TEXAS & OKLAHOMA

TRENCHLESS REPORT 2020

OFFICIAL PUBLICATION OF THE NASTT SOUTH CENTRAL CHAPTER (NASTT-SC)

- Evolution of Pipe Ramming
- Nederland to Beaumont Corridor
- Crossing Nueces Bay
- Hydrofracture Analysis

2020 ANNUAL EDITION


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CONTENTS

Cover Feature:

The Evolution of Pipe Ramming

Used successfully for over 30 years to install steel casings, pipe ramming is a versatile trenchless application with a widening range of use, spawning newer methods such as pipe extraction, pipe swallowing, and pipe crushing. It has expanded to other industries including installation of culverts under railroads and highways, oil and gas pipeline installations, and casing installations from 4 to 144 inches. Pipe ramming techniques provide underground contractors with additional alternatives for completing jobs. The method continues to gain greater acceptance as more engineering firms become aware of the benefits of this technology.

Features:

Southern Congestion: Case Study Nederland/Beaumont Corridor

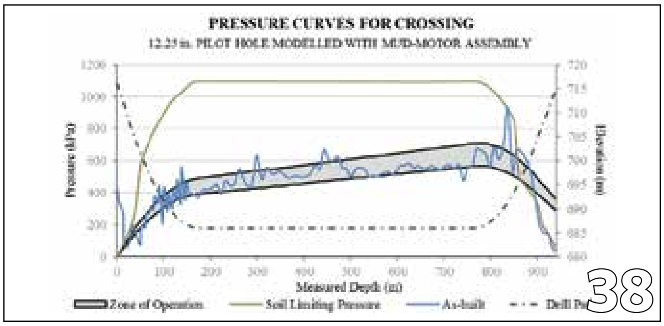
Careful HDD planning and design for pipeline installations is always important, especially in heavily congested corridors such as the Nederland to Beaumont Pipeline Corridor, which add extra complexity to a project. Case study details the completion of 15 HDD bores, with lengths from 886 to 5,400 feet, installing 6 – 24-inch pipe. Load-dispersing materials and timber mats were laid out to protect active pipelines during construction.

Crossing Nueces Bay: 9,430 LF of 20-Inch Steel in One Pull

Challenges posed by the varied ground conditions due to the crossing length and project timing in the middle of hurricane season. Additionally, H2S was detected during preliminary geotechnical explorations with readings as high as 200PPM. Protecting crews and those around the job site was critical so detailed safety plan and H2S alert systems was implemented.

Dallas Water Utilities Uses Sliplining to Rehab Aging Waterline

With a high-profile project location, consistently heavy traffic flow, and affluent residential and business populations, Dallas Water Utilities considered trenchless options to rehabilitate a 5,100 LF section of 24-inch water transmission main built in the 1920s.



A New Perspective in Hydrofracture Analysis

HDD projects continuously monitor drilling fluid pressure during construction to reduce the risk of inadvertent returns of fluids to the surface. Real-time downhole pressure data collected during HDD bores is useful to test the validity of theoretical drilling fluid and confining pressure calculations.

Also:

Departments:

Cover Photo: Morrison Energy

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MESSAGE FROM THE NASTT SOUTH CENTRAL CHAIR

Jim Williams, NASTT South Central Chair

Welcome back to the 3rd publication of the ***Texas and Oklahoma Trenchless Report***. Established four years ago, the South-Central Chapter of the North American Society for Trenchless Technology (NASTT-SC) is proud to present this journal documenting trenchless projects which are the result of the growth and impressive level of support from professionals within our industry.

The South-Central regional chapter of NASTT represents Texas and Oklahoma, two states comprising a geographic area experiencing significant growth in population. As the population grows, so does the need to expand, upgrade and replace existing infrastructure. Now more than ever, the benefits of trenchless technologies are critical to addressing our infrastructure challenges. The ***Texas and Oklahoma Trenchless Report*** is focused on providing a better understanding of trenchless methods and best practices on a regional level.

The South-Central chapter (NASTT-SC) was formed in January of 2016, and has since hosted four chapter events in 2016, 2017 and 2019 at The University of Texas at Arlington and at Oklahoma State University in 2018. These events are averaging roughly 150 attendees that ranged from utility owners to engineering firms to municipalities. At these events, attendees learned about the trenchless projects that were taking place in their local areas and enjoyed the professional networking opportunity to learn from their peers. The 2020 annual conference planned to occur in Sugar Land, Texas has been postponed due to the current Covid-19 conditions. Please check back often for updates on this event.

The South-Central Chapter is committed to supporting education through scholarships for our members. A total of 3 student scholarships at $2500 each will be awarded in October for the 2020-2021 school year. For more information on this year's scholarships, see info below. The South Central Chapter will continue to support eligible student and members through scholarships, education, and future employment within our industry. To further this effort, the board unanimously voted to expand scholarship eligibility to Louisiana Tech University students. Louisiana Tech has had a strong NASTT student chapter for many years.

> *"The South Central Chapter has seen exceptional growth"*

The South Central Chapter has seen exceptional growth over the past year with a 25% increase in membership. I challenge each of you reading this publication to consider joining the South-Central Chapter of NASTT and get involved with our organization. We hope you find this publication to be a valuable resource for all things trenchless and we truly appreciate your continued support.

Sincerely,

Jim Williams

Jim Williams
NASTT South Central Chair

MESSAGE FROM THE NASTT CHAIR

Craig Vandaelle, NASTT Chair

With the trenchless market growing so fast now is the time to join us!

Hello South Central Chapter Members. For everyone 2020 has been quite a whirlwind year! Like the rest of the world, the staff and volunteers here at NASTT have been pivoting and evolving on a near daily basis to changes in how we do business due to the COVID-19 situation.

As this unprecedented year continues to unfold, NASTT is working diligently to continue to provide the training and education you need to do business and stay up to date with innovations in our industry. We are looking forward to rolling out virtual events and training opportunities in the coming months as we fulfill our mission to be the premier trenchless educational society in North America.

In August we will launch our NASTT Good Practices Courses as virtual events. These courses are a rescheduling of the 2020 No-Dig Show Good Practices Courses and our entire suite of courses will be available as live training events. Our four-hour courses will take place in one day and our eight-hour courses will be split into two-day sections to allow for schedule flexibility for our attendees. All NASTT Good Practices Courses include Continuing Education Units, a training manual and the accompanying NASTT Good Practices Guidelines book if applicable. Visit nastt.org/training/events for the full schedule and registration details.

Our goal is to represent our industry and provide valuable initiatives. To do that, we need the involvement and feedback from our members. We are always seeking volunteers for our various committees and programs. If you are interested in more information, please visit our website at nastt.org/membership/volunteer. There you can view the committees and learn more about the ways to stay involved with the trenchless community and to have your voice heard. Please consider becoming a volunteer – we would love to tap into your expertise.

We are looking forward to coming together in Orlando next March for the NASTT 2021 No-Dig Show. It will be particularly exciting to come together again as a group and celebrate the trenchless industry in North America as we learn and network together. By all accounts, the NASTT 2019 No-Dig Show in Chicago was a resounding success, hosting a record breaking 200+ exhibitors and over 2,200 attendees. We're going to come roaring back strong and break these records at No-Dig 2021 in Orlando!

We look forward to growing and learning from these recent challenges and coming back stronger than ever. Thank you for all your support and dedication to NASTT and the trenchless technology industry. We are only as strong as our Regional Chapters. We are always looking for volunteers and new committee members not only locally but nationally. Don't be afraid to get involved! With the trenchless market growing so fast now is the time to join us!

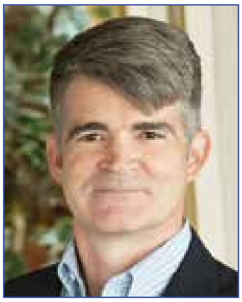
Thank you for being a part of our organization and for dedicating your careers to the trenchless industry.

Craig Vandaelle

NASTT Chair

NASTT SOUTH CENTRAL REGIONAL CHAPTER

ELECTED OFFICERS



JIM WILLIAMS – CHAIR

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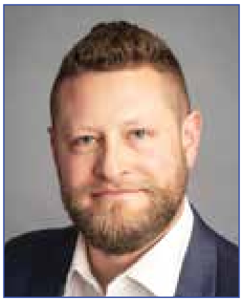
Jim Williams is a Senior Associate with Brierley Associates, located in Austin, Texas where he works exclusively on trenchless projects. He has 26 years of experience in a wide range of projects primarily in horizontal directional drilling and other trenchless methods. His experience includes design, planning, construction, and construction management of trenchless projects throughout North America.

Jim received his bachelor's degree in engineering from the University of Florida and is a licensed civil engineer in 17 states. He began his career working for several engineering firms in Jacksonville, Florida before founding a trenchless engineering firm in 2006 that focused on contractor support services. In 2010 he joined Mears Group as HDD Engineering Manager until late 2017 when he joined Brierley. He has also authored numerous technical papers and taught many HDD training classes in North America, Europe and Australia.



NIK TAYLOR – TREASURER

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Nik Taylor has worked in the underground construction industry for five years. Nik began his career with HammerHead Trenchless and is currently employed by Subsite Electronics & HammerHead as the Regional Sales Manager for the South-Central Region of the United States. Nik began his professional career as an Art Director at a Newspaper in San Diego County and worked in marketing and project management in electrical sign construction before joining the underground construction industry.

Nik has worked with the Ditch Witch dealer channel, assisted damage prevention associations, and has helped develop training and best practices for large organizations. Nik is a certified underground utility locator and is a trained HDD tracking expert. Nik currently serves as the Treasurer for the NASTT South Central Chapter.

JONGHOON "JOHN" KIM, PH.D. – VICE CHAIR

jongkim@okstate.edu

Dr. Kim is currently working in the Department of Construction Engineering Technology at Oklahoma State University (OSU) as an Assistant Professor. He has a B.S. in Civil Engineering from Colorado State University, a M.S.in Civil Engineering from the University of Louisville, KY and he received a Ph.D. in Civil Engineering with emphasis on Construction Engineering at Arizona State University. He has over ten years of professional industry experiences in construction and heavy/civil engineering areas in the United States and South Korea. He was involved in the areas of various civil projects, which include utility design (e.g., water and wastewater), roadway and bridge. His research interests are sustainable infrastructure development, Civil Integrated Management (CIM), underground pipe evaluation and construction using 3D modeling.

SHAI JOSHI – SECRETARY

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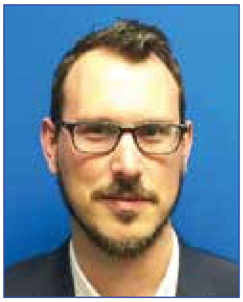
Shai Joshi has been involved in the trenchless pipeline industry since 2012. He began his career working as a Project Coordinator for a pipeline installation contractor. Shai spent most of his time in the field documenting on-site activities and learning horizontal directional drilling operations. Two years later Shai accepted the role of Project Manager and became responsible for the planning and budgeting of trenchless crossings and interfacing with clients over the course of construction.

During his time in the industry Shai has been exposed to many aspects of the business including estimating, business development, management, design, and construction. He has been involved with projects in several markets including gas, electric, water, sewer, telecom, and chemical. Over the past eight years he has gained experience with drills in challenging formations, and complex crossings with multiple pipe bundles, large diameter pipe, and intersect crossings at lengths over 9,000 feet.

BOARD OF DIRECTORS 2020-2021



JUSTIN TAYLOR – DIRECTOR OF MARKETING

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Justin Taylor, P.E. is the VP of Engineering for CCI & Associates, an engineering, design, and inspection firm specializing in trenchless technology. Justin holds a B.Sc. in Mechanical Engineering from the University of Alberta. After almost 10 years of various engineering and management roles in the Western Canadian CCI offices, Justin moved to Houston, Texas to head the engineering team in CCI's first stateside offices. Justin is a licensed P.Eng. in Alberta, among other provinces, as well as a licensed P.E. in multiple states including Texas. In his time with CCI, Justin has worked on trenchless crossings for various high profile projects such as Keystone/Keystone XL, Enbridge Line 3, and Kinder Morgan TMEP Pipelines, and has been involved in the development of tools for real-time measurement of strain and stress on steel pipe during Horizontal Directional Drill installations. Justin is an active member of NASTT, having authored and co-authored several papers for the organization, and being a member of the NASTT Program Committee.

DANNY CRUMPTON - DIRECTOR OF MEMBERSHIP & CONFERENCE REGISTRATION

dcrumpton@geoengineers.com

Danny Crumpton BS, M-ASCE, MD-NASTT, M-SPE is Senior HDD Construction Consultant at GeoEngineers, Inc. He has over 35 years of accumulated experience, spending 20 years designing horizontal directional drilling (HDD) projects for pipelines up to 54 inches in diameter and lengths of more than 11,000 feet. Danny has extensive knowledge in HDD drilling, and subsurface exploration programs for pipeline crossings in the US and internationally.

ALAN GOODMAN – PAST CHAIR

agoodman@HHTrenchless.com

Alan Goodman has more than nineteen years of experience in the underground construction industry. Alan began his career in the auger boring industry as a sales representative and is currently employed with HammerHead Trenchless & Subsite Electronics as Market Development Manager in the United States & Canada. After learning Japanese in high school, Alan studied abroad in Japan and served as an Ambassador for the Rotary International exchange program. Alan completed his education with a B.A. in International Business from the Stephen F. Austin State University in East Texas.

During his tenure at HammerHead Trenchless, he has worked closely with municipalities and gas utilities including engineering firms and contractors around the world providing customer training, technical support, pre-project planning, project specifications, and installations for pipe ramming, pipe bursting, cured-in-place pipe (CIPP) and other trenchless projects.
Alan currently serves as Vice Chair on the national board of NASTT (North America Society for Trenchless Technology) as well as the Program & Finance Committees. He is also Past Chair of the South Central chapter which includes Oklahoma & Texas.

Alan is also an active member of the following industry associations: DCA (Distribution Contractors Association), AGA (American Gas Association), PLCAC (Pipe Line Contractors Association of Canada), & NUCA (National Utility Contractor's Association).

UTA NASTT Student Chapter

By: Dr. Mo Najafi, Ph.D., Director, CUIRE

The NASTT Student Chapter at the University of Texas at Arlington (UTA) is has been busy with field trips, guest speaker presentation, educational programs and research projects. The Center for Underground Infrastructure Research and Education (CUIRE) annually conducts certification schools, which delivers training in horizontal directional drilling, pipeline renewal methods, geotechnical investigations for trenchless technology, different types pipes, and microtunneling and pilot tube Schools. Last schools were held in January 2020 in conjunction with Underground Construction Technology (UCT) Conference and Exhibition in Fort Worth. These Schools are offered in ½ day sections, so attendees may attend different classes for ½ day, 1-day or 1.5 days. Next CUIRE Schools will be offered in conjunction with UCT 2021 in January 25-26, in Nashville, Tennessee. The UTA NASTT student chapter usually helps with organization and offering of these classes and attend some of these classes. For more information on our upcoming certification, courses contact us at cuire@uta.edu or 817-272-9177.

