ASCE AMERICAN SOCIETY OF CIVIL ENGINEERS

Pipeline Division

Proceedings of

Pipelines Research Needs Symposium
Saturday, June 22, 2013

In Conjunction with ASCE 2013 Pipeline Conference

Fort Worth, TX

Edited by Dr. Mohammad Najafi, P.E., F. ASCE

Graduate Research Assistants:
Sahar Habibzadeh, S.M. ASCE
Vinayak Kaushal, S.M. ASCE

Publication Date: November 8, 2017

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Foreword

These proceedings present results of the ASCE Pipelines Research Needs Symposium held on Saturday, June 22, 2013, in Fort Worth, Texas in conjunction with the ASCE Pipelines Conference 2013. The Symposium was sponsored by HDR Engineering, Inc., Water Research Foundation and Freeze and Nichols. The Symposium provided a forum for presenting and discussing pipeline technologies, processes and techniques that are in use or under development. The presented technologies came from research institutions, universities, consulting/engineering companies, government agencies and associations.

The Symposium included presentations by seventeen speakers on pipeline technologies. Five separate breakout sessions were subsequently held to develop strategies to assist emerging technologies become accepted in the marketplace. Each session addressed two technologies and included facilitators, a report leader, and a recorder to capture information during each breakout session.

The presentations include the following topics:

- Underground Container Freight Transport System
- Pipeline Asset Management
- Pipeline Design, Operations and Maintenance
- Interactive Pipe Broadband Electro-Magnetics (BEM)
- Pipe Condition and Earthquake Damage
- Staged Construction Modeling of a Large Diameter Steel Pipe
- Future Conveyance System and Asset Management Research Needs
- Water Conveyance Infrastructure Research Needs
- Energy Pipeline Challenges & Related Research
- Pipeline Corrosion Prevention
- Trenchless Technologies

Attendees included a strong cross section of practitioners, suppliers, researchers, academia and students. Each of these groups has an important role to play in the advancement of pipeline technologies.

Our industry needs a continuing friendly and objective forum where people from within and outside of the industry can showcase new technologies. It is our hope that that this type of forum can continue to serve this role and support the advancement of the pipeline profession.

We are very appreciative of the many individuals who graciously contributed their time to make this Symposium a success.

James Thomson
Symposium Co-Chair

Mohammad Najafi, P.E.
Chair, ASCE Pipeline Research Committee
and Symposium Chairperson

Agenda

ASCE Pipelines Research Needs Symposium

The Worthington Renaissance Hotel, Fort Worth, TX, Saturday, June 22, 2013

Table 1. Agenda

	Time	Topic	Speaker	Organization
	8:00 A.M.	Welcome and Introduction	Dr. Mohammad Najafi	Conference Chair
	8:10 A.M.	Goals and Objectives	James Thomson	Symposium Co-Chair
Research\Government Organizations	8:30 A.M.	Water Research Foundation Pipeline Research: on-going work, future directions	Frank Blaha	Water Research Foundation (WRF)
	8:45 A.M.	Werf - Future Conveyance System and Asset Management Research Needs through The Lift Program - Overview	James Thomson	Symposium Co-Chair
		Water Conveyance Infrastructure URE Research: an EPA/ORD Perspective	Mike Royer	U.S. Environmental Protection Agency (USEPA)

	Time	Topic	Speaker	Organization
Research\Government Organizations	9:15 A.M.	A Summary of Common Energy Pipeline Challenges and Related Research	Robert Smith	Pipeline and Hazardous Materials Safety Administration (PHMSA)
	9:30 A.M.	Pipeline Corrosion Prevention: What is Needed?	James A. Hart	NACE International – The Corrosion Society
Pipeline Owners Perspective	9:45 A.M.	Shanghai Municipal Underground Container Freight Transport System of China National Convention and Exhibition Center	Dr. Kesi You	Shanghai Municipal Engineering Design Institute Co., Ltd.
	10:00 A.M.	Pipeline Asset Management Specific Oil and Gas Pipeline: Issues and Needs	Jonathan Faughtenberry	Oasis Petroleum
	10:15 A.M.	Improving Transmission Pipeline Design, Operations and Maintenance	David Marshall	Tarrant Regional Water District (TRWD)
10:30 A.M.		BREAK WITH REFRESHMENTS		

	Time	Topic	Speaker	Organization
Condition Investigation and Assessment	10:45 A.M.	New Developments in Pipeline Condition Assessment Technologies	Xiangjie Kong	Pure Technologies
	11:00 A.M.	The Interactive Pipe: Broadband Electro-Magnetics (BEM)	Martin Roubal	Rock Solid
	11:15 A.M.	Advancement of Acoustic Condition Assessment Methods	Marc Bracken	Echologics
	11:30 A.M.	Pipe Condition and Earthquake Damage and The Information That is Currently Not Recorded for Research Needs	John Black	Opus International Consultants
Lunch with Keynote Speaker	12:00 P.M.	Pipeline Crisis: Why Research Matters	Dr. Neil S. Grigg	Colorado State University

