels. During this meeting, shop drawings were reviewed, and panel thickness were measured. Pipeflo confirmed that only straight panel sections were shipped, not the required radius panels. Pipeflo and Channeline reviewed this issue and new radius panels were constructed and shipped in September 2018 from Dubai to Toronto. Figures 6 and 7 at right show the new GPR panel and confirming panel thickness.

Figure 6. *Photo showing GRP panel*
Figure 7. *Verifying GRP panel thickness*

Figure 8. *Top of existing pipe during shaft excavation*

Figure 9. *Enlarging shaft entrance*

SHAFT CONSTRUCTION

Shaft construction commenced in late September of 2018. Deso Construction Limited was retained by Pipeflo to excavate and install the access shaft. The shaft was excavated to an approximate depth of 8 m and required a week to install. See Figures 8 and 9 at right.

GRP PANEL INSTALLATION

After the successful installation of the access shaft, Pipeflo mobilized back to Barton Street to install the GRP panels.

Pipeflo crews moved four panels at a time from their temporary storage warehouse, which was located 3 km from Barton Street. Each panel was carefully lowered down the access shaft from a crane to the bottom of the shaft. Pipeflo crews, using a hydraulic trolley, complete with jacks, transported the panels one by one down the sewer. once the panel reached the required location, the trolley jacks were lowered, and the panel was removed from the trolley, and pushed into position to the forward panel. The panels were pushed together by a bell and spigot joint, complete with a rubber gasket. Panels, that were installed within the two radius sections, were connected without a rubber gasket. This was a field decision that was reviewed with Channeline. An approved epoxy (Sikaflex 1a) polyurethane-based

elastomeric sealant was injected into each joint.

GRP panel installation took 16 days to be installed. The new manhole was installed within the access shaft, and final site cleanup and restoration was completed in early December 2018. See photo at right showing the installed GRP liner.

CONCLUSIONS

The magnitude of repair to a sewer and the selection of rehabilitation methods depend on the pipe size and depth. The deeper the pipe is buried, the farther apart the manhole spacing, along with major radius bends, the greater the degree of difficulty in accessing it for inspection and rehabilitation.

Historically, the industry neglected the management of the critical buried infrastructure. Assets were repaired when they broke. A proactive approach, such as the one developed by the City, allows for better management and sustainment of assets.

The City clearly benefitted from their large diameter CCTV inspection program by identifying deficiencies that need to be repaired before they become a major problem.

The direct outcome of this project was a successful rehabilitation of the Barton Street sewer using a GRP segmental lining system. To date, this is the largest for the City. Going forward, the City intends on using this GRP technology to rehabilitate their large diameter sewers.

Figure 10. *Looking downstream from the Barton/Weir manhole at the newly installed liner*

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NO-DIG NORTH

East Brampton Sanitary Trunk Sewer – Challenges Associated with Designing & Constructing a Gravity Trunk Sanitary Sewer Pressure Tested to 350 kPa by Microtunnelling

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Trenchless Technology Canadian Chapters
2019 No-Dig North

Calgary, Alberta
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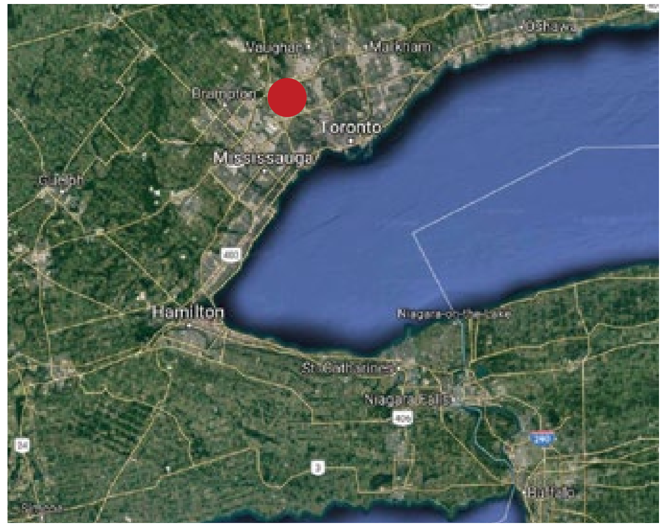
ABSTRACT