CUIRE Schools held at UCT Conference & Exhibition, Fort Worth TX, January 2020

Visiting Tunneling Site in Dallas

Two of our Ph.D. Candidates, Zahra Kohankar Kouchesfehani and Amin Darabnoush Tehrani received the 37th International Society for Trenchless Technology (ISTT) NO-DIG Florence 2019 Academic Research Award. They conducted a study on *"Structural Design Methodology for Spray Applied Pipe Liners (SAPLs) in Gravity Storm Water Conveyance Conduits as a Trenchless Renewal Application,"* under the supervision of Dr. Mo Najafi, PI of the project and CUIRE director. This study presented methodologies for use of SAPLs for structural application in renewal of culverts and drainage structures. The award selection committee found the methodology to be a significant contribution to the trenchless world.

(l to r): Amin Darabnoush Tehrani, Dr. Mo Najafi, Ph.D., and Zahra Kohankar Kouchesfehani with ISTT NO-DIG Florence 2019 Academic Research Award

SAPL Testing on CMP at CUIRE Lab

Visiting Vermeer Texas Louisiana

NASTT-SC and CUIRE Co-Host the Fourth Trenchless Technology and Pipe Conference (TTP 2019)

On Tuesday, May 21, 2019, the South Central Chapter of NASTT (NASTT-SC) and CUIRE hosted the Fourth Trenchless Technology and Pipe Conference (TTP 2019) at the University of Texas at Arlington. Previous TTPs have attracted more than 300 professionals from municipalities, government agencies, consulting and design engineers, contractors, utility companies and manufacturing. All TTP2019 attendees received a copy of all the presentations on a USB drive and a CEU/PDH certificates of completion were also awarded.

NASTT-SC Chairman Alan Goodman with Student Scholarship award recipients Zahra Kohankar Kouchesfehani (left) and Amin Darabnoush Tehrani (right). Missing from photo: Todd Enlow, Oklahoma State

The 4th annual TTP Conference provided numerous opportunities for networking and close personal access to industry expertise

Dr. Mo Najafi, Director, CUIRE, Alan Goodman, Chairman, NASTT-SC, and Michelle Hill, Program Director, NASTT addressed the morning plenary session

Informative presentations covered a wide range of trenchless technology topics with three separate tracks providing a wealth of information to conference delegates

The conference began with a welcoming plenary session with introduction and keynote address. NASTT-SC awarded three students scholarships of $2,500 each during this plenary session. After a morning break at the exhibit hall, the conference continues with three separate presentation tracks. During these presentations, industry experts provided information on the latest developments in trenchless technology methods and pipe materials, including several case studies.

Ditch Witch and Hammerhead jointly sponsored the buffet BBQ luncheon...

Conference Exhibitors and Sponsors have great opportunities for close one-on-one conversations with potential clients

NASTT-SC Board Members with NASTT Program Director Michelle Hill at University of Texas at Arlington (UTA)

Conference delegates had easy access to exhibits on trenchless technology and many industry experts

Members of the UTA NASTT Student Chapter were instrumental in helping to organize the conference and assist with logistical details

Dr. Mo Najafi, Director, CUIRE, Alan Goodman, Chairman, NASTT-SC, and Michelle Hill, Program Director, NASTT addressed the morning plenary session

The following companies and organizations have exhibited their products and services during past TTP conferences:

- Ace Pipe Cleaning Inc.
- Acoustical Control LLC
- Akkerman
- Alliance for PE Pipe
- CUES, Inc.
- CUIRE
- Ditch Witch
- Ductile Iron Pipe Research Assoc.
- Forterra
- Fuquay Inc.
- Hammerhead Trenchless
- Hobas Pipe USA
- HTS Pipe Consultants
- Insituform
- IPR- South Central
- LMK Technologies
- Mears
- NASTT
- Perma Liner Industries
- Primus Line
- S & B Technical Products
- SpectraShield Liner System
- StraightLine HDD
- Tulsa Rig Iron
- Vacmasters
- Vortex

For more information on the planned TTP 2021 Conference, contact Jim Williams at jwilliams@brierleyassociates.com

Profile of Amir Tabesh – A Success Story

First-Ever NASTT-SC Student Scholarship Award Winner Launches Trenchless Technology Career

"Success has no time limit", is the phrase Amir Tabesh uses to describe the path of his life and belief that everything happens for a reason, and generally turns out well in the end. The first-ever recipient of the NASTT-SC Student Scholarship at the TTP Conference at University of Texas at Austin (UTA), in the summer of 2016 has worked hard to fulfill a long held childhood dream, developing a successful career in Civil Engineering with a focus on trenchless technology applications.

Currently a Design Engineer at DAL-TECH Engineering, Inc., a professional survey and engineering firm located in Dallas for over 30 years, Amir has amassed an impressive resume of experience in municipal infrastructure improvement projects, including paving, drainage, grading, and utility design. He holds a Doctoral Degree in Civil Engineering specializing in Construction Engineering, and has gained extensive experience in pipeline design, construction, and rehabilitation utilizing Trenchless Technology applications. To date, Amir has published 19 technical and conference papers across the globe related to Trenchless Technology.

> *"Success has no time limit."*

Born in Tehran, Amir experienced disruption and turmoil during his early childhood. Amir's father worked in heavy civil road construction companies for many years and was the greatest influence on his personal development, teaching Amir the importance of hard work and standing up on his own. When he was 18, Amir visited the Karoon 3 Dam under construction in southern Iran. His cousin was the Project Manager and gave him a complete tour of the facility. Right then and there, Amir was inspired to become a Civil Engineer designing and building heavy infrastructure!

Earning his Bachelor of Science degree in 2005, Amir moved to the US in 2010, with his Iranian-American wife. Initially, he struggled to find work relating to his experience and interests, yet persisted in following his dream. He began taking steps down the path of progress, working in construction from 2010 to 2014, while taking college courses at night. Eventually he decided to get his MS degree in Civil Engineering, under the supervision of Dr. Mohammad Najafi at the University of Texas at Arlington (UTA).

Ultimately, Amir's determination and hard work paid off as he was granted direct admission into the Civil Engineering PhD program at UTA. Amir was heavily involved with Dr. Najafi's ongoing research at the Center for Underground Infrastructure Research and Education (CUIRE), and participated in several conferences such as NASTT, UCT, ASCE, and ISUFT. Dr. Najafi's supervision was an excellent experience for Amir, since he is one of the most well-known individuals in the pipeline industry specializing in trenchless technology. Today, Amir proudly continues to work with Dr. Najafi to develop several standards and guidelines for underground infrastructure.

Amir Tabesh at DAL-TECH Engineering exhibit at 2019 TTP Conference, with (l-r: Dr. Mo Najafi, Director, CUIRE, Alan Goodman, Chairman, NASTT-SC, and Ms. Pooja Raganath, Graduate Research Assistant)

Justifiably proud of his achievements, Amir never stops setting goals. Recently, he has received his PACP and PMP certifications. Currently, he's planning to obtain his PE license, then his CFM certification, and in the spring of 2021, he plans to start his MBA. Ultimately, Amir's goal is to start his own engineering firm by the year 2025. His success story is an inspiration and lively example to follow for all other up and coming young trenchless professionals.

For further information, or to apply for NASTT-SC Student Scholarships, please contact NASTT-SC Chair Jim Williams at jwilliams@brierleyassociates.com.

5TH ANNUAL NASTT-SC TEXAS/OKLAHOMA

TRENCHLESS TECHNOLOGY CONFERENCE

NASTT SOUTH CENTRAL CHAPTER

OCTOBER 5 & 6, 2020

SUGAR LAND TOWN CENTER MARRIOTT
16090 CITY WALK, SUGAR LAND, TX 77479

Based on public health directives in response to the COVID-19 pandemic, the NASTT-SC Board of Directors has made the difficult decision to postpone the 2020 Trenchless Technology Conference until 2021.

Please visit our website for updates:
https://talk-trenchless.nastt.org/south-central/home

Monday Events:

- Pipe Bursting & CIPP Best Practices Course - join industry professionals who can train your inspectors or employees on the latest methods. Sponsored by the City of Houston and City of Sugar Land, TX.
- Welcome Reception & Networking Event at Bar Louie, Sugar Land Town Square, across the street from the Marriott, 5pm – 7pm

Tuesday Events:

- Full Day Conference Agenda - Technical sessions, networking, exhibits and field demonstrations on Trenchless Technology PACKED with leading industry professionals there to help you with your projects! New forums this year!
- TX Fish and Game Entertainment for lunch

A great opportunity

to network, build relationships, and develop business opportunities with attendees and exhibitors from all aspects of underground infrastructure including public works officials, utility company personnel, oil and gas companies, engineers, underground contractors, industry suppliers and students. Registration includes complimentary USB of the Conference proceedings.

Limited space available! Act Now!

For 2020 Conference Information and Registration Visit: **www.nastt-sc.ticketleap.com/nastt-sc**

The Evolution of Pipe Ramming

By: Alan Goodman, Hammerhead Trenchless,
Jason Pollock, HURK Underground,
Blake Barnett, Morrison Energy,
Jim King, Krapff Reynolds

PIPE RAMMING

The pipe ramming process has been successfully used for more than thirty years to install steel casing. A pneumatic pipe ramming hammer is one of the most versatile pieces of equipment as it can be used in variety of ways. The most common casing installations have been under railroads and roadways installing oil and gas pipelines, and water and storm drains/culverts. Many years ago, hammers were introduced to the HDD Industry, where the hammers can be used in a number of ways to assist or remove stuck pipe. Hammers have been used in large part for Maxi Rig HDD projects to install a washover casing/conductor barrel from the drill down to bedrock. Recent increases in pipeline replacement have led to using pneumatic hammers to replace a pipeline without having to dig it up.

Pipe ramming tools allow the extraction of a pipeline using a hammer and extraction cradle. This trenchless method uses the force of the pneumatic hammer to pull the old pipe from the ground while simultaneously pulling new pipe in its place. Recently, a new method for replacing culverts near rail and highways has been developed called "pipe swallowing". This trenchless method uses a hammer to drive a larger diameter casing around the existing culvert. While pipe swallowing allows a larger diameter pipe to be installed in the same place as the existing culvert, it does not address cleaning out the pipe. With a new advancement in pipe swallowing technology, a lead casing is used to swallow the existing pipe while simultaneously crushing the old pipe inward from the newly installed casing. This allows the existing pipe to be easily extracted from the newly installed casing. This method is called "pipe crushing".

> *The Pipe Ramming method has evolved into many new applications*

The use of pneumatic hammers to install casing has evolved into many new applications so pipe ramming continues to play a significant role in the installation and replacement of this expanding category of infrastructure. This article discusses the pipe ramming method and its current role in the installation and replacement of pipeline infrastructure as illustrated by several case studies of recent projects using pipe ramming technology.

Pipe ramming is defined as a non-steerable method of driving an open-ended steel casing using a percussive hammer from a drive pit. The soil is commonly removed from the casing by augering, jetting, drill removal, or compressed air. The advantage to using the pipe ramming process is that it swallows the spoil reducing the risk of voids. Running sand and cobble are the most common conditions where pipe ramming is preferred. While pipe ramming can address many soil conditions, the method shines in the lack of setup and production for shots in the 150-foot range with casing installations from 12 to 144 inches in diameter. Pipeline and boring contractors will use hammers for installation and replacement of pipeline throughout the country.

Figure 1 – Boulders and cobble spoils inside casing

PIPE RAMMING IN COBBLE

Demand for petroleum products has pushed the energy industry for continued exploration and distribution of oil and gas. Kinder Morgan, a North American oil and gas pipeline operator, sought to expand their pipeline system to transport oil from northeastern Alberta, Canada, out west. Years ago, the Trans-Mountain pipeline became the only direct pipeline link between Edmonton, AB, Vancouver, BC, and the state of Washington in the United States. Challenging terrain, difficult crossings and stringent environmental requirements made the installation process tricky.

The Anchor Loop Project was a segment of the Trans-Mountain Pipeline located in the Rocky Mountain Parks World Heritage Site which includes Jasper National Park and Mount Robson Provincial Park. This stretch of pipeline included crossings under rail and road with extreme soil conditions. North American Constructions Group subcontracted completion of the crossings to Calgary Tunneling based out of Calgary, Alberta, Canada.

Calgary Tunneling was chosen because of its vast experience doing crossings for pipeline contractors using auger boring, pipe Jacking, and pipe ramming. Calgary Tunneling has done a lot of work across Alberta including the northern regions where the Anchor Loop Project was located. The location's soil conditions are harsh; the soil is replete with rock and heavy cobble. Typically, an auger flighting can move cobble as large as one third the diameter of the flighting. To auger bore in these conditions, a much larger casing would need to be installed. For this reason, Calgary tunneling chose pipe ramming.

Calgary Tunneling chose a 24-inch pipe ramming hammer from HammerHead Trenchless to install 25 segments of 42-inch steel casing to carry the 36-inch product line. The hammer was successfully able to drive the 42-inch casing across the crossings and penetrate through the large cobble and boulders.

CULVERT REPLACEMENT

As pipe ramming became a proven installation method, it continued to

> *"Pipe Ramming is used for oil and gas pipelines, culvert replacement, and even for simple casing installations under a driveway"*

Figure 2- Large boulder removal

Figure 3 – Spoils inside 60-inch casing

Figure 4- BNSF railroad with minimal access on both sides

expand to other industries including use by railroads and DOT's as a practical solution for the trenchless installation of culverts. Culverts are designed to direct water away from areas that need protection from erosion specific to roads and railroad tracks. No matter how well a culvert was built, time and erosion eventually start to affect its structural integrity.

On one occasion, the Burlington Northern Santa Fe Railway Company (BNSF) identified three deteriorating culverts around Ardmore, Oklahoma, that were in need of immediate replacement. Ardmore is located about 100 miles south of Oklahoma City.

The jobsite was at the bottom of a 200-foot rock wall bluff, with the tracks running between the bluff wall and a river. So difficult was access to the site that there was only one way to get equipment in and out: by the very railroad tracks the project was designed to save.

In addition to these extreme site conditions, the steel casings that would help form the new culvert would have to be installed on-grade through soil conditions that included approximately two feet of rock and eight inches of cobble. And one more critical factor: the job would have to be done without stopping traffic along the railway, which had as many as 56 trains moving through it every day.

BNSF contacted Hurk Underground Technologies to provide a replacement solution for this difficult project. Headquartered in Altoona, Iowa, Hurk Underground Technologies specializes in culvert cleaning, culvert restoration, and specialized subsurface drainage. Based on their many years of experience with similar projects around the country, the Hurk team decided that the pipe ramming process would be the most practical method to facilitate the project.

When project specifications call for little to no soil displacement, pipe ramming is considered one of the most cost-effective alternatives to methods such as auger boring, open cutting (trenching), and micro-tunneling—especially when conditions involve cobble or free-flowing soil. And with rail traffic continuing during the project, it was absolutely essential to displace as little soil as possible in order to maintain the railbed's integrity.

Understanding the tight conditions in which they would be operating, the

Figure 5- 60-inch casing installation with air compressors sitting on railroad tracks

Figure 6- 36-inch casing installation using hydraulic lifting jacks: "Pipe Mules"

Hurk Underground team chose to use 20- and 24-inch HammerHead pipe ramming hammers. HammerHead pipe rammers are recognized in the underground construction industry for being easy to set up, extremely durable and low-maintenance.