	Time	Topic	Speaker	Organization
Pipe Consultants and Designers	1:00 P.M.	Integrity Management for Piping Infrastructure	Ernest Lever	Gas Technology Institute
	1:15 P.M.	Research Needs of Material Properties and Operational Surge in Pipeline Failures	Dr. Graham Bell	HDR Engineering, Inc.
	1:30 P.M.	Pipeline Research Needs for Future Practice improvements – A Designer's Perspective	Dr. Sri Rajah	HDR Engineering, Inc.
Academics	1:45 P.M.	Development of Asset Management Certification and A Living Lab	Dr. Tom Iseley	IUPUI
	2:05 P.M.	Water and Wastewater Research Needs Identified at 14TH ITT Research Colloquium	Dr. Mark Knight	University of Waterloo
	2:25 P.M.	Staged Construction Modeling of A Large Diameter Steel Pipe Using 3-D Nonlinear Finite Element Analysis	Dr. Ali Abolmaali	The University of Texas at Arlington
	2:45 P.M.	BREAK WITH REFRESHMENTS		

	Time	Topic	Speaker	Organization
Breakout Sessions	**2:55 P.M.**	**Breakout Session Introduction and Objectives**	**James Thomson**	**Symposium Chair**
	3:00 P.M.	**1. Pipeline Failures** **2. Pipeline Inspection and Monitoring** **3. Pipeline Materials, Corrosion and Biofilm** **4. Pipeline Asset Management and Sustainability** **5. Trenchless Technologies**		
	4:00 P.M.	**Presentation by Small Groups**		
	4:40 P.M.	**Conclusions & Recommendations**		
	4:50 P.M.	**Closing Remarks**		
	5:00 P.M.	**Conclusion of Symposium**		

Paper No. 1

Water Research Foundation Pipeline Research: Ongoing Work, Future Directions

Frank Blaha and Jian Zhang, Water Research Foundation
6666 W. Quincy Avenue, Denver, CO 80235
Emails: fblaha@waterrf.org and jzhang@waterrf.org

Refer to Appendix A, Page A-1, for a copy of presentation

1. Water Research Foundation Pipeline Research: Ongoing Work, Future Directions

Frank Blaha and Jian Zhang, Water Research Foundation
6666 W. Quincy Avenue, Denver, CO 80235
Emails: fblaha@waterrf.org and jzhang@waterrf.org

Background

The Water Research Foundation (WaterRF) was started in 1966 as a division of the American Water Works Association (AWWA). The WaterRF became independent of AWWA in 1984, when the organization established an independent funding mechanism and a separate Board of Trustees. While the name of the organization and our logo have changed a few times through the decades, our focus has not – advancing the science of water through a centralized research program. The WaterRF has worked with a variety of professional partners to identify, prioritize, fund, manage and communicate scientifically-valid research across the globe. The WaterRF is a 501(c) 3 non-profit organization that carefully invests and leverages research dollars to tackle an array of issues related to the treatment and delivery of clean drinking water. Since 1966 the organization has managed over 1,000 research studies valued at more than $500 million. The primary source of funding for the WaterRF has been, and remains, voluntary contributions from over 950 water utilities in the United States, Canada, Europe, Australia, and North Asia. The utilities that support our program are considered "subscribers" and benefit from our research through early access to the research reports and findings, as well as, frequently, involvement in projects of particular interest to those utilities. In addition, the WaterRF also has a number of consulting and manufacturing companies that also support our program and are subscribers.

Research Programs

The WaterRF subscribers guide our work in almost every way, and play a substantial role in setting the research agenda for the WaterRF. At this time we have three primary research programs:

1. **Focus Area Program** – addresses broadly relevant subscriber issues to be solved with a strategically targeted, multi-year research response. This area of work currently consists of ten focus areas, and 60% of our annual research funding.
2. **Emerging Opportunities Program** – tackles subscriber challenges and opportunities as they develop throughout the year, and are typically smaller in monetary value ($50,000 or less) and one year or less in length. This area of research currently represents 20% of our annual research funding.
3. **Tailored Collaboration Program** – allows for partnerships with and among utility subscribers on research that maybe be more targeted or regional in impact and which involves cost-sharing between the utilities and the WaterRF (WaterRF matches utility dollars committed to the project). This area of work also currently represents 20% of our annual research funding.

A fourth research program also exists, termed the "Facilitated Research Program" but while a few projects are active under this program, the program is being re-defined and re-focused. No research moneys are committed to the Facilitated Research Program.

While the exact details vary, there are some commonalities amongst these research programs in how the worthy and valuable research projects are identified. The greatest commonality is that volunteer committees approve a given project for funding, and these committees are dominated by subscribers to the WaterRF. The WaterRF staff can participate in these discussions and deliberations, but staff has no vote in the decisions. The decisions are ultimately made by the volunteers. Some of the volunteer committees are considering wide-ranging research ideas from many different categories, this being the case for the Focus Area Program or the Tailored Collaboration Program overall. Other committees are simply considering which proposal received in response to a solicitation is the superior proposal, since the selected research teams are typically identified through a competitive proposal process. Many projects are reviewed and impacted by multiple volunteer committees before the project starts.

For instance, in the case of a Focus Area, each Focus Area has a committee of volunteers (Technical Advisory Committee) that helps identify a broad range of projects for funding consideration every year. These projects are guided by the overall goals of the Focus Area, but projects vary year by year depending on other active WaterRF projects and results from research conducted outside the WaterRF. The suggestions of the Technical Advisory Committee for each Focus Area are brought to the Focus Area Council (FAC) which oversees the Focus Area Program. The FAC decides which of the suggested projects from across all the Focus Areas will be funded. While it is an unlikely outcome, it is possible that the FAC could be so compelled by the identified needs and projects in one Focus Area to put all the Focus Area funding in a given year into that one area (approximately $3 million in total Focus Area funding for 2013 projects).