The cost of inflow and infiltration (I&I) of ground and surface water into the sanitary sewer system represents a significant cost to municipalities and cities all over North America. As the standards for discharge of treated wastewater become more stringent and the intensity and frequency of storms and urban population increase, so does the cost of I&I. The Region of Peel (municipality in the Greater Toronto Area, ON) implemented new design and construction standards for their sanitary sewer systems in 2017. The new standards require that their sanitary sewers and associated manholes be pressure tested to 350 kPa (50 psi) even though the system will ultimately be operated as a gravity system. One of the first projects to implement the new standards was the "Twinning of the East Brampton Trunk Sewer" which was completed in January 2019. The project included 5.4 km of new 1,500 mm, 1,650 mm, and 1,800 mm diameter sewer and several custom elements to enhance operational flexibility; the entire alignment was completed by microtunnelling with the tunnel pipe ultimately being used as the carrier pipe and pressure tested to 350 kPa. This project was an opportunity for evaluation of system components that apply technology more frequently used in water conveyance systems to a linear sanitary sewer. The construction requirements necessitated collaboration between the owner, consultant, and contractor to deliver the project to the required standards on time and budget. This paper provides a project overview and discussion of: pipe material selected to deliver a reliable watertight system; pressure testing of large diameter piping and chambers; and the trenchless challenges involved with the installation of the 5.4 km of linear infrastructure.

INTRODUCTION

The Region of Peel (the Region) provides drinking water and wastewater conveyance and treatment services to approximately 1.4 million residents and approximately 163,000 businesses in Brampton, Caledon, and Mississauga in Ontario, Canada.



Site location

This includes operation and maintenance of two water treatment and two wastewater treatment facilities, as well as pumping stations, reservoirs, water mains and sanitary sewers. To optimize the function of the wastewater collection system, maximize its useful life, and minimize life-cycle costs, the Region developed a new set of standards for the design, construction, and rehabilitation of its sanitary sewers.

The new standards change the approach to construction of new local and trunk sanitary sewers to eliminate inflow and infiltration into the system by focusing on the following:

- Pipe material
- Testing of the constructed pipe
- Human access considerations

One of the first projects to implement the standards was the Twinning of the East Brampton Trunk Sewer. Associated Engineering (Ont.) Ltd. (The Engineer) was retained by the Region to complete a Schedule "B" Environmental Assessment, detailed design and construction phase services for the twinning of the existing trunk sanitary sewer which consisted of approximately 5.4 km of 1,500, 1,650, and 1,800 mm diameter trunk sanitary sewer to be installed by trenchless construction. The sewer alignment was located between the intersection of Queen Street and Goreway Drive in the City of Brampton, ON to south of Highway 407 and Steeles Avenue and includes three creek crossings, a crossing of the 407ETR (Express Toll Highway), and a CN rail crossing.

The project scope included live connections to the existing trunk sewer on the downstream end and live interconnections to the existing trunk sewer to facilitate the construction of an overflow weir chamber and transfer chamber over the existing live trunk sewer. The entire project needed to be constructed without impacting flows in the existing trunk sewer, even while undertaking final tie in connections and interconnections to the existing trunk sewer. The requirements of the design for the East Brampton Trunk Sewer Project generated a significant amount of discussion between the Engineer, the Region, and the Contractor during construction. Specific items included the details of the proposed pipe and joint configuration, engineering requirements for pressure testing, and the configuration of maintenance access provisions. These three main challenges are discussed in the following sections.

DESIGN REQUIREMENTS

A. Pipe Selection

Concrete pressure pipe (CPP) in conformance with AWWA C302 standards was specified by the Region and the Engineer for this project so that the carrier pipe could be directly installed by microtunneling, thereby eliminating the need for a two-pass tunnel system. However, AWWA C302 pipe is not commonly used by the microtunneling industry in southern Ontario and the design requirement to install the majority of the works through microtunnelling led to a discussion with the Contractor regarding the joint configuration and subsequently the suitability of the proposed C302 pipe.

The contractor, Ward and Burke Microtunnelling Ltd., raised concerns that the typical joint configuration for AWWA C302 Non-Cylinder Pipe with steel joint rings, as shown in Figure 1 below, can result in the slow ingress of fine clay silt into the joint for microtunneled sections longer that 50 meters, resulting in the pipe joint creeping apart as the microtunnel drive progresses along the designed alignment. The Contractor observed this ingress of soils into the pipe joints on one of their projects in Montreal in early 2016, whereby the C302 AWWA Non-Cylinder pipe joints, proceeding the microtunnel boring machine (MTBM), began to separate as the MTBM progressed towards the reception shaft. During the retrieval of the MTBM it was observed that the joint gap had grown to nearly 90 mm on a number of pipe joints.