The Ardmore project consisted of installing one 95-foot section of 60-inch steel casing at a two percent grade, and two 80-foot sections of 48-inch casing at a one percent grade. To facilitate installation for the casings on-grade, the Hurk Underground team used an advanced hydraulic leveling system that allowed them to make grade adjustments on the fly.

Hurk Underground Technologies has continued working for railroads throughout the country. Today, Hurk Underground is still putting in casing for BNSF using the pipe ramming method, several recent projects being in Texas including the project shown in Figure 6 below installing 36-inch casing 80 feet in distance.

Figure 7- 24-inch Extraction Cradle with 20-inch Hammer replacing 24-inch Pipeline

PIPE EXTRACTION FOR PIPELINE REPLACEMENT

Many of the pipelines and culverts that are in need of replacement are in areas where open cut replacement is generally not the preferred method either due to cost or inconvenience of disruption to rail or public transportation. Using a trenchless method reduces cost and inconvenience in most cases. When a bare steel casing pipeline is being replaced, a hammer with an extraction cradle can be welded to one side of the casing being replaced. An extraction cradle is a solid piece of steel casing that locks the pneumatic hammer inside. On the other side of the pipeline a new coated steel pipe is welded to the old pipeline. This trenchless method uses the force of the pneumatic hammer to pull the old pipe from the ground while simultaneously pulling new pipe in its place. As more pipeline replacement continues, the advancement and utilization of this method will continue to grow as more contractors and operators learn about this technology.

PIPE SWALLOWING

One of the more recent steps in the evolution of the pipe ramming method is the development of a process called "pipe swallowing". With the pipe swallowing method, pipe ramming is used to install larger-diameter casing over an existing culvert. In this method, the existing casing or culvert must also be extracted as part of the spoil from inside the larger diameter pipe rammed over it. Pipes made of materials that can be fractured, like cement or vitrified clay, can be broken as they are removed.

Figure 8- Auger removing CMP in sections

Figure 9- CMP pipe crushing extraction

In 2018, the Oklahoma Department of Transportation (OK DOT) had several culverts in need of replacement. Most of the pipes ranged from 24 to 36 inches in diameter and were in 60 – 120-foot lengths. Both the pipe swallowing and pipe crushing methods were used in replacing the Corrugated Metal Pipe (CMP) culverts. In 2019, Krapff Reynolds Construction replaced a 30-inch CMP with a 42-inch Casing using the pipe swallowing method. An auger was used in extracting the CMP pipe as the initial CMP pipe was collapsed and had debris requiring an auger to extract.

PIPE CRUSHING

Pipes made of deformable materials must be cut, dragged or pushed out. Corrugated metal pipe (CMP) is more problematic; often the structural integrity of the existing CMP to be replaced has been compromised. This problem necessitated the most recent advancement of pipe ramming technology, a technique called “pipe crushing”. The pipe crushing technique was developed with CMP specifically in mind. CMP is difficult to extract because its corrugations mechanically lock into the compressed spoil between it and the interior wall of the larger casing installed in the pipe swallowing process. Attempts to push it out of the larger casing can result in an “accordion” effect, wedging it tighter still. Attempts to pull it out can mean taking out the CMP in small pieces that result when hooks or other fasteners tear free.

The pipe crushing technique makes extracting CMP with the spoil easier by deforming the existing CMP into a cloverleaf-like shape. The first pipe driven over the CMP is a sacrificial “dummy” pipe equipped with interior, tapered blades. As the pipe ramming operation progresses, the blades crease and collapse the pipe. Deforming the CMP reduces its circumference, unlocking and decompressing the spoil, significantly reducing drag. In some applications, a contractor can simply use a backhoe, excavator, boring machine or similar piece of equipment to push or pull the CMP out together with the spoil. This allows a crew to extract longer sections at a time, reducing project time with fewer trips in an out of the pipe if using an auger or directional drill to remove the CMP pipe and spoils.

Krapff Reynolds has demonstrated to the satisfaction of OK DOT the value of pipe swallowing on several culvert replacement applications. These projects demonstrate how swallowed culvert lying beneath heavily traveled roadways was replaced effectively without impeding traffic and with minimal impact on the environment. More importantly, the pipe swallowing projects installed a larger diameter casing successfully on grade.

GAINING GROUND

The pipe ramming method continues to gain ground as more methods and applications become available. Today, this method is used in the oil and gas pipeline sector, for culvert replacement and installations, and even for simple casing installations under a driveway. From a 144-inch casing down to a 4-inch casing, the limits and applications of pipe ramming tools continue to drive the manufacturing of these hammers and accessories. The method continues to gain acceptance as more engineering firms become aware of this technology's benefits., Following the existing path of the utility that has been in the ground for so many years can reduce cost, significantly lessen potential damage to third party utilities, and, in many cases, increase the diameter of the existing pipe. The ability to perform both the replacement and installation of pipes trenchlessly prevents costly delays to both DOT & railway commerce and commuters.

Figure 10 – Pipe ramming method continues to evolve and gain ground

The above case studies demonstrate the multiple uses of pipe ramming tools and methods. They give contractors additional alternatives to choose from for completing a job. In addition to the advantages offered by pipe ramming as a construction method, the superior capability of pneumatic hammers for installing pipe and casing in free-flowing soils allow them to be used in conjunction with other trenchless methods. They demonstrate that obstacles that present challenges on a project are not necessarily barriers to completion.

ABOUT THE AUTHORS:

Alan Goodman *is Market Development Manager for Hammerhead Trenchless, looking after the US and Canada. With over 19 years' experience in underground and trenchless construction, Alan's expertise includes directional drilling, pipe ramming, auger boring, pipe extraction, pipe slitting, pipe bursting, and cured in place lining.*

Jason Pollock *has over 20 years' experience related to the underground and trenchless industry. After some time spent in management at Vermeer Jason became a managing partner at Hurk Underground Technologies and is responsible for the rail road pipe ramming division nationwide.*

David Spellman III *is currently a project manager at Morrison Energy and has over 35 years of Onshore and Offshore pipeline construction working both domestic and international markets.*

Krapff Reynolds Construction Company (Inc) *was founded in 1983. The company's line of business includes providing general contracting services such as constructing and rehabilitating water, sewer, and storm drain/ culverts.*

Southern Congestion:

A Case Study Working in the Nederland to Beaumont Pipeline Corridor

By: Cole Byington, Integrated Trenchless Engineering

Working within the Nederland to Beaumont Pipeline Corridor created additional complexity for the project

Completing horizontal direction drill (HDD) projects in areas congested with other utilities comes with unique difficulties. These difficulties can be exacerbated when the congested area is a pipeline corridor such as the busy ExxonMobil Nederland to Beaumont Pipeline Corridor. In order to successfully complete projects in these crowded areas HDD contractors must be thorough in their attention to detail during the planning and construction phases of the project.

ExxonMobil commissioned the design and installation of seven pipelines between various Phillips 66, Enterprise, and ExxonMobil facilities located in Beaumont and Nederland, Texas. Six of the pipelines share the same Nederland to Beaumont pipeline corridor extending from the Phillips 66 Terminal in Nederland, Texas to the ExxonMobil Beaumont Refinery. The seventh pipeline was a standalone pipeline located in a separate pipeline corridor west of the Nederland to Beaumont corridor.

ExxonMobil partnered with UniversalPegasus International (UPI) to contract and manage the design and installation of the pipeline project. UPI contracted GeoEngineers (GEI) to perform the engineering and design of the trenchless pipeline installations, and Troy Construction, LLC (Troy), was selected to complete the construction scope of the project. Troy subcontracted Laney Group, Inc. (Laney) to perform 15 trenchless installations utilizing the HDD construction method.

Pilot hole was highest risk part of construction due to potential of intersecting an existing pipeline

PROJECT OVERVIEW

The construction phase of the project consisted of installing seven pipelines each carrying a different product. The pipeline systems consisted of 3.1 miles of 6-inch diameter pipe, 2.4 miles of 10-inch diameter pipe, 8.1 miles of 12-inch diameter pipe, 0.9 miles of 20-inch diameter pipe, and 2.2 miles of 24-inch diameter pipe.

Laney was responsible for the completion of 15 HDD installations with lengths between 886 feet and 5,400 feet. The installed product pipes ranged between 6-inch and 24-inch diameter, installed either in single pipes or as bundles. The single 10-inch diameter HDD installation had a final reamed hole size of 18 inches while the largest diameter bundle required a final reamed hole diameter of 48 inches. While some of the HDD installations were routine, several were complex and included multiple horizontal curves, limited workspace areas, and working within the highly congested pipeline corridors.

In the weeks between GEI completing final HDD designs in February 2019 and Laney mobilizing drilling equipment to the project in May 2019, new structures were constructed in the vicinities of

Load-dispersing materials and timber mats placed to protect existing pipelines

> *Careful HDD design and planning for installations in congested pipeline corridors is very important.*

Completing HDD projects in areas congested with other utilities comes with unique difficulties.

HDD 11 and HDD 14. Because of these new obstacles, HDD 11 and HDD 14 were combined to accommodate the need to pass beneath the newly constructed surface obstructions. To safely avoid the obstructions Integrated Trenchless Engineering (ITE), a Laney Group Company, redesigned the HDD installations to combine them into a single HDD; however, it added to the design complexity because of the increased length and horizontal curves required to combine the two original HDD installations. ITE worked closely with the Laney operations team to design an HDD that avoided the obstructions and was constructible. The new bundled HDD consisted of a 10-inch-diameter, 12-inch-diameter, and 20-inch diameter product pipes. The HDD was 3,650 feet long and included two horizontal curves. ITE also provided site layout drawings, installation force calculations, tooling schedules, and pullhead designs for the 15 HDD installations.

HDD ENGINEERING IN A PIPELINE CORRIDOR

GEI completed the initial design and ITE completed revised designs, adjusted because of field conflicts. Whether part of the design phase or during the preconstruction phase, HDD design plays an integral role in the success of any HDD, but for HDD installations in congested areas like the Nederland to Beaumont pipeline corridor it is even more important. First, accurate as-built data for all pipelines in the area are necessary in order to plan the appropriate locations for the entry and exit points as well as the profile of the HDD. In addition, the immediate area around the entry and exit points must be able to accommodate entry and exit pit excavations and the placement of heavy construction equipment.

For this project, deadman anchors had to be driven to provide lateral load capacity at the rig during drilling and pullback operations. Existing utilities in and around the workspaces had to be avoided. In addition, the depths of the existing utilities were compared to the proposed HDD geometry in order to avoid potential conflicts. A minimum of eight feet of separation was designed between the drilled hole and any existing pipelines. Finally, drill tolerances provided by ExxonMobil were taken into account during the design so the HDD contractor had sufficient space to make any adjustments necessary to complete the HDD successfully, but still avoid existing utilities.

HDD OPERATIONS IN A PIPELINE CORRIDOR

The project was located mainly in the Nederland to Beaumont Pipeline Corridor, one of the most congested pipeline corridors in the country. Working in the corridor added additional complexity to the project. The operations team took great care during the

Detailed planning by the construction team was important to mitigate the risks of working in and navigating around the active pipeline corridor

planning phase of the construction to reduce the risks during the construction phase. The primary risks the Laney Drilling Team mitigated were working in and around the numerous pipelines in the corridor and accurately steering during pilot hole operations in the soft soils.

Before the Laney operations crews arrived on site, steps were taken to mitigate risks of working in the congested pipeline corridor. A plan was established to place load-dispersing materials and timber mats to protect the integrity of the pipelines that were to remain active during construction. Additionally, ITE created site layout drawings for each HDD installation to place equipment where they would not interfere with the existing pipelines. The primary factors driving equipment placement were the equipment weight and if there were any ground disturbances necessary to operate a piece of equipment safely. Placement of heavier equipment, such as the fluid cleaning system and drilling rig directly over shallow pipelines was avoided where possible. The Laney team was especially cautious of the placement of the drill rig to provide space for deadman anchors and excavation of the fluid containment pit.

After the workspaces were completed and equipment staged, the construction phase of the project began. As construction began, the pilot hole was the highest risk part of the construction phase because of the potential of intersecting an existing pipeline. A secondary survey system used while steering the pilot hole was critical in helping the HDD surveyor evaluate the position of the drill bit compared to the existing utilities. The magnetic tools utilize a surface grid to verify the tools precise subsurface location. The magnetic ranging process between the tool on the drill string and the surface coil will experience interference when the tool is near another pipeline, thus alerting the surveyor when the drill bit is near a pipeline.

Project success was due to detailed planning, expertise, and execution of the entire Laney team

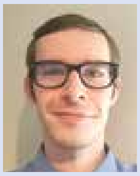
While not used on this project, another steering tool that may be utilized is a gyroscopic steering tool. Gyroscopic tools do not require a surface wire to provide a magnetic field above the drill path. The gyroscope steering tool is not influenced by external magnetic interference such as pipelines because it does not use an induced magnetic field. This allows the pilot hole to be drilled without magnetic interference; however, the driller is not alerted when near an existing pipeline.

CONCLUSION

There are extensive risks to performing pipeline installations utilizing the HDD construction method in congested pipeline corridors. These risks can be mitigated during all phases of the project from design to construction by careful planning and execution. The design phase requires detailed information gathering and HDD designs that take into account the locations of the existing pipelines and provided as-built designs, so that the HDD installations are constructible. In addition, detailed planning by the construction team is important to mitigate the risks of working in and navigating around an active pipeline corridor.

Because of high quality HDD designs by GEI and ITE, along with proper planning and execution, Laney successfully completed all 15 HDD installations between June and December 2019. Laney's Project Manager, Larry Hereford, attributed the project's success to the detailed planning, expertise, and execution of the entire Laney team, both in the office and in the field. Laney takes a detailed approach to all aspects of any project and prides itself on being a full-service trenchless solutions provider.

ABOUT THE AUTHOR:



***Cole Byington** is a Project Engineer for Integrated Trenchless Engineering, a Laney Group Company, based in Houston, TX. Cole has 4 years of experience in the construction and engineering aspects of the trenchless industry. Cole specializes in engineering, planning, and execution of HDD and Direct Pipe installations.*

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Crossing Nueces Bay:

9,430 Feet of 20-Inch Steel Pipe in One Pull

By: Chris Jones, HardRock Directional Drilling

In the late summer months of 2019, HardRock Directional Drilling successfully crossed Nueces Bay in Corpus Christi, Texas. The crossing was one of the final obstacles to complete the Phillips 66 Grey Oak project. The total length of the crossing measured 9,430 LF, with 20-inch steel pipe welded into one pull string and installed. Progressive Pipeline was the general contractor and completed all support activities associated with the crossing.

WHAT WAS USED

This crossing utilized two drilling rigs and was completed via intersecting methods for the pilot. A Vermeer 1000x900 (pull rig) and a 500x500 (intersect rig) were the drilling rigs. The gyro steering tool with the intersecting radar was used to complete the intersecting pilot. It was accomplished using two 8-inch drill motors equipped with 12 ¼-inch drill bits. Once the pilot was completed, the final hole was reamed out to a total of 30 inches.