Once a (Focus Area) project has been selected for funding, a Project Advisory Committee (PAC) is formed of, typically, 3 to 4 volunteers that will review and modify the Request for Proposals prior to release, select the winning research team, and follow the project as peer reviewers throughout the project period. Most WaterRF projects have an in-kind match requirement, typically at 25% of overall project funding, but this does vary. The idea of the in-kind match requirement is largely to encourage utility involvement and support for the project. By having utilities involved in the research it is believed that the projects stay more focused on issues of relevance to water utilities, thus helping to provided more value to the utilities, and that the utilities tend to stay more active in the WaterRF programs.

The Infrastructure Funding Gap

Managing the physical infrastructure (the assets) of a water utility is critically important, since water utilities are among the most capital intensive of all utilities (Olstein, et al, 2009). A major part of this capital is invested in the buried utility infrastructure, especially the transmission and distribution system, which is also among the most long-lived of all utility infrastructure. Nonetheless, these systems begin deteriorating as soon as they are installed, yet utilities have not typically banked money for replacement of this infrastructure on an ongoing basis. Inevitably the assets reach the limit of their lifespan, and there is concern that a large number of assets across the country will be reaching their effective life in the near future, placing a huge burden on the water utilities in terms of funding the renewal of those deteriorated assets.

In a recent EPA study of drinking water infrastructure replacement needs, out of total water system replacement needs of $334.8 billion over the next 20 years, $200.8 billion of need (60%) is in the transmission and distribution area, with much of this need being associated with pipe renewal (USEPA 2009). The EPA has termed this need the "Infrastructure Funding Gap" since the funding necessary to address these needs is not immediately available.

Infrastructure and Pipes Research at the WaterRF

Most of the pipes research has been done as part of a slightly broader area of infrastructure research. Through the years the infrastructure area of research has received approximately 25% of overall funding, which has resulted in nearly 100 completed projects in this area of work. This work has included a broad range of subjects and topics, but much of it has been focused on pipe deterioration mechanisms, pipe failure prediction, and pipe longevity predictions. We have worked on programs to help utilities better plan possible future replacement needs.

For instance, the KANEW program was one of the earlier ones (which continues in existence as an expanded and more comprehensive program than that described in the WaterRF study) published in 1998 and completed by Roy F. Weston, Inc., the University of Karlsruhe, and the Philadelphia Water Department. This project modified and applied to North American water systems an existing computer model that was initially developed by the University of Karlsruhe. This modified model forecasted pipe rehabilitation needs and rates as a function of pipe material, pipe 4 technology, environmental stresses, based on an expert learning system from previous experience with similar pipe.

In creating the Focus Areas in 2011 and 2012, the volunteers felt that infrastructure work under the Focus Area should emphasize condition assessment and risk management techniques, since these ideas, when thoughtfully applied, seem likely to significantly decrease the gap between projected buried infrastructure renewal needs at water utilities and committed funding. Thus, the "Infrastructure Focus Area" is defined as:

Water Utility Infrastructure: Applying Risk Management Principles and Innovative Technologies to Effectively Manage Deteriorating Infrastructure: By 2017, provide utilities with tools and strategies to optimize the use of condition assessment and risk management in making infrastructure renewal decisions and the use of innovative renewal techniques.

Objectives:

1. Increase the use and understanding of risk assessment approaches for evaluating the need for renewal of deteriorating assets, particularly pipe assets.
2. Increase the use and understanding of condition assessment approaches for evaluating the need for asset renewal, especially pipe assets.
3. Provide research on improved condition assessment technologies for evaluating the condition and possible need for renewal of deteriorating assets.
4. Increase the use and understanding of the full range of renewal technologies and provide research on improved renewal technologies for more cost-effective asset renewal.
5. Increase the understanding of deterioration mechanisms of different assets with an eye towards extending the life of these assets and improved condition assessment and renewal technologies.
6. Aid the field testing and case study documentation of condition assessment and renewal techniques to better establish the value of these techniques.

For 2013 the funded projects under this Focus Area are:

1. Project 4490: Practical & Visual Guide to Common Pipe Failures: Understanding and Classification of Pipe Failures (What to Look for and Why it is Important). This project will try to aid utilities in capturing valuable information on pipe failures based on pipe and environmental conditions that can be noted when the pipe is being repaired. These data will be put into perspective so that they can be effectively used in developing a long-term pipe renewal program. Proposals are due July 10, 2013, funding level is $100,000.

2. Project 4498: Potable Water Pipeline Defect Condition Rating System. This project will try to aid utilities by developing suggested standard defects and scores for those defects to allow improved assessment of the condition of a given pipeline, and to make more 5 consistent evaluations between various pipelines. Proposals are due August 7, 2013, funding level is $300,000.

Of course, other projects relevant to buried infrastructure can be identified in our other research programs, but the focus and nature of the projects is not predictable since the project ideas are brought to us by other parties. In 2012, for instance, in addition to two buried infrastructure-relevant focus area projects we also funded the following buried infrastructure-relevant projects under other programs:

Three projects funded under the Aging Water Infrastructure program with the EPA:

1. Project 4465: Environmental Impact of Asbestos Cement Pipe Renewal Technologies

2. Project 4473: The Assess-and-Fix Approach: Using Non-Destructive Evaluations to Help Select Pipe Renewal Methods

3. Project 4485, Durability and Reliability of Large Diameter HDPE Pipe for Water Main Applications

Two Tailored Collaboration projects:

1. Project 4471: Leveraging Data from Non-Destructive Examinations to Help Select Ferrous Water Mains for Renewal

2. Project 4480: Development of an Effective Asbestos Cement Distribution Pipe Management Strategy for Utilities

The totality of infrastructure-related projects at the WaterRF (seven projects funded in 2012) is clearly a more valuable and compelling set of projects than the two Focus Area projects alone. The relevant infrastructure projects identified through other funding schemes is indicative of utility interest in this topic of managing buried infrastructure.