During the installation of a microtunnel pipe, the pipes follow the alignment produced by the tunnel boring machine. In a typical well-controlled microtunnel installation, the tunnel boring machine will follow the design alignment within +/- 25 mm vertically and horizontally. However, it is important to note that the tunnel boring machine is constantly being steered to maintain this alignment tolerance as it constantly moves left, right, up, and down within this tolerance. Therefore, the pipe joints following the tunnel boring machine are constantly moving until the end of tunnel construction. As the tunnel length increases, the potential for joint movement also increases. Because of this movement of the pipe string during trenchless installation, the Engineer recognized the fact that the potential for fine material to enter the joints was a legitimate concern for the Contractor. The gasket in the pipe joint must be able to handle this continuous movement until the end of tunnel construction wherein the joints will then become static. The pipes only come to rest once the tunnel construction is complete.

This concern led the team to consider the joint configuration shown in Figure 2. The steel band, as traditionally seen on the typical microtunnel reinforced pipe, will alleviate fine material from entering between the joints and subsequently stop the pipes from creeping apart, while the primary teardrop gasket seal shown in Figure 2 provides added security against this concern also.

The final configuration developed by the supplier and contractor utilized a hybrid joint configuration, complete with zinc metallized steel rings on the outside of the bell and spigot sides as shown in Figure 3. In addition, the Contractor proposed to make the pipe 50 mm thicker than the minimal allowable thickness requirements outlined in AWWA C302 to allow the Contractor to increase the drive lengths between shafts and introduce horizontal bends. Although the introduction of horizontal bends and associated pipe joint rotation reduces the jacking capacity of the pipes, the increased wall thickness of the design made the contractors proposal feasible. A detailed review of AWWA C302 and the proposed pipe undertaken by the contractor and engineer demonstrated the proposed pipe met and exceeded AWWA C302 specifications that were required for the project.

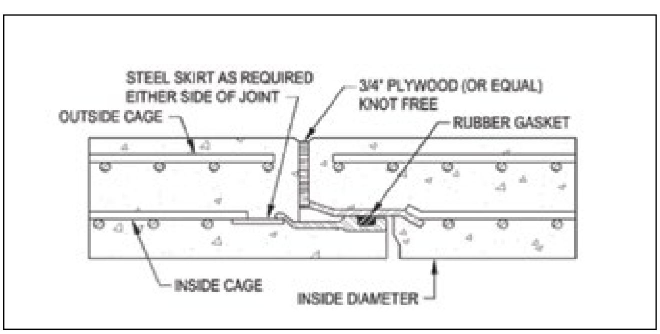


Figure 1. *AWWA C302 non-cylinder pipe with steel joint rings (ACPPA)*

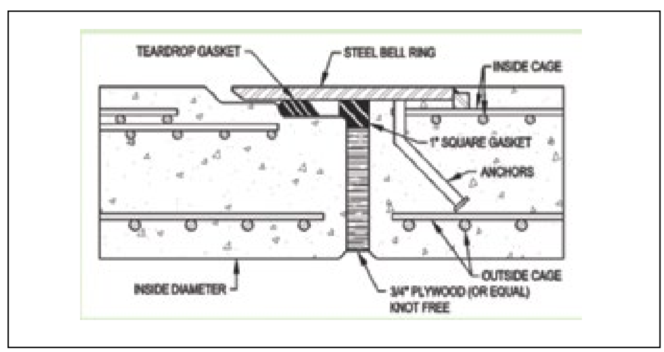


Figure 2. *Concrete and steel joint on non-cylinder reinforced concrete pipe (ACPPA)*

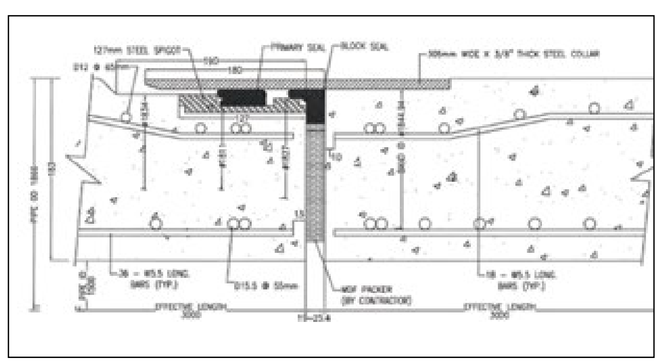


Figure 3. *Final joint configuration (Decast Ltd. and Ward and Burke Microtunnelling Ltd.)*