THE CHALLENGES OF NUECES BAY

Although successful, crossing Nueces Bay posed many challenges. When a crossing spans over a mile and a half the underground conditions can change greatly. Numerous geotechnical bores were done prior to construction, and a favorable layer was chosen. Due to the length and the ever-changing conditions many different formation transitions were

Pulling pressures averaged 450,000 ft/lbs throughout installation with 16 hours total pulling time

> *"When a crossing spans over a mile and a half the underground conditions can change greatly.*

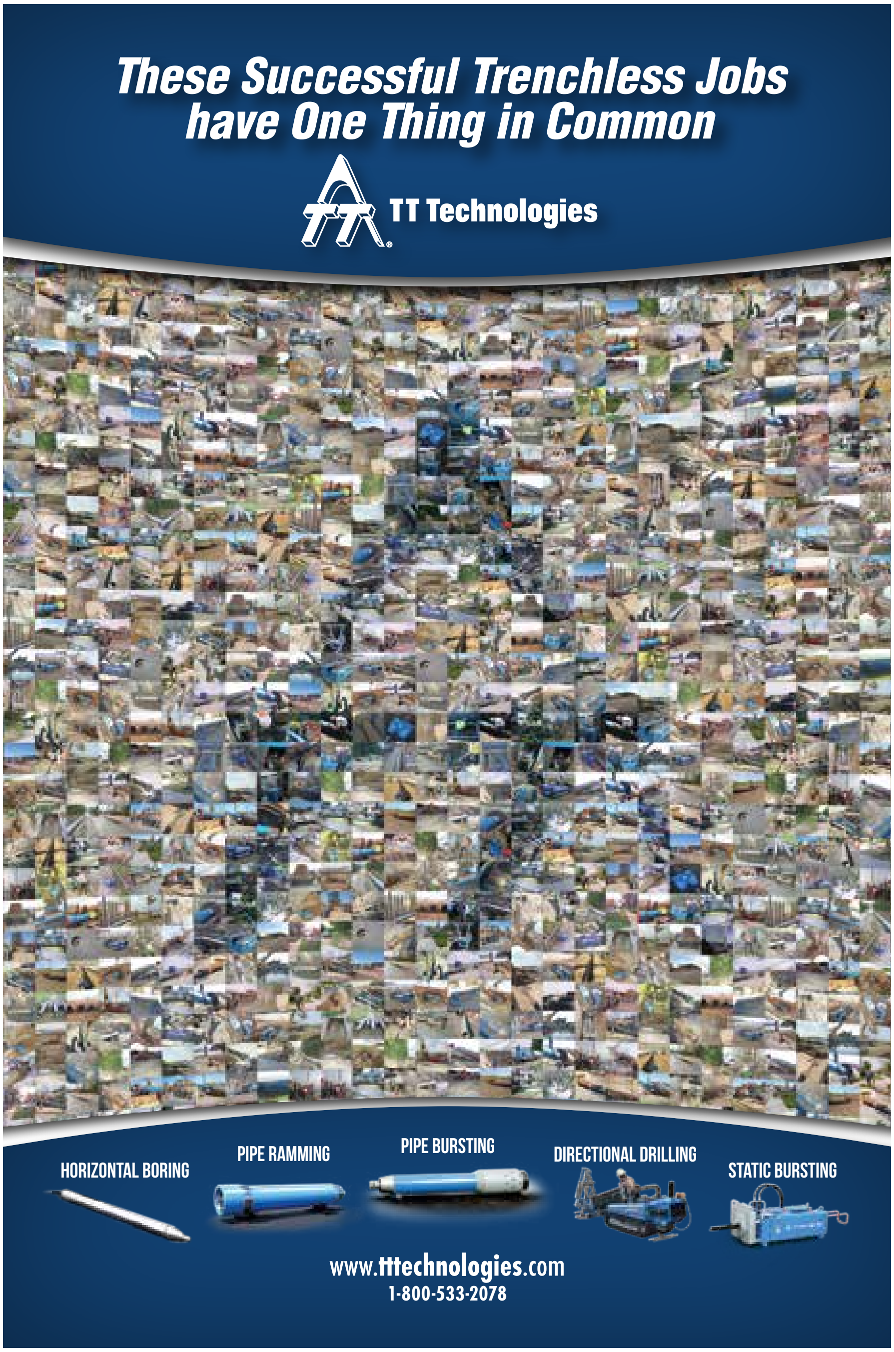
encountered on the pilot. These included soft soils, stiffer clays, and eventually very hard oyster reefs. This made completing the pilot process challenging, mainly due to the weight of the tooling required for each condition. If a tool is heavy and in a soft condition the tendency is for that tool to drop. There where were numerous trips in and out of the hole in order to match the tooling with the current conditions. A jetting assembly was used for a portion of the pilot (on each side), until the formation changed to hard, and a mud motor was needed to complete. The scenario of going from soft to hard back to soft was very challenging and made adapting to these changes very critical.

Ground conditions weren't the only challenges on this crossing. The timing of the project dictated construction was to be right in the middle of hurricane season. Fortunately, a named storm did not affect it, although all contingency had to be ready in the case of one. H2S gas was detected while the geotechnical bores were being completed. Knowing this prior to construction allowed a detailed safety plan and H2S plan to be established. An advanced monitoring system was established on both rig sites to alert of any possible H2S readings. During pilot operations an alert was reported, and the site was evacuated. All parties worked together to formulate a plan on how to proceed safely and protect all involved. Additional monitoring and mitigating equipment were implemented. Fortunately for the remainder of the crossing no other readings were reported.

When attempting a crossing of this size and length the pull section and support are a critical component. Progressive and Phillips 66 worked together with the landowners involved and were able to weld the entire 9,430 feet of pipe in one pull section. This was not as easy as it sounds. There were numerous driveways and county roads to contend with, in addition the section was not necessarily in a straight line with the exit hole. Progressive had to utilize numerous pieces of equipment to maintain the angles needed for a successful installation. The anticipated pulling pressures were calculated at 611,072 ft/lbs. The actual pulling pressures averaged 450,000 ft/lbs throughout the entire installation and around 16 hours of total pulling time.

PRE-PLANNING

Pre-planning on a complex HDD is extremely important and is the reason for any successful crossing. Many of



Crossing Nueces Bay posed many challenges

the challenges describe above were known before the drill started. Geo Engineers were responsible for the geotechnical exploration, evaluation, and final design for this crossing. Their data and interpretation were critical on this project. From the data provided HardRock was able to develop their drill plan and execution strategies.

During the geotechnical exploration pockets of natural gas were encountered. One specific location vented for approximately 35 days, and H2S was

The 9,430 LF of 20-inch steel pipe was welded into one continuous pull string detected with readings as high as 200 PPM. The OSHA PEL (permissible exposure limit) is set at 10 PPM. This obviously was the biggest concern and obstacle for HardRock. The challenge of protecting not just their crews, but everyone on or near the job site was critical. A very detailed plan needed to be created and strictly adhered to, in order to ensure everyone's safety.

All parties involved worked together to develop a detailed and safe plan to proceed, knowing the possibility of H2S exposure. Any one on site (both drill rig locations) were equipped with personal gas monitors. Fixed gas detection systems and monitors were also placed on both sites in strategic locations, including downstream monitoring. During early pilot hole operations, one of the personal gas monitors attached to a worker on the mud cleaning system (on the north side of the bay) alerted to a spike of H2S. It was a reading of 10 PPM. An all stop was called, and everyone was evacuated to preplanned muster locations. All parties involved then referred to the contingency plans that were in place. Before work would resume, the site was evaluated to assess the possibility of being able to work safely.

The H2S reading was recorded from the drilling mud that returned from the pilot hole and was transferred in a soluble form. When agitated by the cleaning system, this is what caused it to become a gas again. After the evacuation and evaluation process, the preplanned contingency plan was implemented. New AreaRAE monitors were used to detect Oxygen, Lower Explosive Limit or LELs, and Hydrogen Sulfide or H2S. Calibration alerts both audible and visual for H2S were set for 4ppm. Air Moving equipment was placed in all work areas to dissipate any possible gas present in relation to wind direction. Safety technicians were onsite calibrating, monitoring, and documenting all readings. Additional equipment such as Emergency Escape Packs was kept on site at all times for the remainder of the project.

Fortunately, for all involved during the remainder of the project there was never an H2S reading above .4 PPM on either drill site for the remainder of the project. HardRock is very thankful for everyone that assisted in the mitigation of the H2S on this project. Knowing that there was a high probability of encountering H2S, allowed for the proper planning and contingencies to ensure everyone's safety. Which at the end of the day is what matters the most.

This drill crossing Nueces Bay was very challenging in many aspects. With extensive preplanning and tremendous help from both Phillips 66 and Progressive Pipeline this crossing was completed successfully, and most importantly, safely.

Pipe support is critical to maintain the angles needed for a successful installation

ABOUT THE AUTHOR:

***Chris Jones** is the Vice President of Business Development for HardRock Directional Drilling.*

He has over 20 years of sales experience and over 14 years in the HDD industry. He was the Number 2 worldwide salesman of the year for Vermeer in 2009 and Number 5 in 2010. While at HardRock Chris has consulted and assisted in many of the largest HDD projects in the country. He is an active member of APCA, SAPA, & HPLA.

Dallas Water Utilities uses Sliplining to Rehab Aging Waterline in Urban Setting

By: Kevin Minkler, P.E., Pacheco Koch,
Eduardo Valerio, P.E, Dallas Water Utilities,
Thelma Flores Box, P.E., Pacheco Koch,
Shawn Garcia, P.E., Kyle Wroblewski, P.E., Underground Solutions Inc.

Preston Road is the major north-south thoroughfare in the Town of Highland Park

The Town of Highland Park ranks among the top 10 wealthiest communities in the U.S. The affluent community, surrounded by the City of Dallas, is home to many Texas sports and business icons. Preston Road is the major North-South thoroughfare through the Town. It's a collector with consistent heavy traffic flows and bordered by large estates. When construction is performed in this area, lots of emphasis is put forth to mitigate social impact to the community. This project would run adjacent to Jerry Jones' residence, the Dallas Country Club, and Highland Park Village, an upscale shopping plaza and National Historic Landmark.

In 2016, the Town of Highland Park, Texas began a street improvements project on Preston Road. This project caused Dallas Water Utilities (DWU), the wholesale provider to the Town, to evaluate options for the 5,100 linear feet of 24-inch water transmission main located under the road. This transmission line was originally installed in 1920. Decommissioning and removal from service was evaluated as well as full replacement and rehabilitation options.

Pacheco Koch Consulting Engineers, Inc. was contracted to evaluate these options for the water transmission main. They utilized a copy of DWU's H_2OMap hydraulic model, which included Summer Day and Winter Day Extended Period Simulation (EPS) scenarios. Since development near the project location was already near buildout and fully developed, there'd likely be no significant changes in demand patterns in the future.

Pacheco Koch ran the hydraulic model with the 24-inch main in Preston Road in service versus the main abandoned. This revealed only a slight difference (negligible velocity changes and system pressure) when comparing system performance with the 24-inch main in-service versus out-of-service. A parallel 36-inch transmission main located just east of Preston Road provides DWU significant north-south transmission capacity in the area even with the 24-inch main removed from service.

Although the DWU system performance was not impacted by the abandonment of the 24-inch transmission main, the Town of Highland Park needed to maintain service to its Emergency Interconnection, the only service point along this section of pipe. The decision was made to reduce the size of the main from 24-inches to 12-inches to match the piping at the Interconnection. This would improve the water quality by reducing the water volume and age.

Sliplining using FPVCP supports long pull length and large pull forces

DESIGN

Due to the high-profile project location, consistent heavy traffic flow, and affluent residential and business populations, it was established that a trenchless methodology would be a better option in lieu of open cut in order to avoid extensive disturbance to the area. Because system capacity wasn't an issue, and with consideration to the clay filled soil in the area, sliplining was determined as the most advantageous rehabilitation solution. The existing 24-inch main would provide a suitable casing host pipe, allowing for the sliplining process to be streamlined, and providing an additional barrier of protection from traffic loading above.

This method also allowed for minimum disruption to existing utilities. A storm sewer network of pipes parallels and

Existing 24-inch main provided suitable casing host pipe for the 12-inch FPVCP

crosses Preston Road. This includes inlets and manholes within the right-of-way. In addition, telephone conduits, that run the entire length of the project, are located on both the east and west sides of Preston Road. Buried telephone cable is also located within the project area. Gas lines traverse the pavement in both north-to-south and east-to-west directions. Electrical service is underground and runs along the length of the road.

Since as-built drawings for the 24-inch water transmission main were not available due to the age of the installation, ground penetrating radar was used to locate the main horizontally and vertically, and to establish the location and dimension of curves along the main.

The determination of the curvatures of installation was particularly critical in guiding the selection of pipe material. The maximum deflection angles of pipe joint are restricted by DWU to 80 percent of the manufacturer's recommendation. In addition, the maximum allowable pull-in force and maximum straight pull length were compared. DR14 Fusible Polyvinyl Chloride Pipe (FPVCP), DR14 RJ Polyvinyl Chloride Pipe, and DR7.3 High-Density Polyethylene Pipe were all evaluated during the selection of pipe material.

FPVCP was sole sourced as the pipe product for the project. Its jointless, gasket-less, fully restrained nature provided the benefits of a fused monolithic piping system as well as the traditional preference for Polyvinyl Chloride Pipe in water systems due to the material's inherent resistance to corrosion and hydrocarbon contamination. In addition, it had the largest Maximum Pull-in Force. Also, its curve radius would allow the pipe to be safely pulled through the existing vertical curves, while its uniform cross section would allow the pipe to rest on the invert of the host pipe and be fully supported along its length. The use of standard waterworks appurtenances was an added benefit as well, since connections to PVC pipe are common to DWU (Standard waterworks fittings used to tap, connect, and change direction).

BIDDING

In mid-April, 2018, the project to rehabilitate the 24-inch transmission main was bid simultaneously with the project to reconstruct Preston Road. In order to allocate costs appropriately, separate bid forms were included in the bidding documents. Seven bids were received on April 30, 2018. At $4,197,437.88, the low bidder for the combined projects was Ragle, Inc. This amount included $1,048,200.00 for the downsizing of the

Sliplining method allowed for minimum disruption to existing utilities

24-inch water main by North Texas Contracting, Inc., which was 63 percent of the engineer's $1,669,374.00 estimate.

CONSTRUCTION

Construction was started in August, 2018. Preston Road is a 4-lane road and required the closure of one north-bound lane of traffic, adjacent to the east-side curb line, for the fusion, insertion and pulling processes. The entry and exit pits were installed at approximately 800-foot intervals. Although the pipe could be pulled over greater lengths, the interval length was limited to accommodate the cable lengths available for cleaning, CCTV and sliplining.

12-inch diameter DR14 FPVC was delivered in lengths of 45 feet and fused on-site by Underground Solutions (UGS). UGS provided a technician trained and certified in the fusion of PVC pipe to ensure the integrity of the joints. Each joint fusion performed was recorded and logged by an electronic monitoring device (data logger) connected to the fusion machine. The fusion data logging and joint report was generated by software developed specifically for the butt-fusion of FPVCP.

Prior to construction, the existing 24-inch transmission main was prepared for the insertion process. This included cleaning, pigging, and inspection using CCTV. Since the emergency interconnection, the only service point along the main, could be fed from either the north or the south, temporary water service was not required. Instead, the emergency interconnection would be fed from the north, while construction was being performed south of the interconnection, and fed from the south while the construction was being performed north of the interconnection.