The Future for Infrastructure and Pipes Research at the WaterRF

As in the stock market, past performance is not a guarantee of future returns, but it seems clear the WaterRF will stay substantially involved in infrastructure research. The Infrastructure

Focus Area continues to 2017, where that would be the last year in which funding of projects under the Focus Area would be considered. Projects funded in 2017 might not be completed until 2019 or 2020, depending on the scope and nature of these projects. Also, the infrastructure area of work also continues to be an important area of concern for water utilities as expressed by utilities responding to a recent WaterRF survey to ascertain their needs. Clearly, work will continue on trying to understand and predict the failure of pipes, as well as renewal methods, including innovative approaches, that can help address the infrastructure funding gap.

However, it would appear that as we go forward there will be more buried infrastructure projects oriented around a common goal and/or activity, which will put this work into a more comprehensive context. This will partly be driven by risk concerns associated with our buried 6 infrastructure such as expressed in the recent National Academy of Sciences (NAS) study *Drinking Water Distribution Systems: Assessing and Reducing Risks* (2006). In this report it was suggested that three "integrities" are necessary for distribution systems to pose minimal risk of waterborne disease outbreaks, namely, physical integrity, hydraulic integrity, and water quality integrity. While we have emphasized in this paper the infrastructure work to date that has focused on physical integrity of the distribution system, considerable resources have also going into work related to the other two integrities, but much of this work has been done on a project-by-project basis, with little unification of long-term vision and goals. We believe that this will change as we go forward. A prime unifying concept will be risk management. Risk management concepts will be used to help avoid huge and catastrophic failures of buried infrastructure, but risk management will also be used more comprehensively to help manage hydraulic and water quality integrity of the distribution systems.

As the Revised Total Coliform Rule (RTCR) and the Distribution System Rule were discussed by the Federal Advisory Committee in 2007 and 2008, the need for further distribution system research, in areas related to the three integrities was highlighted. These research needs were expressed in a continuing research partnership between the EPA and the WaterRF, the Research and Information Collection Partnership (RICP), formally entered into in January, 2009 through a Memorandum of Understanding (MOU) between the two groups, and as expressed in a research plan completed in April 2010. This partnership is continuing at this time, and while personal expectations were low of a partnership that had no committed funding and no special priority placed on the needed work, it seems that the partnership has been reasonably successful in encouraging reasonable and important work to be completed, and providing a means to discuss how the results of that work might be applied and made practical.

Partly because of the RICP, work continues on issues related to pressure management of distribution systems, and the relationship of pressure management to waterborne disease outbreaks (ongoing work related to the cost and effectiveness of boil water orders) but also the relationship of pressure management to main breaks. Empirical evidence from various research projects indicates that lowering higher pressures, and attenuating pressure fluctuations, results in both less lost water as well as fewer main breaks. Work in this area continues, especially considering what might be considered the best pressure monitoring approaches for the distribution system. There is interest in improving our understanding and applications of pressure and pressure transient knowledge to better manage our distribution systems.

The Federal Advisory Committee of 2007 and 2008 also expressed that "excellence" programs associated with the distribution system should be promoted. One such program is the Partnership for Safe Water (PSW) which recently expanded a near 20-year program focused only on encouraging excellence in filtration plant operations into a two-pronged program that also includes encouraging excellence in distribution system operations. The distribution system 7 program only became active this year, but it is based upon the results of a WaterRF study that was cofounded by PSW that reviewed and suggested optimization criteria for distribution systems. The WaterRF study suggested that there should be three optimization variable that can be measured, and for which goals were established, with these variables being breaks and leaks as a measure of the physical integrity of a distribution system, pressure monitoring and management as a measure of hydraulic integrity of a distribution system, and disinfectant residual as a measure of the water quality integrity of a distribution system (Friedman, et al, 2010).

References

Friedman, M., et al, 2010, Criteria for Optimized Distribution Systems, Water Research Foundation, Report 4109.

Olstein, M.A., et al, 2009, Improving Water Utility Capital Efficiency, Water Research Foundation, Report 91257.

USEPA, 2009, Drinking Water Infrastructure Needs Survey and Assessment, Fourth Report to Congress, Office of Ground Water and Drinking Water, EPA 816-R-09-001.

Paper No. 2

A Study on Underground Container Freight Transport System of China National Convention and Exhibition Center

Fan Yiqun, Yu Mingjian and You Kesi, Shanghai Municipal Engineering Design Institute (Group) Co., Ltd., Shanghai, China, 200092
Email: fanyiqun@smedi.com

Refer to Appendix A, Page A-16, for a copy of presentation

2. A Study on Underground Container Freight Transport System of China National Convention and Exhibition Center

Fan Yiqun, Yu Mingjian and You Kesi, Shanghai Municipal Engineering Design Institute (Group) Co., Ltd., Shanghai, China, 200092
Email: fanyiqun@smedi.com

Abstract

With respect to adverse effect of freight transport of China National Convention and Exhibition Center on transport and environment of Shanghai Hongqiao CBD, three different technical schemes for logistic system of the Center are presented. Through comprehensive analysis, comparison and selection in light of construction investment, project risk and environmental impact, underground container system is chosen as the mode of transport of freights on show, and conceptual designs of underground container system for the convention and exhibition center are further expanded. The results show that traditional logistic modes fail to meet freight transport requirement of China National Convention and Exhibition Center, which calls for innovative ideas and the development of a new mode of freight transport. The underground container freight transport system is more advantage in such aspects as guaranteed effective transportation of convention & exhibition goods, reduced impact on road network, and environmental protection.