Figure 4. *Manufactured joint configuration (Associated Engineering (Ont.) Ltd.)*

The construction of the East Brampton Trunk Sewer was very successful utilizing the C302 pipe with an upgraded joint configuration. The pipe was designed to withstand increased thrusting forces in such situations where boulders were encountered along the tunnel drive. The maximum allowable thrusting force designed for the C302 pipe was 14,000 kN with concentric contact and 8,800 kN at full eccentric contact. The contractor did encounter large boulders along the constructed tunnel alignment, however the maximum thrusting force recorded on the C302 pipe while the boulders were encountered was 7,000 kN.

The upgraded joints prevented the migration of fines between segments and as a result prevented separation of the pipe segments. Numerous shafts were eliminated and tunnel drives were increased due to the assurance that the pipe and joints would be able to withstand the dynamic and static forces imposed on the pipe. To ensure the joints were completely sealed, the newly constructed trunk sewer was required to undergo a 350 kPa pressure test for two hours to ensure watertight joints – a new concept being introduced by the Region of Peel to prevent inflow and infiltration into the collection and treatment system.

PRESSURE TESTING

The project alignment was 5.4 km total in length and included crossings of the 407ETR Highway, CN Rail Tracks, CN Intermodal Yard, Mimico Creek, and several busy intersections, all of which needed to be pressure tested to 350 kPa. The pipe/tunnel sizes varied from 1,650 mm to 1,800 mm internal diameter. Ward and Burke completed 19 separate tunnel sections ranging from 300 m to 650 m in length in soils ranging from hard Halton tills complete with cobbles and boulders to soft sands and silts with high water tables. Most of the alignments included horizontal curves ranging between 400 and 800 m. The design allowed for sunken caisson shafts that would be utilized for the trenchless construction and upon completion of the trenchless works would be converted to permanent chambers.

A key component of this project was to ensure that all C302 pipes, including the microtunneled sections and the manhole access tees, could sustain an internal pressure of 350 kPa for two hours with no pressure drop. Pressure testing of all CPP sections was incorporated not only to provide a high degree of assurance the installed system was watertight, but also to allow operational flexibility by providing a system that can be surcharged should the need arise.

To confirm the system was fully watertight the contractor pressure tested all CPP sections including the C302 manhole access tees to 350 kPa for two hours with no pressure drop. A concrete bulkhead system was incorporated within the construction shafts along each tunnel drive to isolate the pressurized section. The bulkhead system utilized welded steel caps at the end of each tunnel drive, concrete blocks, and cast in place concrete to prevent any movement or release during the pressurization period. The contractor was required to develop a comprehensive, engineered testing plan to confirm the installed sewer was watertight. Specific requirements of the testing included:

- Implementation of a detailed site risk assessment for pressure testing operations
- Preparing a plan to provide water for filling each test section from Region of Peel hydrants
- Determining the required saturation period
- Calculating the anticipated forces on bulkheads and designing temporary engineered restraints

The Contractor successfully pressure tested all of the 19 tunnel sections with no pressure loss in any section. This is a testament to the design and the modified pipe joint configuration proposed by the Contractor.

New design standards for corrosion protection

The CPP chambers for the project ranged in size from 1,200 mm to 2,400 mm diameter. As such the bulkhead assemblies for the largest chambers were required to resist forces up to 1,600 kN (360,000 lbf).

In addition to the project elements listed above, the project included several custom, cast-in-place chambers. The design of cast-in-place chambers as pressure vessels is rare in a municipal context and the initial design did not require these elements to be pressure tested. The performance testing of new cast-in-place elements of the Region's sanitary system also generated significant discussion as the cast-in-place structures were generally much larger than the precast elements to accommodate the required construction methodology.