The installation was performed in seven pulls of approximately 800 feet to meet standard cleaning cable length. Prior to each pull, two 300 to 400-foot lengths of pipe were fused. This length was based on the available laydown length, which was limited by driveways to the adjacent properties. The fusion at each joint required approximately 45 minutes (time varies with ambient temperature conditions). Near the end of the insertion of the first length of pipe, the second length of pipe was fused to the first and the insertion process continued to completion. Each pull was completed in the normal eight-hour workday.

Upon completion of sliplining, the newly installed pipe was pressurized per DWU requirements to test for any leaks. The test water remained in the pipe to keep it on the invert prior to grouting, which prevented any floating. Bulkheads at the ends of the section of pipe to be grouted, and vents equipped with ball valves and pressure gauges were installed. The annular space between the 24-inch and the 12-inch pipes was then filled using low-density cellular-grout with a density of 55 pcf. Low-density cellular-grout is highly flowable and highly pumpable, excellent at filling small irregular shaped voids, and lighter weight than standard sanded grout. It also has lower heat of hydration temperatures. These attributes make low-density grout ideal for annular space grouting. The ball valves and pressure gauges were used to monitor both the pressure testing and the grouting processes.

In total, the entire project to rehabilitate the 24-inch transmission main was completed in six weeks; however, this project experienced a three-month delay following the installation of the entry and

Each pull of approximately 800 feet was completed in a normal eight-hour workday

exit pits. The delay occurred because the valve required to shut off the water to the 24-inch main from the north was found to be inoperable. The upstream shut off point was at a pump station, which if exercised, would result in the loss of water service to many citizens and businesses. Instead, DWU opted to order a new 24-inch valve for installation by the contractor to replace the inoperable valve.

CHALLENGES AND LESSONS LEARNED

The project to rehabilitate the 24-inch water transmission main under Preston Road in Highland Park was constructed as designed. The difficulties encountered were associated with an inoperable valve that resulted in a three-month delay. The three-month delay extended the construction period into the Christmas Season, which resulted in demobilization to avoid interfering with shoppers' access to the upscale Highland Park Village. The delay in the construction schedule could have been avoided by exercising the cutoff valves prior to initiating construction and rectifying the issues presented.

Each joint fusion done was recorded by a data logger on the fusion machine

CONCLUSIONS

Sliplining using FPVCP provides the following benefits:

- Jointless, gasket-less, fully restrained piping system
- Resistance to corrosion and hydrocarbon contamination
- Small minimum curve radius to provide safe pulling through both vertical and horizontal curves
- Long pull length and large pull force
- Uniform cross section that allows the pipe to rest on the invert of the host pipe and be fully supported along its length
- Ability to use standard waterworks fittings/appurtenances at all cross-connections and tie-ins

The use of low-density cellular-grout to fill the annular space between host and carrier pipes also benefits projects by providing a support material with the following attributes:

- Highly flowable and highly pumpable
- Excellent at filling small irregular shaped voids
- Lighter weight than standard sanded grout

In combination, sliplining using FPVCP and low-density cellular-grout provides a piping system that is cost-effective and constructible. For the project to rehabilitate the 24-inch water transmission under Preston Road:

- Cost-effective: $205 per linear foot installed cost
- Constructible: Six-week construction time

Laydown length was limited by driveways to adjacent properties

ABOUT THE AUTHORS:

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A New Perspective in Hydrofracture Analysis

By: Stefan Goerz, M.Sc., P.Eng, P.E, CCI Inc.,
Nicolas Boelhouwer, P.Geo, CCI Inc.,
Justin Taylor, P.Eng, P.E, CCI & Associates Inc.

1. OVERVIEW

Most critical Horizontal Directional Drilling (HDD) projects in North America continuously monitor drilling fluid annular pressure during construction for mitigating risk of inadvertent returns (IR) of drilling fluids to the surface or to waterbodies (which is also sometimes called hydrofracture, or "frac out"). Downhole tooling automatically records "real-time", or "as-built" pressure data throughout the length of the HDD crossing and relays it back to the driller. While this data is extremely important during the construction of an HDD, the data is also useful to determine whether the theoretical drilling fluid and confining pressure calculations used by the HDD designer are valid. This article will give readers an insight into recent findings which show how the measured data compares to the industry standard calculated values.

To begin, the authors collected this as-built annular pressure data from past HDDs and compared it to the calculated theoretical drilling fluid pressure within the annulus of the borehole. Results of this analysis show the accepted drilling fluid models (in particular, the Bingham Plastic model) used to calculate the annular pressure during drilling generally compare well to the data obtained.

Although the accepted models accurately predict actual fluid pressure downhole, the accurate prediction of confining pressure (ie hydraulic fracture) is a different story. In order to assess the accuracy of the confining pressure calculations the authors have used as-built annular pressure data to determine the date, time, and pressure magnitude of actual hydraulic fracture occurrences in HDD crossings. Through careful evaluation, these occurrences have been isolated within the as-built data and compared to the predicted hydraulic fracture pressure calculated by the industry-standard "Delft" equation using site specific geotechnical parameters.

Results of the analysis of as-built data show that in most, if not all cases the "Delft" solution over-predicts the actual hydraulic fracture pressure, which can lead to severely unconservative designs and fluid release issues during construction. Additionally, the suggested factors for the "Delft" equation variable $\mathbf{R}_{p,max}$ of 1⁄2 and 2⁄3 multiplied by the overburden height for clay and sand, respectively, have not been previously investigated and compared to actual hydraulic fracture data. Contained within this research, the $\mathbf{R}_{p,max}$ value is modified to determine at what value the Delft equation best predicts the actual hydraulic fracture pressure.

2. A BRIEF INTRODUCTION TO HYDROFRACTURE EVALUATION

Hydrofracture / Inadvertent Return evaluation during HDD construction has increasingly become a more significant stage of engineering design. Typically, a hydrofracture evaluation includes a comparison analysis of the expected drilling fluid pressures (see Section 3 below), and the expected confining or "frac-out" pressure (see Section 4 below). These are two exclusive parts of the evaluation. However, the underlying principle is that the expected fluid pressure should be maintained below the soil confining pressure (in other words the pressure of the fluid in the borehole should be less than the earth pressure pushing back on the borehole walls), otherwise hydraulic fracture may occur.

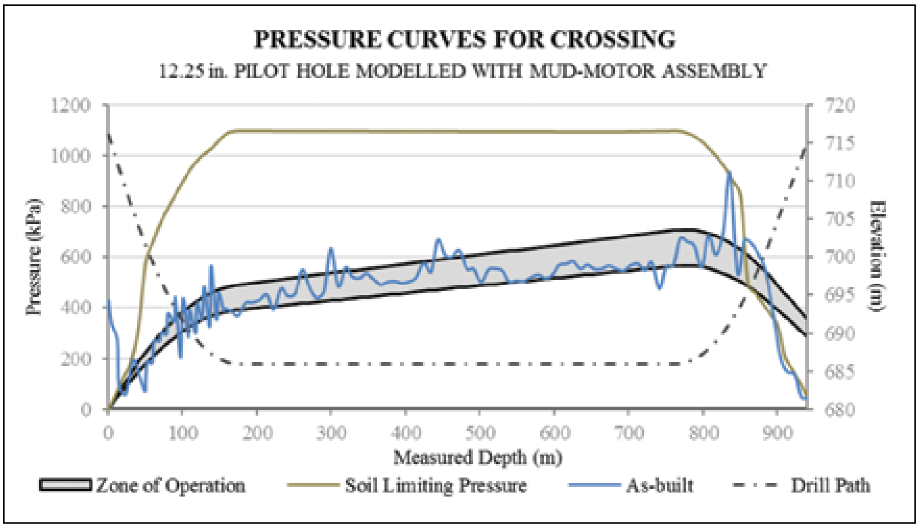

Figure 1: Example of as-built data overlain on the annular pressure model and design calculations

$$P'_{max} = [\sigma'_0(1+\sin\varphi) + c\cos\varphi + c\cot\varphi]\left[\left(\frac{R_0}{R_{p,max}}\right)^2 + \frac{(\sigma'_0 \cdot \sin\varphi + c \cdot \cos\varphi)}{G}\right]^{\frac{-\sin\varphi}{(1+\sin\varphi)}} - c\cot\varphi \quad [1]$$

Where:

	σ'_0 =	Effective Stress [kPa]
	φ =	Effective Angle of Internal Friction [degrees]
	c =	Cohesion [kPa]
	R_0 =	Initial Hole Radius [m]
	R_g =	Hole Radius [m]
	$R_{p,max}$ =	Maximum Plastic Radius [m]
	G =	Shear Modulus [kPa]
	P'_{max}=	Maximum Allowable Pressure [kPa]

(1) The 1988 Delft Equation used to predict hydrofracture pressure

3. DRILLING FLUID PRESSURES DATA ANALYSIS AND COMPARISON

There are various models designers and contractors may use to estimate the fluid pressures during HDD construction, however the Bingham-Plastic Non-Newtonian fluid model is the most common and has been used for this analysis.

Over 50 HDD projects with recorded annular pressure analysis data have been evaluated by use of spreadsheet tools developed by the authors. Following extensive analysis of each as-built data set obtained, the organized data was overlain on the HDD design annular pressure chart calculated during the design stage.

The example chart shown in Figure 1 demonstrates the result when the average as-built pressures are overlain on the design annular pressure calculation chart. The two solid black lines and grey shading represent the “Zone of Operation” of which the base line is the calculated drilling fluid pressure and the upper line is a 1.25 times factor multiplier on the design calculation. The 1.25 times factor is intended to account for field variation in fluid parameters during construction that may be different from the design stage and allow an acceptable tolerance for the operator. The green solid line represents the “Soil Limiting Pressure” which is the calculated pressure threshold the soil surrounding the HDD path is anticipated to withstand before a hydrofracture is induced. This is discussed in greater detail in Section 4. In an ideal fit, the as-built data tracks entirely within the upper bound of the zone of operation. In the example above, the fluid pressures (blue line “As-built”) are mostly maintained throughout the crossing, however there is evidence of a few high-pressure events.

In general, the data compares well with the model used during the design phase. Based on actual measured pressures during construction, we can see that the Bingham Plastic model typically used in these design calculations is suitably accurate.

4. CONFINING PRESSURE DATA ANALYSIS AND COMPARISON

The most common method to predict the hydrofracture pressure is the well-known “Delft” equation which was first developed for use in HDD construction by Luger and Hergarden, in 1988. The Delft equation [1] is shown at the top of this page.

As shown in equation [1], a very important parameter within the equation is the value of the maximum plastic radius ($\mathbf{R}_{p,max}$). This value is considered the extent of the yielding soil material around the borehole at the maximum allowable pressure. Additionally, it has been assumed that if this radius extends to the topographic surface, hydrofracture will occur. Commonly, $\mathbf{R}_{p,max}$ is taken as the height of the soil above the HDD path multiplied by factors of 1/2 and 2/3, for clay and sand, respectively. Notably, these factors for $\mathbf{R}_{p,max}$ have been adopted for use in hydrofracture calculations by the United States Army Corps of Engineers (USACE) through the publication of the Construction Productivity Advancement Research Program report CPAR-GL-98-1, *“Installation of Pipelines Beneath Levees Using Horizontal Directional Drilling”*. These factors and their common use in USACE-sanctioned HDD projects provide the basis for comparison.

4.1. METHODS

For select HDD construction projects where hydraulic fracture has occurred, the as-built annular pressure data, in combination with HDD construction inspection reports, are used to determine the date, time, and pressure magnitude of actual hydraulic fracture occurrences in HDD crossings. These pressure magnitudes can be used to evaluate the design calculation, and as used in this research, evaluate the size of the maximum plastic radius.

To identify a hydraulic fracture within the data, the largest as-built pressure before the release is observed on surface, should be taken as the fracture pressure. Often the data will show a distinct trend as shown on the chart in Figure 2, on page following.

In most cases the entire fracture characteristic curve is not observed, and only the “breakdown” and “fracture propagation” pressures are present. Generally, the pressures are monitored

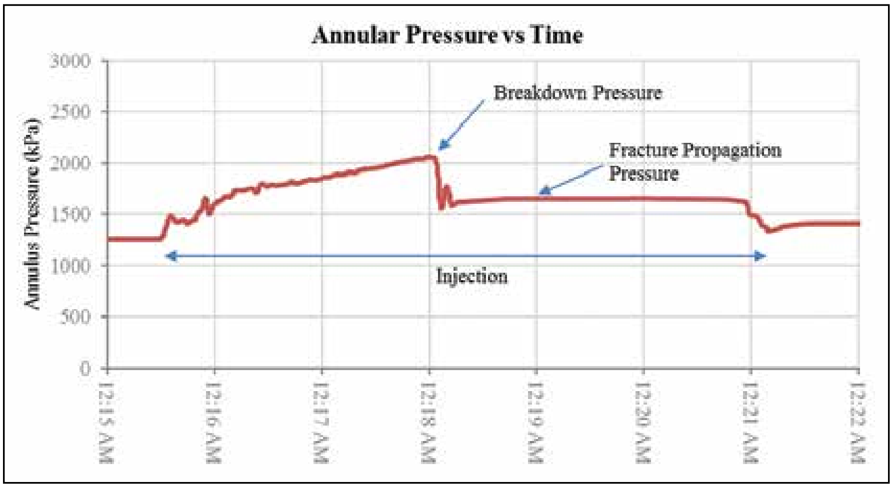

Figure 2: Hydraulic fracture characteristic curve. During the injection phase, drilling fluid is introduced into the borehole through the drill bit

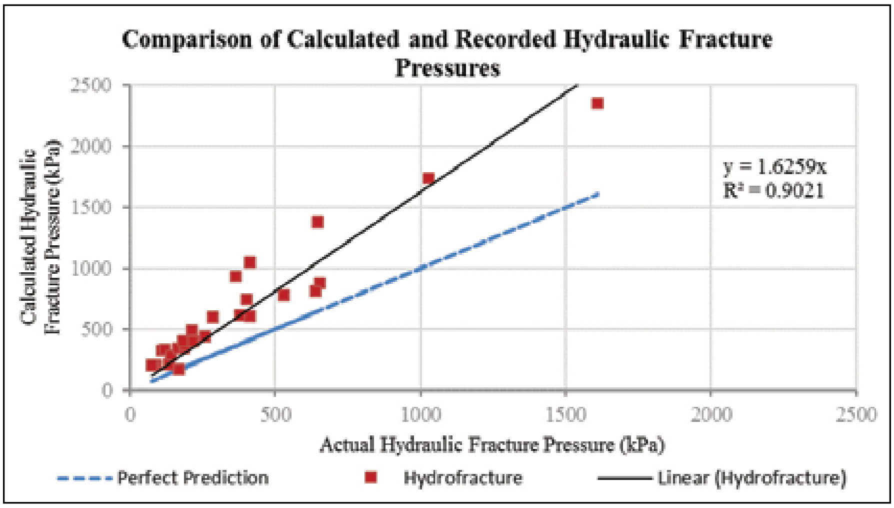

Figure 3: Calculated hydraulic fracture pressure as a function of measured hydraulic fracture pressure

very closely and immediately after viewing abnormally high pressures during construction, the operator stops to evaluate the situation.