Keywords: convention and exhibition logistics; underground container freight transport system; comprehensive benefit analysis; motor driven container railway transportation equipment; transportation tunnel

Introduction

China National Convention and Exhibition Center is located to the east of Zhuguang Road and to the south of Songze Elevated Road within Hongqiao CBD and has an area of some 1500 mu, as shown in Figure 1. It comprises exhibition venue, comprehensive supporting facilities and logistic supporting facilities. The floorage of exhibition venue, which will be the world's largest exhibition venue by exhibition area, is approximately 500,000 m^2; the floorage of comprehensive supporting facilities is about 300,000 m^2, and the floorage of logistic supporting facilities is about 200,000 m^2. It is a national key project involving cooperation between the Ministry of Commerce PRC and Shanghai Municipal People's Government and is included in the list of Shanghai major projects. After completion, China National Convention and Exhibition Center will be used for large specialized exhibitions scheduled by governments, e.g., biannual "China (Shanghai) Exposition" based on East China Fair and China International Industry Fair, and may also undertake international leading trade fairs like Bauma and CeBIT in Germany and establish exposition brands.

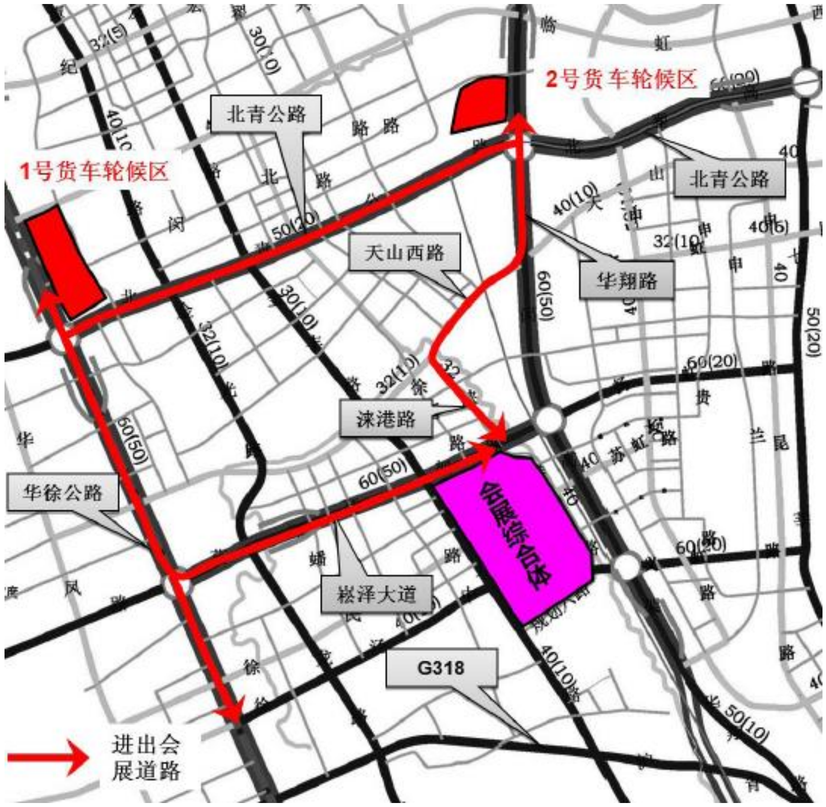


Figure 2.1. Relationship between China National Convention and Exhibition Center and Neighboring Road Network

Due to its immense exhibition area, China National Convention and Exhibition Center has to endure the transportation of 200,000 persons and 3,000 trucks per day in the worst-case scenario. According to traffic analysis of China National Convention and Exhibition Center under current planning, neighboring Zhuguang Road, Laigang Road, Middle Xujing Road and Songze Avenue provide a total of 22 lanes in two directions and total capacity reaches 15,000pcu/h. Peak flow of passenger cars (including taxi) to and from China National Convention and Exhibition Center will be up to 15,000pcu/h. With the addition of peak flow of passenger cars from supporting zone and neighboring vehicles in transit, regional roads will be fully saturated and unable to withstand traffic load of the convention and exhibition. In addition, large quantities of freight transport will inevitably generate a great deal of exhaust gas and noise and increase carbon emissions, thus affecting the construction of Hongqiao CBD as a national low-carbon demonstration area. Therefore, it is especially important to conduct systematic research on logistic schemes of China National Convention and Exhibition Center, guarantee efficient transport of exhibition logistics and reduce environmental impact on neighboring road network.

Three technical schemes are presented to cope with adverse impact of convention and exhibition logistics on transport and environment. The underground container system is determined as the best convention & exhibition cargo transport scheme based on comprehensive benefit analysis, and further expand the conceptual designs of underground container freight transport system.

Freight Transport Requirement Analysis of China National Convention and Exhibition Center

With reference to transport requirement features of Shanghai World Expo and other domestic and international large-scale conventions and exhibitions, freight transport requirement of China National Convention and Exhibition Center during exhibition move-out is predicted below:

(1) Traffic flow prediction

Calculated according to 50 trucks/10,000 m^2 of exhibition area during move-out of a typical large-scale convention and exhibition, China National Convention and Exhibition Center will attract 2,500 trucks of various types per day. With reference to 100 trucks/10,000 m^2 of Canton Fair on the date of move-out, China National Convention and Exhibition Center will attract 5,000 trucks on the move-out day.