ACCESS AND OPERATIONAL CONSIDERATIONS

In addition to the stringent performance standards discussed above, the standards also include several improvements to the man access provisions. Fibre Reinforced Plastic (FRP) ladders, platforms, and railings were specified to improve the service life. To address safety concerns with staging maintenance activities from sloped benching, platforms were provided for all chambers above the obvert of the pipe. For larger cast-in-place custom chambers, the platform extends over the flow and a permanent recess is provided in the benching with an FRP ladder to the invert of the pipe. For precast chambers a portable ladder is stored within the chamber above the flow and can be attached onto the fixed ladder to access the pipe invert.

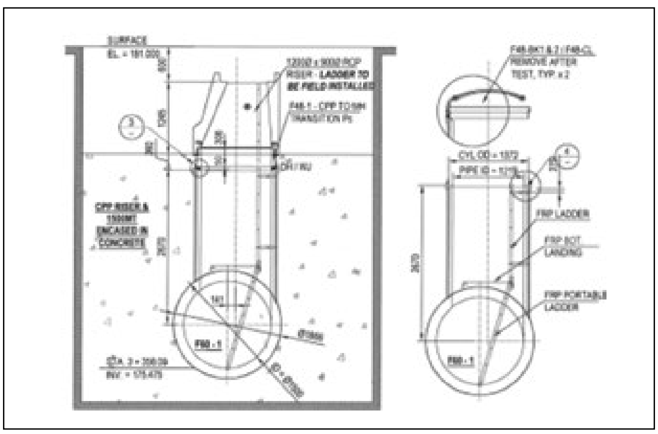


***Figure 5**. Precast manhole tee and bulkhead configuration (Decast Ltd. and Ward and Burke Microtunnelling Ltd.)*

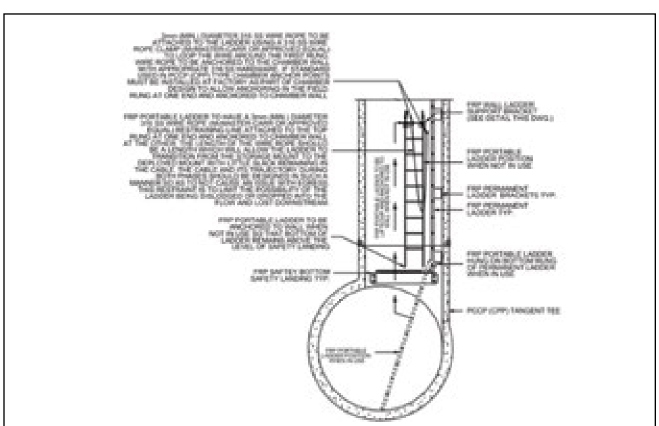


***Figure 6**. Region of Peel Standard CPP platform and ladder configuration (Region of Peel)*

CONCLUSIONS

In specifying a pipe type with respect to a specific standard it is important to identify submission requirements early on. Where a specified product is based on an industry standard not commonly applied in this geological area, specific guidelines and a process for evaluating the product (and potential equivalent products) should be considered as part of the specifications. In general, a project team could consider whether a given project element may be better suited to a performance specification or if only certain products will be acceptable. The performance specification approach may, however, present unacceptable risks to the owner, for example the potential for higher risk construction methodologies, or unproven products.

Such issues require potential mitigations in the specifications, which clearly apportion the performance risk between owner and contractor and mandate a process for resolving uncertainties. This could include shop and field testing requirements for proposed products, stipulations on construction staging to demonstrate performance, and/or requirements to provide contingency plan(s). Applying such approaches can be considered as an approach to increase the potential for innovative methodologies and products, while managing the risk between contractors and owners. In addition, writers of specifications should consider whether there are explicit processes and standards in the contract for the review of equals (usually included in the general conditions and technical specifications respectively) and if additions or modifications to the generic language is required to address specific components of the design.

Worker safety both during the construction and operational phases must be paramount in the minds of the engineers involved in any project. Opportunities to incrementally improve these features should be seized upon. With the ever-increasing advancement of safety regulations and standards, projects that strive to make safety, operational flexible, and reliability a priority during construction and throughout the service life of the project will provide the greatest value to owners.

Implementation of new approaches and improved performance standards can be expected to yield some resistance from both designers and contractors. It is the responsibility of the industry to strive for continual, incremental improvement in the design and construction of new infrastructure thereby increasing the overall resiliency. Ultimately, as community members and tax payers we all bear the cost of the infrastructure we construct, therefore we all benefit as we improve our standards and practices.

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