4.2. COMPARISON OF CALCULATED AND AS-BUILT HYDROFRACTURE PRESSURES

Using the pressure magnitude of over 30 hydraulic fracture occurrences, the as-built pressure could be compared to the theoretical confining pressure values. The chart shown in Figure 3, above, demonstrates the differences between calculated hydraulic fracture pressures using $R_{p,max}$ factors of 1/2 and 2/3 for clay and sand, respectively, and as-built hydraulic fracture pressures.

As shown on the chart above, the calculated pressure line of best fit is sloped greater than one to one (Perfect Prediction). This suggests that the calculated theoretical fracture pressure is generally larger than the actual measured as-built fracture pressure and is therefore considered unconservative. This analysis shows that, for the data obtained, the Delft equation predicts hydraulic fractures consistently at a value of 1.6 times the actual hydraulic fracture pressure.

4.3. ACTUAL $R_{P,MAX}$ COMPARISON

After extensive review of the as-built fracture pressure data, the maximum plastic radius ($R_{p,max}$) was back-calculated using the Delft equation in order to obtain the actual radius of the plastic zone at hydrofracture failure.

The chart shown in Figure 4, on page following, shows the back-calculated plastic radius at failure for the data obtained from previously published experimental work, and actual HDD projects.

As shown in Figure 4, the data suggests that the maximum plastic radius at failure likely doesn't extend to surface for hydraulic fracture to occur. In fact, the recommended 2/3 and 1/2 factors placed on the height of the overburden also overestimate the extent of the plastic zone. This overestimate becomes more evident as the bore path gains depth. Additionally, there is no apparent linear correlation to conclude that the depth of the HDD alignment has large influence on plastic zone development. A reduction of the maximum plastic radius to a value more localized around the pilot borehole, as suggested by the research completed herein, reduces the maximum allowable pressure as calculated by the Delft equation.

5. CONCLUSIONS AND RECOMMENDATIONS

The first part of this research investigated the comparison between recorded fluid pressure and the calculated fluid pressure at the design stage. Generally, the data compares well with the prediction using a modified Bingham Plastic model.

In the second part of the research, the data analysis provided a basis for examining actual hydraulic fracture pressures and comparing the values to the prediction using the Delft method. Additionally, the maximum plastic radius was back calculated and the values were assessed. According to the data obtained, the values of actual fracture pressure were overestimated by the calculation, when the suggested maximum plastic radius values were used. When the values of the maximum plastic radius were back calculated, the data suggests that the values are substantially lower than as suggested, and there is no apparent correlation to depth of cover. By using a much lower, more localized plastic radius the calculated hydraulic fracture pressure becomes more comparable to the actual hydraulic fracture pressure.

Hydrofracture during HDD is one of the construction method's most prominent issues, and requires careful bore design, construction planning and monitoring in order to effectively manage the risk of severe environmental consequences and property damage that may occur. The reduction in maximum allowable pressure suggested by this research provides a more conservative HDD design, and will lead to much less inadvertent return events on trenchless projects. Reduction of inadvertent fluid release is not only important to the success of a particular HDD project, but also in maintaining a positive image for the entire HDD industry.

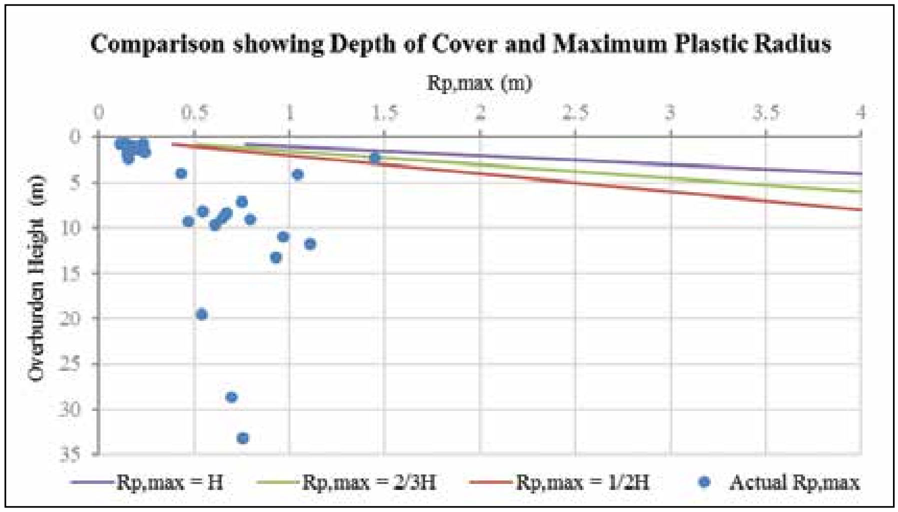

Figure 4: Plastic radius at failure as a function of overburden height

ABOUT THE AUTHORS:

Stefan Goerz, M.Sc., P.Eng, P.E., has over seven years of experience as a geotechnical engineer with CCI Inc., based in Alberta, Canada in the field and office delineating subsurface conditions and providing recommendations for a variety of trenchless pipeline projects.

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Justin Taylor, P.Eng, P.E is the VP of Engineering for CCI & Associates Inc., based out of Houston, TX, and has over 13 years of trenchless experience, focusing on HDD and Direct Pipe installations.

Avoiding Problems in HDD Projects with Accurate Subsurface Investigations

Soil & Bedrock Abrasivity for HDD Projects

By: Nick H. Strater, P.G., Brian C. Dorwart, P.G., P.E., and Jim Williams, P.E., Brierley Associates

Successful trenchless installations rely on a thorough and accurate subsurface investigation and characterization for design, planning and construction of the project. The drill geometry, project cost and schedule estimates, drilling fluid and selection of drilling tools are all heavily dependent on the anticipated subsurface conditions. Among the potential hazards are the risk of inadvertent releases (IR) of drilling fluid (frac-outs), or fractures of the surrounding soil or adjacent bedrock resulting from excessive down-hole pressure. This can be caused by uninformed design, poor choice of drilling fluids or by unsuitable drilling practices, all of which may be a result of an inadequate understanding of the subsurface conditions. It is imperative that a subsurface investigation be made that provides relevant information for the planned construction method and is commensurate with the scope of the project.

In addition, excessive tool wear from abrasive soil and bedrock materials is a leading cause of cost and schedule overruns associated with HDD projects.

Understanding the factors that cause abrasion and identifying their presence through a geotechnical investigation is necessary to avoid unforeseen costs and schedule delays. Subsurface investigations and laboratory testing typically focus on density, strength and gradation, for soil, and for bedrock help determine lithology, fracture patterns, weathering, hardness, and compressive strength. The frequency of trips, or retracting the drill string out of the hole, to inspect the drill bit or other components, is an unappreciated reality in HDD. One trip to inspect and possibly change a bit, motor, or guidance instrument may take two or more shifts and is often the result of limited or the absence of subsurface information. This situation can easily add days or even weeks to the duration of the project.

A variety, and often a combination, of methods to evaluate hardness (measuring a material's relative abrasivity in relation to the drill tools), and toughness (which measures a mineral's resistance to fracture) can be used to define and potentially avoid adverse impacts, reduce cost and schedule over-runs, and help the contractor with the appropriate selection of means and methods. Some of the traditional ways to evaluate soil abrasivity include mineralogical composition identification by petrographic examination of samples, following impregnation with a bonding agent and X-ray diffraction. Although less common (and more expensive) scanning electron microprobing may also be used. Two other soil testing options are Soil Abrasion Test (SAT™), and the Penn State Soil Abrasion Index (PSAI). Currently, neither test method is well established. The textural characteristics of soil can be visually identified using hand sample and microscopic analysis. Thin

> *The frequency of trips... is an unappreciated reality in HDD.*

section petrographic analysis and Cerchar Abrasivity are common rock evaluation techniques. If thin section petrographic analysis is used, characteristics such as total content of hard, tough minerals, microcracking and weathering should also be documented.

Using the results of soil and rock testing along with other subsurface data, three types of abrasion damage should be evaluated for each project: Primary abrasion which occurs when rotation and movement of the drill tool against the face and sidewall of the bore results in abrasion of the drag bits and buttons. Secondary abrasion is associated with the degradation of the steel housing or body of the drill tool. Tertiary abrasion is caused by suspended soil and rock particles in the bentonite-based drilling fluid which can impact the pump impellor blades and other fluid transport mechanics. To mitigate this from occurring, the drill fluid recycling system needs to efficiently remove these particles so that mud motor components and jet assemblies are not unduly damaged.

HDD design elements can be modified to reduce adverse impacts. These may include avoiding compound curves and tight drill path curve radii, which can increase the rate of tool wear. The designer should consider whether subsurface zones of suspected or confirmed abrasive zones within the proposed drill path can be avoided altogether. When a drill path is planned in bedrock, large radii are beneficial, not only to reduce tool wear, but to improve the steering accuracy and allow larger inclination and azimuth tolerances. A design radius should be specified as well as a minimum single joint radius and three joint radius.

The rate of tool advance must be carefully balanced with the drill fluid pumping rate to ensure that abrasive materials are efficiently removed from the face and transported away from the drill tool. Requesting that the contractor reduce or minimize the pumping rate to reduce annular pressures (and IR risk) is common. However, this may result in additional tool wear, requiring more frequent trips to replace or condition tools, and more time downhole, which may ultimately increase IR risk. This may also affect hole cleaning which is the primary purpose of the drilling fluid.

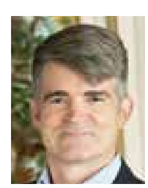
During design or during tooling selection by HDD contractors, equipment manufacturers are a good resource and should be able to provide recommendations with regard to suitable tooling and its corresponding optimal RPM, weight on tool, reasonable reamer diameter steps, and pump rate to help reduce tool wear potential and maximize efficiency. The recommended life expectancy of the tooling can also be used to determine the length of the hole it can drill or ream. For example, if a drill bit has an estimated life span of 100 hours and the penetration rate is expected to be 50 feet/hour for a 2,000 foot crossing, 40 hours are anticipated for the pilot hole and the selected bit should easily complete the entire pilot hole. In some cases, two or more bits or hole openers are needed to complete a single pass due to the wear on the tooling.

A successful HDD installation begins with the subsurface investigation and evaluation of the conditions underground. Having a Trenchless Specialist and experienced HDD contractor on your team who understand the effects of geological conditions and characteristics and know how to develop solutions for design and construction challenges will deliver a successful project.

ABOUT THE AUTHORS:

Nick H. Strater, P.G *has over 25 years of geotechnical and trenchless consulting experience and has served as a project and construction manager for a large variety of trenchless projects. Nick is also a member of the ASCE Trenchless Installation of Pipelines Committee.*

Brian C. Dorwart, P.G., P.E. *is a registered Professional Engineer in 25 states and a Registered Professional Geologist in 2 states. He has more than 40 years of field, design, and forensic experience in underground engineering concentrating in trenchless technologies.*



Jim Williams, P.E. *received his bachelor's degree in Engineering from the University of Florida and is a licensed civil engineer in 15 states. He has over 25 years of experience in a wide range of projects primarily in HDD and other trenchless methods by conventional and design build delivery methods. Jim previously served as engineering manager for a leading HDD contractor then joined Brierley Associates in 2017 as a senior consultant.*

Pipe Bursting using Certa-Lok® Cartridge-Style Assembly Speeds Repair to Water Line Services for Rowlett, Texas

In-house Pipe Bursting Maximizes Resources of City

By: Brian Goad P.E., NAPCO Pipe & Fittings

When a 2,300 LF section of existing 8-inch Cast Iron water line decayed too far to continue repairing, the City of Rowlett was tasked with finding a solution to restore the distribution line to homes with minimal disruption to the busy neighborhood.

> *Certa-Lok® Restrained Joints are usually assembled in less than one minute.*

CHALLENGE

The existing Cast Iron pipe supplying water to the affected community between Cheyenne and Lynnwood Drive, west of the George Bush Tollway, was originally installed in the 1970s. The challenge for the city was finding a low-impact means to replace the existing line without affecting the surrounding neighborhood which included homes, a school and a busy thoroughfare. It was critical the city keep the school entrance and exit accessible for daily activities and open for emergency vehicle access. Another task was ensuring that the streets were left open to support the continuous flow of local traffic to and from the homes located near the project.

APPLICATION

Considering the busy neighborhood location and amount of traffic, pipe bursting was the preferred method to install the new water line. The city served as the contractor on the repair using city-owned static pipe bursting equipment. Pipe bursting is a trenchless installation method that can be used to effectively replace installed pipe that has failed or no longer offers sufficient capacity all the while minimizing disruption to and impact on the local community. The repair plan included segmenting the pipe bursting into 500-foot lengths, and the entrance and exit pits were carefully staged to ensure the school was not blocked at any point during the trenchless installation.

SOLUTION

The replacement pipe selected for the job was NAPCO Pipe and Fittings' 8-inch Certa-Lok C900 RJIB (Restrained Joint Integral Bell) as the trenchless pipe solution for the City of Rowlett. The city has successfully installed Certa-Lok RJIB for water line and sewer bursting since 2013 and recognizes the product benefits including reduced installation time and crew size, and the elimination of the need for expensive machinery and its specially trained labor. Certa-Lok also saves time and money by eliminating the need for thrust blocks on lines repaired. The Certa-Lok Restrained Joint PVC system can be quickly assembled through cartridge-style loading with joints usually assembled in less than one minute; once the locking

Pipe is ready to go into service with minimal preparation time

Pits were carefully staged to ensure school access was not blocked during the installation

Pipe bursting equipment has compact footprint. Installation was completed and service restored to residents on the same day

> *"Pipe Bursting is much cheaper performed in-house."*
>
> - Mark Leal, Utility Supervisor, City of Rowlett

spline is inserted the pipe is ready to go into service without additional preparation time.

The city, as contractor for the job, mobilized their bursting crew using the city-owned 80-ton Hammerhead Hydroburst equipment. They were able to complete the installation and restore service to residents the same day. "Pipe Bursting is much cheaper performed in-house vs using contractors," said Mark Leal, utility supervisor with the City of Rowlett. "It provides significant cost savings vs. open cut and allows our team to get hands-on construction experience. We maximize the resources of our city by alternating our staff so everyone can learn how to run this piece of equipment." The city's forward thinking in training allows them to have multiple crews ready to work on the bursting equipment in case emergency repairs are needed. This ensures consistent water and sewer service to the local residents without disruptions. Since late 2012, the city has bursted 18,346 LF of water pipe.

"Certa-Lok works great - if we are to going to use fused pipe we have to check every joint before installation. Fusion is a more complicated process while with Certa-Lok, all you have to do is insert the pipe and spline without worrying about the integrity of the joint," Leal said. A fused solution would have taken an additional day for the crew to fuse each pipe joint. The effectiveness of trenchless tools like pipe bursting and Certa-Lok help reduce the cost and time needed to replace failing infrastructure.

The City of Rowlett has a population of 63,000 and is located on Lake Ray Hubbard, 19 miles northeast of Dallas, Texas.