(2) Parking berth prediction of truck waiting zone

To avoid unauthorized parking of freight vehicles in large numbers during exhibition move-out, a truck waiting zone with sufficient area must be set up. It is forecast that truck waiting zone for China National Convention and Exhibition Center will need 5000 berths or total parking area being around 500,000 m^2 (100 m^2/berth). In order to reduce traffic impact and noise from trucks in large numbers, the truck waiting zone shall be built where there is low environmental and traffic sensitivity.

(3) Transportation requirement prediction in the worst scenario

China National Convention and Exhibition Center with an exhibition area of 500,000m^2 can simultaneously hold 2~3 large-scale exhibitions with at least 150,000 m^2 each, and the move-out and overlapping of different exhibitions will most likely result in the conflict and superposition of passenger and vehicle flow in large quantities.

In the worst scenario, the period of large-scale consumption exhibitions will overlap that of large-scale specialized exhibitions and China National Convention and Exhibition Center will receive the transportation of 200,000 persons and 3,000 trucks each day. Traffic organization of exhibition visitors and goods is rather difficult.

Logistic Schemes for China National Convention and Exhibition Center

According to location and surrounding environment of China National Convention and Exhibition Center, the following schemes are put forward through research: Scheme 1, 2 truck marshaling yards and truck-only lanes will be built on existing Minbei Road and Laigang Road, and trucks will first gather and queue in marshalling yard before entering the convention and exhibition zone via Minbei ground road and Laigang special ground road; Scheme 2, based on Scheme 1, an underground truck-only road will be built beneath Minbei Road with transport route unchanged; Scheme 3, an underground logistic system and a logistic park will be constructed to process goods before transporting them into convention and exhibition zone via freight logistic lane. The detailed three schemes are as shown in Table 2.1.

Table 2.1. Comparative Analysis of the Three Schemes

Comparison items	Scheme 1: ground freight-only road	Scheme 2: underground freight-only road	Scheme 3: underground container freight transport system
Facilities	Truck marshalling yard + Minbei truck-only road + truck waiting zone + Laigang special road 1.ground road: Minbei truck-only road (2 lanes); Laigang truck-only road (4 lanes) 2.Truck marshalling yard: 5000 berths 3.Truck waiting zone: 1000 berths	Truck marshalling yard + Minbei underground truck-only road + truck waiting zone + Laigang special road 1.ground road: Laigang truck-only road 2.underground road: Minbei underground truck-only road 3.Truck marshalling yard: 5000 berths 4.Truck waiting zone: 1000 berths	Logistic park + underground logistic system + facilities in convention and exhibition zone + parking zone + Laigang special road 1.ground road: Laigang truck-only road (4 lanes) 2.Minbei and Laigang underground logistic lane (7 km) 3.Logistic park: 18 gantry cranes and corresponding means of horizontal transport 4.Convention and exhibition zone: 14 vertical shafts, 14 cranes
Occupation of land	Total area: 728,000 m^2 1.Ground road: 128,000 m^2 2.Truck marshalling yard: 500,000 m^2 3.Truck waiting zone: 100,000 m^2	Total area: 704,000 m^2 1.ground road: 104,000 m^2 2.Truck marshalling yard: 500,000 m^2 3.Truck waiting zone: 100,000 m^2	Total area: 204,000 m^2 1.ground road: 104,000 m^2 2.Truck marshalling yard: 100,000 m^2 3.Truck waiting zone: 100,000 m^2

Environmental impact	Big environmental impact 1.Exhaust gas, vibration and noise from trucks will impact greatly on CBD; 2. Annual carbon emissions of 89000t will impact on the goal of building a national low-carbon CBD.	median environmental impact 1.No impact on CBD 2. Annual carbon emissions of 89000t will impact on the goal of building a national low-carbon CBD.	Certain impact in the short run and negligible impact in the long run 1.No impact on CBD 2. The near-term annual carbon emissions of 58000t will adversely impact on the realization of the goal of building a national low-carbon CBD but such impact will be negligible given high cargo containerization in the long run.

Comparison items	Scheme 1: ground freight-only road	Scheme 2: underground freight-only road	Scheme 3: underground container freight transport system
Risk	High operating risk, low technical, organizational management risk Given particularities of convention and exhibition logistics including heavy traffic load and limited time during dismantling and arranging an exhibition, it is most likely that trucks will queue outside the convention and exhibition venue before entry. Additionally, exhaust gas, vibration and noise from convention and exhibition trucks will exert big environmental.	High operating risk, low technical, organizational management risk At the section of Minbei road, the adoption of underground road will reduce environmental impact. Other same as Scheme 1	High technical, organizational management risk, low operating risk Convention and exhibition underground logistic system will be the first of its kind in China and elsewhere and require innovative containerization integrated technology and model of organization management involving convention and exhibition third-party logistics.

Table 2.1 shows that three schemes are feasible in terms of construction. Compared with Scheme 1 and Scheme 2, Scheme 3 featuring the adoption of underground container freight transport system has the following 3 unique advantages: (1) ensuring efficient and safe container collection and distribution, (2) alleviating regional traffic pressure, cutting energy consumption and reducing environmental damage, (3) improving convention and exhibition center's collection and distribution system through close combination with large-scale convention and exhibition center. However, Scheme 3 calls for high investment. Scientific and objective evaluation of logistic schemes shall focus on comprehensive system analysis, which looks at the change in distribution of interests of the whole incurred by change in logistic link from the angle of the entire value chain. Despite certain increase in underground logistic investment and operating costs, such logistics might not result in considerable increase of the exhibitors' total cost and will instead bring about external effects and added value. The above mentioned increase in investment and operating costs may be offset by exhibition organizers' exhibition incomes. Through comprehensive analysis, Scheme 3 has the optimal effect.

Conceptual Design of Underground Container Freight Transport System for China National Convention and Exhibition Center

State-of-the-art on Underground Container Freight Transport System

Most of earlier researches on underground logistic transport system are restricted to the application of small-diameter pipeline logistics. For instance, Royal Mail Ltd used to build a 37 km-long track dedicated to transport of correspondences and parcels, which processes more than 4 million pieces of postal mail and parcel from 9 counties during daily peak period. A research team of the University of Bochum in Germany constructed an underground transport pipeline (maximum diameter: 1.6m) between downtown area and industrial park in Ruhr District. In the pipeline a pill shaped transport box is used to carry cargo and the box is driven by a traditional 3-phase motor to run in a driverless condition along the pipeline route and under supervision by a radar monitoring system.

Thanks to further development of related technologies in recent years, especially the research and application of underground tunneling machine, the research of underground logistic transport system has evolved toward the development of large-diameter underground tunnels and the importance of underground container freight transport system is increasingly recognized. There are relevant research projects underway in other countries including Port of New York and Port of New Jersey in the US, Port of Antwerp in Belgium, Port of Tokyo in Japan and Ruhr Industrial District in Germany, and there is conceptual design of technical feasibility and economic feasibility. With critical underground horizontal transport technology, such schemes as Pneumatic Capsule Pipeline (PCP), Conveyors Belt, Cargo Cap, Save Freight Shuttle and Automated Guided Vehicle (AGV) are presented.

In 2006~2008, a research team of Shanghai Municipal Engineering Design Institute (Group) Co., Ltd., based on analysis of driving forces for the development of underground container freight transport system, studied the possibility and technical & economic feasibility of developing underground container freight transport system in Shanghai and put forward possible routes like Yangshan Port ~ Luchaogang logistic park and Yangshan Port ~ Waigaoqiao Port. In

2008~2010, with respect to the transport of Shanghai municipal domestic waste, the conception of using underground container freight transport system for garbage transfer was proposed.

Conceptual Design of Convention and Exhibition Center's Underground Container Freight Transport System

General layout of Underground Container Freight Transport System

The underground container freight transport system means a logistic system where containerized cargo shuttles automatically in a large-diameter underground passage to realize container transportation between ports, between inland cities, and between a port and an inland city, which can be effectively connected to ground terminals and bring about such benefits as high efficiency, low cost and environmental friendliness.

In logistic system of China National Convention and Exhibition Center, the underground container freight transport (UCFT) system comprises three subsystems including logistic park, transport tunnel and exhibition venue, as shown in Figure 2. First of all, convention and exhibition freight vehicles gather at logistic park, where containerized cargo is unloaded before being transferred via underground tunnel to convention and exhibition venue for hoisting and devanning. General layout of underground container logistic route in China National Convention and Exhibition Center's convention and exhibition venue is shown in Figure 2.2.

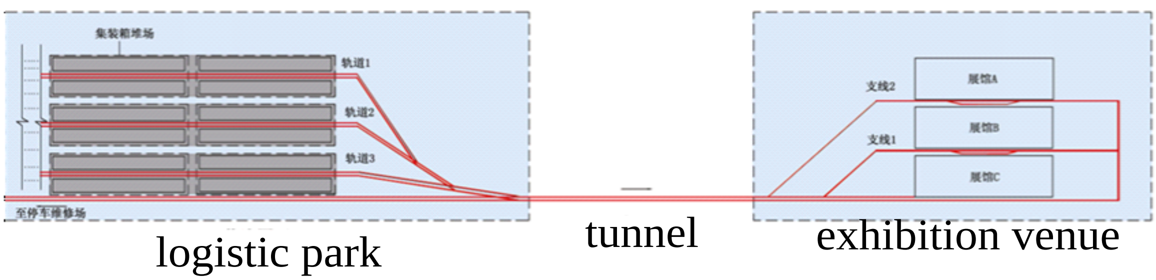


Figure 2.2. Underground Container Freight Transport (UCFT) System

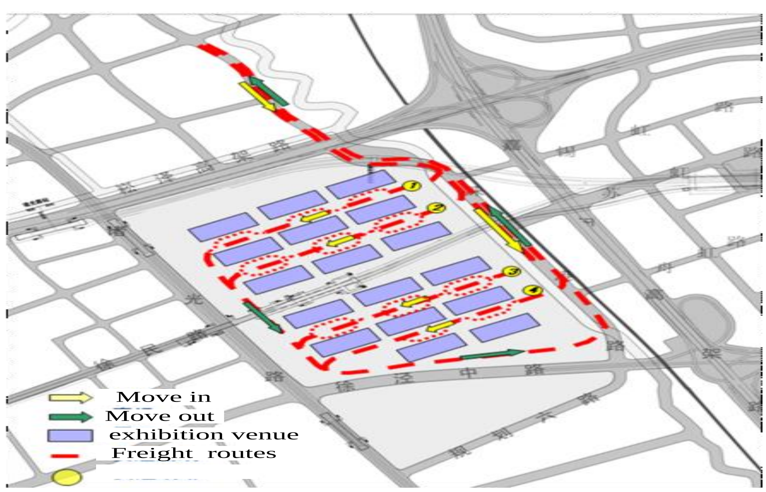


Figure 2.3. Horizontal Routes of Underground Container Freight Transport

Delivery Means of UCFT

Container horizontal transport equipment for underground logistic system of China National Convention and Exhibition Center may adopt tractor + semitrailer, motor tractor + container flat car, battery driven AGV, motor driven container railway transportation equipment, etc. Through comprehensive comparison, linear motor driven container railway transportation equipment is adopted due to its benefits like excellent climbing capacity, small curve radius, flexible route and low pollution. The system adopts 40t standard containers and 1~3 vehicles per group for cargo transport.