ABOUT THE AUTHOR:

***Brian Goad** is a P.E. and Sales Engineer for NAPCO Pipe & Fittings based out of Houston, TX, with 8 years of consulting design experience in water and wastewater, and a focus on trenchless construction.*

City of Beaumont Pipe Bursting In-house

Popular Trenchless Application Helps South Texas City Eliminate I&I

"Once you get the equipment, the actual pipe bursting is quite inexpensive."

- Mike Harris, Director of Sewer & Water Operations, City of Beaumont

As understanding and knowledge about the cost and social advantages of trenchless technology becomes more widespread, municipalities are increasingly using trenchless methods in-house as the best means to upgrade and repair their sewer and water systems while remaining socially, fiscally and environmentally responsible.

In Texas & Oklahoma a growing number of municipalities are acquiring equipment and training crews, in order to conduct their own in-house trenchless technology programs. There is a great need for cost effective and flexible solutions that allow municipalities to stay on top of rehab and repair of deteriorating buried assets, while also minimizing disruption to residents, businesses, communities and surface traffic.

PIPE BURSTING

With a compact footprint, and a mobile easily transported equipment platform, the pipe bursting method has the unique ability to upsize existing services in the same pipe path. In-house pipe bursting programs enable municipalities to have full control over their rehab and repair efforts. Pipe bursting allows optimal deployment of workforce and equipment, using resources in a more cost-effective, timely and efficient manner. Equipment manufacturers generally provide initial on the job training to municipal crews, and are available for ongoing support, upgrades and additional training as required. These factors make pipe bursting an appealing trenchless technology option to explore for many local public works departments in rapidly growing communities throughout both states.

The City of Beaumont, an hour east of Houston, was an early adopter of pipe bursting technology, acquiring its first pneumatic bursting rig in 1992. As Mike Harris, present day Director of Sewer & Water Operations explains, the City wanted to implement an ongoing program to steadily upgrade and repair large sections of its sewer infrastructure in order to reduce I&I and save ratepayers money over the long term. Nowadays, using the pipe bursting method the City is "replacing two per cent of the system per year, using both in-house crews and outside contractors, which is definitely a good expectation for us."

With most of sewer network installed before 1970, the majority of the system is close to or beyond its 50 year design life, with I&I placing a major burden on system capacity. Ground conditions are generally heavy clays, subject to overland flooding during extreme weather events like Hurricanes Harvey & Imelda. Given Beaumont's weather, according to Harris I&I "presents a good challenge whenever we get heavy rains".

EXPERIENCE

Pipe bursting is the primary trenchless application used today by the City of Beaumont in its quest to progressively eliminate I&I from the sanitary sewer system, and the range of use and diameters of burst pipe continue to increase. Largest pipe bursting project to date in Beaumont was done using an outside contractor last summer 2019 when 4,000 LF of 18-inch sanitary sewer main under Tyrell Park Road was burst and successfully upsized to 27-inch HDPE. The City now has two dedicated pipe bursting crews working full time, primarily bursting 6-inch sewer main at 3 to 10-foot depths, and upsizing these to 8-inch HDPE. A total of 60,000 LF of aging mains were burst by City of Beaumont crews in 2019.

THE FUTURE

Harris foresees a bright future for the expansion of in-house pipe bursting projects in his community as this versatile trenchless technology application very economically and efficiently meets the growing infrastructure needs of the City. He sums up, "Once you get the equipment, the actual pipe bursting is quite inexpensive. These days we try to do as much as we possibly can in-house."

City of Sugar Land, TX Addresses Infrastructure Rehabilitation Needs

By: Taylor Savoie, Granite Inliner LLC

Two-phase bypass for influent lines connected to municipal WWTP. Precise placement of equipment was critical

The City of Sugar Land set out to rehabilitate its Wastewater Collection System as part of a larger Capital Improvement Program. In 2009, a Sanitary Sewer Evaluation Survey and Infiltration/Inflow (I&I) Study identified high volumes of I&I and critical infrastructure in need of repair. Sugar Land then used this evaluation to prepare a 2011 Pre-Design Report that would work to put a plan in place to bid and construct a series of projects to help rehabilitate system deficiencies.

First order of business was to contract with ARKK engineering to design the wastewater main program that would address the most critical areas in Sugar Land's system that were experiencing the worst sanitary sewer infiltration/inflow. After the preliminary engineering report and subsequent design concluded, the proposed scope of work was split into separate bid packages that would utilize two different rehab methodologies. The first package consisted of repairing approximately 10,800 linear feet of 12-to 48-inch wastewater mains with cured-in-place pipe (CIPP), and would include service reconnections and manhole rehabilitation. The second portion of this project bid separately and was designed around pipe bursting.

In April 2018, bids were received by the City for Project D, East Interceptor Improvements and Granite Inliner (formerly Layne Inliner) was the apparent low bidder. After reviewing the bid documents and List of Qualifications, a recommendation to award the work to Granite Inliner was issued in May. In addition to the Qualifications, Granite Inliner had experience working with the City on previous projects involving trenchless rehabilitation within the Sugar Land collection system.

PROJECT OVERVIEW

The lines rehabbed with CIPP were in three separate areas of the City's system, with the bulk of the work being located along Highway US 59. The portion of the job running through smaller residential neighborhoods consisted of about 1,800 feet of 12- to 36-inch sanitary sewer pipe. The remaining footage to be rehabilitated ran alongside US 59 Southwest Freeway South of 36- to 48-inch sanitary sewer pipe.

The overarching challenge of the project was the high-profile location running along this stretch of highway, which was prone to ongoing high-speed vehicular traffic. In addition, a separate area was located along Century Square Blvd., which housed several restaurants and shops that were always busy with pedestrian shoppers and diners.

A pre-construction meeting was held and proved vital in ensuring that both Granite Inliner and the City of Sugar Land had a clear understanding of the safe-work plan and schedule that was developed in order to accommodate the needs of all parties involved. The construction Notice to Proceed was issued in August 2018 and had a

The overarching challenge of the project was the high-profile location and ongoing high-speed vehicular traffic.

Liners are vacuum-impregnated with a polyester resin

Proximity to high speed traffic was a major challenge for the contractor and bypass subcontractor

completion time of 270 calendar days.

After deciphering the critical lines that needed attention first, an initial cleaning and CCTV schedule was established and the work subcontracted to AIMS. Granite Inliner then evaluated the information provided by AIMS and teamed with the City to create a tailored CIPP solution based on the data from those videos and reports.

CHALLENGES

The next challenge faced was creating a viable plan for the bypass portion of this project. The lines running along the freeway required bypass pumping in order to properly line with CIPP. Rain for Rent supplied a 10 MGD two-phase bypass for the influent lines running to the next downstream manhole. Because of the limited space and high traffic volume, detailed site plans for each area were submitted and coordinated with the City. To complicate matters, a portion of the bypass required the line to run through a public accessway. To safely accommodate daily traffic, a ramp was built, and equipment strategically placed to optimize the limited space that was available.

Once the bypass plans were submitted and approved, Granite Inliner coordinated with TXDOT to obtain the proper trafficking permits necessary to begin work. A detailed traffic plan provided by ARKK Engineering set the framework for a safe work environment, for both the workers and area public.

IMPLEMENTING THE PLAN

After notifying the impacted Home Owner Associations (HOAs) and communicating the plan, the lining scheduled for the residential neighborhoods was tackled first. These lining segments were grouped into five work settings and totaled eight shots ranging from 12 to 36 inches in diameter. These liners were all installed using Granite Inliner's direct air-inversion method and utilized hot steam for curing. The reconnection of service laterals was accomplished using robotic cutters, and residents were typically inconvenienced for only a matter of hours.

Following the residential lining work, the bypass and traffic controls were set up to prepare for the larger diameter lining along US 59 and Century Square Blvd. After notifying local businesses and residents, the crew began to stage for the remaining lines needing rehabilitation. For this work, the segments were grouped into 6 work stations with a tailored bypass plan for each. Granite Inliners' experienced crews installed a total of 40 shots of these

Communicating in advance to residents and businesses was crucial to success

large diameter lines with the longest shot measuring an impressive 832 feet! For this segment of work, water cured CIPP was utilized in lieu of the steam cure used for the smaller diameter lines.

Liner Products, a Granite Inliner company with an ISO 9001:2015 certified manufacturing facility located in Paoli, IN., supplied all liner tubes for this contract. All tubes used on the project were vacuum-impregnated with a polyester resin. Samples of the completed liners were provided to the City, as specified.

The final liner was installed in August 2019 and the overall project totaled 48 shots. In addition to the CIPP rehabilitation, 14 manholes ranging in depth from 9 to 25 feet were rehabilitated. All of the work closed out in September 2019.

CONCLUSIONS

Upfront planning, which included input from all parties, especially the bypass subcontractor, was critical to the overall success of this project. Communicating with the residential HOAs in advance of construction helped them understand how residents would benefit from the work on their sewers, and exactly how the work would be accomplished. Lastly, while there were some delays to the original schedule, all parties were able to work together to finish the project. The City, the engineer, and the contractor all adapted as needed along the way, and because of this were able to collectively navigate a successful finish to a very complex project.

> *"Upfront planning was critical to the overall success of this project."*

Lining project completed in 48 shots, with longest 832 feet

ABOUT THE AUTHOR:

***Taylor Savoie** handles Business Development for Texas and Louisiana, working out of the Granite Inliner Houston TX office. Taylor has a BS degree from LSU in Petroleum Engineering and is currently pursuing her PE license.*

Repeaters Extend HDD Tracker Range Cutting Job-time

By: Subsite Electronics

Like any good businessman, Michael Melson knows time is money. The more productive his crew can be on a jobsite, the more profitable that HDD bore will be. That's why he invests in HDD equipment he can rely on, from his drill to his tracking system. But one of the newest tools in his arsenal is a simple signal repeating accessory that has made a big impact on his work. Repeaters, like the TK RECON™ Repeater from Subsite® Electronics, are designed to extend the telemetry range of HDD trackers. This recently came in handy for Melson.

"Every minute you're out there is an expense," said Melson, vice president of L&M Construction. "That's why a repeater is a must-have in your toolbox. It doesn't just extend the range of your tracker when you don't have line-of-sight back to your drill, it saves time and money."

"We had a 1,032-foot bore, crossing two streams, with 80 to 90 feet of elevation change," he recalled. "Line-of-sight was definitely an issue. Within 30 feet I was in heavy timber. Then, in the stream beds, I was 35 to 40 feet below the drill level and standing in water. There was no way the tracker was going to communicate with the drill."

> *Within 30 feet I was in heavy timber.*
>
> – Michael Melson, Vice President, L&M Construction

Melson said he could've used his two-way radios to communicate with the HDD operator, but in addition to being a hassle, the start-and-stop nature of communicating with radios would cut into forward progress.

Must-have where line of sight is an issue

Repeaters can be more effective than running a wireline

"Using a repeater solved it all," Melson said. "It sent the tracker signal back to the drill without any issues. It was just like I was standing there in front of the drill within a few hundred feet. It saved a ton of time. Not just with the back-and-forth on the radio, but I would've been walking back through the woods every two or three hours to change out the batteries in my two-way from the constant use."

Melson is quick to point out additional benefits of this technology. For example, he notes many bores traditionally done with a wireline can now be done as a simple walkover locate if you use repeaters (you can link several together to extend your tracker's range even further).

According to Melson, it is easier and cheaper than running a wireline. "The thing is so simple. One button. Just set it up and let it go. I ran it 12 hours straight without a charge on that job. They say it can go 50 hours."

ABOUT SUBSITE ELECTRONICS:

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Brandon Bird Utilities Construction Sees Value in Adding Horizontal Directional Drill to Fleet

By: Kayla Breja, Vermeer Corporation

Vermeer ensured crews were fully trained in operating the new HDD

Growing up on a ranch just outside of Post, Texas Brandon Bird discovered his passion for pipelining while working with his dad in junior high and high school. When Bird graduated from Texas Tech a few years later, he knew exactly what he wanted to do — start his very own pipeline company. Now, with 23 years under his belt, his company, Brandon Bird Utilities Construction, is responsible for installing and rehabbing gas lines throughout the Lubbock, Texas, area. Bird employs more than 50 highly trained individuals and owns a fleet of equipment that includes excavators, several Vermeer trenchers and one Vermeer D8x12 Navigator® horizontal directional drill (HDD).

Horizontal directional drilling isn't new to Brandon Bird Utilities Construction. At one point the company owned and operated several drills, but Bird determined several years back that at the time it was more economical to enlist HDD subcontractors to do the trenchless work when needed. However, as infrastructure work around the area has increased in recent years, those subcontractors are busy with other jobs, and Bird doesn't have the time to wait. So, he decided it was good timing to get back into the HDD business.

FINDING THE RIGHT SIZE RIG

The gas service installs that Brandon Bird Utilities Construction usually perform do not warrant the need for a large HDD since most of these projects are smaller-diameter short bores. "The bores we were outsourcing were usually located in tight urban areas," Bird explained. "So, we didn't want to get anything too big because it may be hard to maneuver in alleys or around buildings. We also wanted a machine that was convenient to use and priced right."

Bird communicated that information to his local Vermeer Texas-Louisiana dealer sales representative, Mitch McCalib, who introduced him to the new Vermeer D8x12 Navigator® horizontal directional drill (HDD). Sized for working in tight spaces, this compact HDD features straightforward controls and delivers quiet operations.

"Horizontal directional drilling rigs have come a long way since we worked on that side of the business, and I'm sure all of the technology in today's machines make a huge difference for contractors specializing in that line of work," Bird added. "However, we wanted a more basic machine, something like we used to run — that's what we got with the Vermeer D8x12 rig. It still has a lot of great features to help our guys get work done quickly and safely, and it's priced to be a real value. It's the exact machine for our needs."

GETTING THE TEAM UP TO SPEED

Chris Altman and Richard Serenil, two seasoned equipment operators for Brandon Bird Utilities Construction, became the proud new operators of the Vermeer D8x12 HDD. "The guys from Vermeer brought the drill out, and they spent a lot of time with us going through the controls and helping us learn how to operate it," Altman said. "By the end, I had already completed my first successful bore. They did a great job of making sure we were up to speed, and Mitch has also been extremely responsive to any questions we've had since then."

Altman went on to say how impressed he was with the controls on the D8x12. "It was real quick to sit down and feel comfortable with how everything worked. And with the locator we're using, I can see where I'm at

Compact HDD unit features straightforward controls and delivers quiet operations

on a bore from the seat of the rig. It does all of the hard work."

ON THE JOB PERFORMANCE

The Brandon Bird Utilities Construction HDD crew has been impressed with the productivity of the D8x12 since putting it to work. Bird and Altman both agree that it has plenty of power to do the short 200-400-foot small-diameter shots they need to go under roadways and in areas where trenching is not an option.

"We're primarily using the drill to install 2-inch poly pipe in urban areas," Altman said. "Some shots are more challenging than others, like a recent 275-foot bore we did down an alleyway near an apartment building. We couldn't restrict access to the apartments, so our equipment had to be strategically placed. We also had to do a lot of potholing to make sure we knew exactly where other utilities were located. Once all of that was done, we got to work, and honestly it didn't take us long to complete. There were no complaints from people living in the apartments — that's sometimes one of the best compliments a crew can get."

SAVING TIME AND REDUCING EXPENSES

According to Bird, adding the Vermeer D8x12 HDD has helped his crews better meet their customers' timelines and reduced the company's expenses. "Waiting on subcontractors was really starting to become a challenge. Waiting meant we couldn't wrap projects up as quickly as we wanted to. On top of that, the costs to hire subcontractors was steadily increasing. With the Vermeer D8x12 HDD, we are no longer waiting on someone else, and we've been able to do a better job of managing our expenses. We're really glad we made the investment," he concluded.

ABOUT THE AUTHOR:

Vermeer Corporation offers one of the most comprehensive product offerings serving the underground construction industry. Products include horizontal directional drills, guided boring systems, trenchers, vibratory plows, rockwheels, piercing tools, vacuum excavators, core saws, and mini skid steers, as well as a range of tooling, accessories, and support equipment.

All Terrain Technology Helps in Rock Drilling

By: Jeff Davis, Ditch Witch

The game changed 25 years ago for the horizontal directional drilling (HDD) industry with the introduction of a dual-pipe, rock drilling package. This All Terrain (AT) technology means operators have an option outside of powering the drill bit primarily with drilling fluid through the use of a mud motor.

Mud motors are still a common tool found in the HDD industry. They take drilling fluids that are pumped downhole, through the drill string, at high volumes, into a rotor and stator and transfers that into mechanical power that drives the rotary bit on a mud motor. Mud motors are high-fluid volume downhole tools that can produce high drilling fluid pressures downhole which increases the possibilities of inadvertent returns. Inadvertent returns happen when the drilling fluid takes the path of least resistance to the surface and does not follow the designated path of the bore and makes its way through to the surface in unwanted areas.

Mud motors can often send much more fluid downhole than what is actually needed on the job. A bore that requires 20 gpm of mud flow to efficiently flush the bore of cuttings, for example, ends up using an additional 180 gpm of fluid to run the mud motor. And, as the drill units become larger or the ground harder, mud motors can send as much as ten times more mud downhole than what is needed to clean the borehole.

The additional drilling fluid results from inefficiencies of creating mechanical

AT Technology helps operators minimize how much fluid is pumped downhole


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power. To accumulate enough energy for the drill bit, mud often flows over a 15- to 30-foot power section. On average, only 50 percent of the power generated makes it downhole. In comparison, 95 percent or more of the HDD unit's inner drive power is successfully transferred downhole using AT systems.

A switch from powering the bit with drilling fluid to All Terrain (AT) technology helps operators minimize how much fluid is pumped downhole. And AT systems provide a way to use the HDD unit's power more efficiently for driving the drill bit.

This is possible because of the dual-pipe technology offered by AT systems. With an inner drive shaft that reaches back to the HDD unit, these motors physically control exactly how much horsepower is sent to the bit.

By reducing operator reliance on drilling fluid, AT technology is a more efficient power option.

This direct connection to an HDD unit also reduces the overall size of an AT system. Instead of a long power section, AT systems are between 3 and 5 feet long. And by placing the electronic locating package in the middle of that system, the shorter length puts the package 1 to 2 feet behind the bit. Locators are then able to more accurately track the location of the drill bit's cutting face, instead of predicting where the bit could be when the electronics package is embedded behind a mud motor's 15-foot power section.

A small footprint is becoming a more and more common requirement on HDD jobsites. AT technology generally provides a smaller footprint jobsite than mud motor-driven jobsites, partially due to having to use much less fluid. Large volumes of fluid usage on the jobsite comes with larger tanks and larger reclamation systems with a mud motor.

Sometimes technological advances don't generate a huge impact, but that is not true for AT technology. The dual-pipe system lets operators control how much fluid is used on varying jobsites. And, by keeping drilling fluid to a minimum, HDD crews can decrease the risk of inadvertent returns and stay efficient and profitable on any jobsite.

ABOUT THE AUTHOR:

__Jeff Davis__ has over 25 years of valued customer experience and extensive underground construction knowledge. He has held multiple roles within the Ditch Witch organization – from sales in the dealership organization, to trenchless training instructor and product specialist. As one of the HDD product managers, Jeff is responsible for the oversight and direction of drills with more than 30,000 pounds of thrust and pullback, helping to meet customer needs and provide solutions for underground constructions professionals globally.

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Elm Fork Project – Eagle Ford Shale:

Tunnel & Shaft Re-Design Prompts Supplemental Geotechnical Investigation Program

By: Dave Sackett & Kent Vest, Southland Contracting

In Fall 2019, Southland Holdings, LLC was awarded the construction contract for the City of Dallas' Elm Fork Project. The project consists of the construction of a 72-inch diameter water main that will extend approximately 1.8 miles starting from the Elm Fork Water Treatment Plant to near where West Crosby Road passes beneath I-35 East Express in Carrollton, TX.

The original design involved the water main invert generally installed between 20 and 40 feet below existing ground surface and extending mostly through alluvial deposits, with portions extending through weathered shale with artesian conditions. The original design was to be installed using a combination of cut-and-cover and microtunneling trenchless construction methods amidst a myriad of existing utilities and surface development features.

However, upon award of the Contract, Southland proposed an alternate design and construction approach, with the pipe lowered sufficiently to allow for construction using tunneling methods, and entirely located within the Eagle Ford shale bedrock. Brierley Associates Corporation was contracted to assist with the redesign of the now deeper various shafts and now longer tunnel. The redesigned project now includes 8,575 linear feet tunneling in total ranging in depth from 65 feet to 75 feet, two tail tunnels each at 40 linear feet, and five vertical shafts ranging in diameter from 18 to 35 feet.

To provide sufficient information for the deeper tunnel and shaft redesign, Brierley developed and implemented a supplemental deep geotechnical investigation program based on a data gap analysis of the original geotechnical program to investigate the properties of the Eagle Ford Group (also called the Eagle Ford Shale). This Group is of the Late Cretaceous Epoch and was deposited in a marine or lagoonal environment. The Eagle Ford Group is primarily composed of organic-rich, fossiliferous marine shales and calcareous marls with interbedded thin limestone layers. The following geotechnical properties are characteristic of the Eagle Ford Shale at the project site:

- Swell potential of the shale unit was evaluated using both the five-point swell test methods recommended by the International Society of Rock Mechanics (ISRM, 1999) and using X-ray diffraction tests to determine the swelling clay mineral content of the rock along the tunnel alignment. Results of the swell and mineralogy testing indicate low swelling pressures are to be anticipated in the shafts and tunnels.
- The susceptibility of the Eagle Ford Shale to degradation when exposed to wetting and drying cycles was quantified by using the slake durability index (SDI). From the test, where no degradation occurs an SDI value of 100 percent is assigned, while an SDI value of 0 percent is assigned for samples which completely degrade during testing. The values of SDI for the Eagle Ford Shale ranged from 0.7 to 32.3 percent for this project, indicating high susceptibility to material degradation or slaking.
- The Eagle Ford Shale material is anticipated to pose a risk of clogging equipment (for both excavation and muck handling) due to the relationship between the high plasticity characteristics and the natural water content (Thewes & Burger, 2004). Clogging potential is evaluated as a function of consistency index and plasticity index. Results of the clogging potential evaluation indicate moderate to high clogging conditions are likely during tunneling.

Five vertical shafts will range in diameter from 18 to 35 feet

- Corrosion potential of the Eagle Ford Shale was evaluated in laboratory tests including pH, sulfates, chlorides and resistivity at two locations. Based on the testing, the pH of the soils is not anticipated to be problematic. Classifications of the sulfate exposure levels from tested rock samples indicate that Class S1 and S2 rock is present at the site.
- Permeability and hydraulic conductivity of the Eagle Ford Shale was analyzed using packer testing, and rising head testing adjacent to the three deep piezometers. The packer test results were analyzed to calculate the hydraulic conductivity of the shale based on water infiltration during testing. No discernible trends were identified by test location or elevation. The rising head test results were analyzed using the Hvorslev (1951) method to calculate the hydraulic conductivity of

The Eagle Ford Group are primarily marine shales and marls with thin interbedded limestone layers

the shale based on the rate of recharge of the water level. The calculated hydraulic conductivity values were used to estimate groundwater inflows along the alignment. It should be noted that though it is considered likely that the variation in bedrock elevation along the southern portion of the alignment is caused by paleochannel erosion rather than by faulting, if the tunnel intersects a fault or sheared zone during tunneling, it would be anticipated that localized increases in rockmass hydraulic conductivity and associated spikes in water inflow could occur over short lateral distances when crossing the feature. The average of the Eagle Ford Shale permeability measurements taken within the tunnel horizon ranged from a minimum of 9.0E-07 cm/sec to a maximum of 9.6E-05 cm/sec.

The five construction and retrieval shafts require redesign of temporary ground support for their excavation in both overburden soils and underlying shale bedrock. The overburden soils generally consist of surficial fill, underlain by alluvial sand, silt, clay and gravel deposits. The alluvial soils in the project area are predominantly silt and clay with sand and gravel deposits confined below the fine alluvium deposits. In these overburden soils, steel liner plates with annular grouting will be used. For smaller diameter shafts, a heavier gauge liner plate will be used, whereas for the larger diameter shafts, steel wide-flange ring beams with a lighter gage liner plate acting as vertical lagging to span between ring beams will be used. The liner plate will extend into the bedrock to provide a transition to the shotcrete lining and provide supplemental groundwater control. Positive means of groundwater control during installation of the liner plate will likely be necessary. In the Eagle Ford Shale, shotcrete with split set rock bolts on a typical pattern with welded wire mesh will be utilized for ground support, with supplemental bolts at the tunnel penetrations.

The tunnel will be excavated using a Southland Contracting Manufactured Single Shield TBM with a 118-inch excavated diameter, with a steel shield with an outside diameter of 116 inches. W-section, cold rolled steel ribs will be used to support

Careful geotechnical investigation and detailed analysis of the data were necessary for the redesigned tunnel alignment

the excavated opening by erecting them inside the 115-inch ID shield with full lagging between ribs. Once the newly erected steel rib is outside the TBM shield, the rib will be expanded using hydraulic jacks and dutchman spacers to match the 118-inch excavated diameter, resulting in full contact with the ground. However, it is assumed that there will be soft areas or areas of sloughing in the excavated perimeter that effectively result in small internal moments. Therefore, the steel rib is designed for the combined effects of moment and thrust. Wood lagging is designed to resist bending between steel ribs and wood lagging is designed to resist the critical loads that are generated from TBM thrust. Steel ribs will be evenly spaced and fully lagged every 4 feet for the full length of the tunnel excavation.

Shaft construction expected to begin on the Elm Fork Project this summer, 2020.

ABOUT THE AUTHORS:

***Dave Sackett** has throughout his 35-year career been responsible for geological interpretations of high-resolution onshore, downhole and marine geophysical data, landside and nearshore site characterization, planning and execution of geophysical surveys and geotechnical investigations, and the preparation of geological and geotechnical reports and technical reviews. Mr. Sackett has designed, managed and performed integrated geophysical and geotechnical programs, logged geotechnical boreholes, mapped three-dimensional geologic exposures including tunnel interiors, installed and monitored geotechnical instrumentation, authored technical reports, and designed/managed geoscience projects on five continents.*

***Kent Vest** is the Operation Manager of Southland Contracting, overseeing all tunnel and general underground structure preconstruction and construction operations. He specializes in managing projects which incorporate deep shaft sinking, sequential grouting and excavation methods, NATM, tunnel boring machines (hard rock and EPB), segment lined tunnels, microtunneling , and conventional drill and blast excavation. He has extensive knowledge of shotcrete design and methodology. On various projects, Kent has gained a reputation for handling the most challenging situations while preserving safety and quality.*

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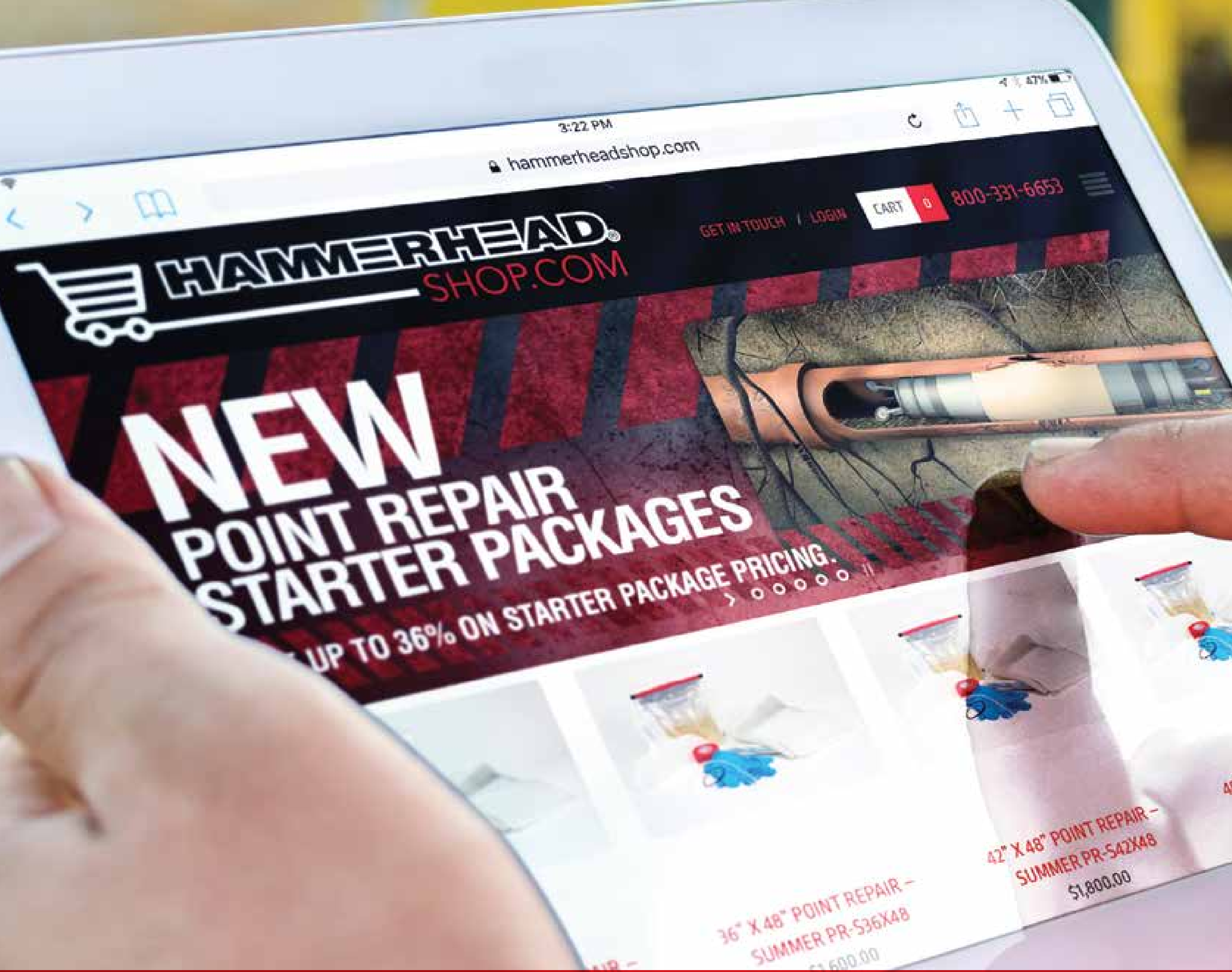
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