Logistic Park

Logistic Park comprises freight yard, transit zone, comprehensive supporting service zone, parking lot and vehicle repair zone. Floor arrangement of UCFT logistic park is shown in Figure 2.4.

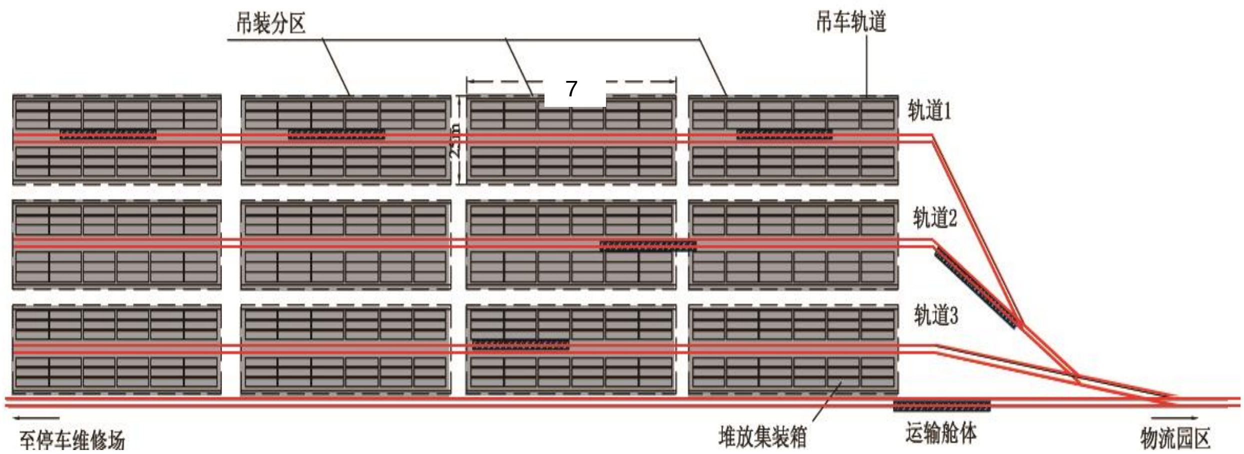


Figure 2.4. UCFT Logistic Parks

Vanning time of each train is 18 minutes. Considering 1.0-minute departure interval, 18 gantry cranes are needed; each site of gantry crane will have 140 containers, which will be placed on both sides of transportation track and cover 70m×25m; the area of freight yard and transit zone combined is approximately 50,000 m^2 (including roads in freight yard).

Transport Tunnel

According to the requirement of container transport vehicle, the cross-section of transport tunnel is shown in Figure 2.5.

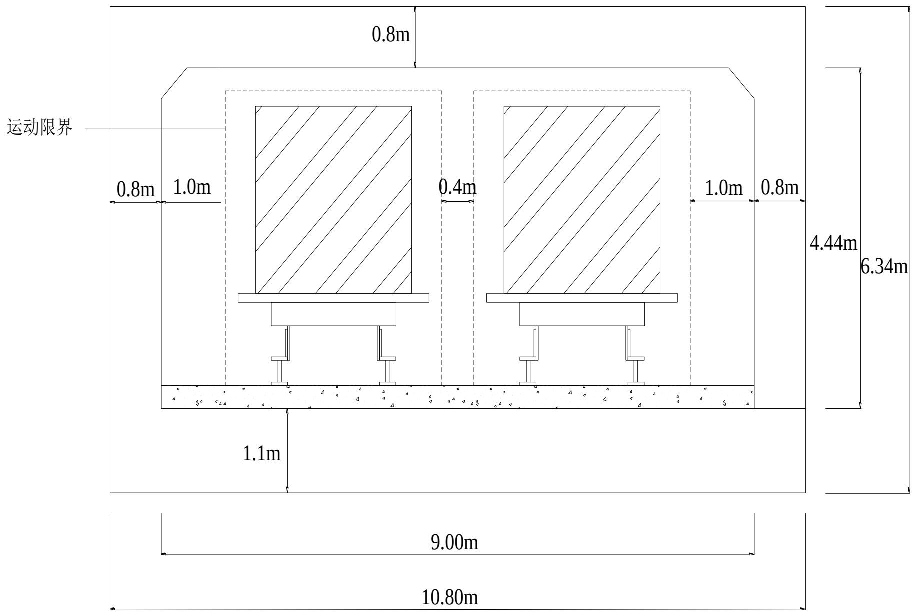


Figure 2.5. Cross-section of UCFT Tunnel

According to the working conditions of dismantling and arranging an exhibition, 2500 containers have to be transported within 16 hours and the departure interval of trains operating in opposite directions on the same route is 1.15 minutes, which exceeds 1.0 minute. Therefore, the system meets the requirement. In addition, according to research scheme of underground container freight transport system in Belgian ANTWARP Port, a total of 2776 containers can be handled per day in opposite directions, with vehicle running speed of 7km/h, departure interval of 33s and train operating interval of 66s. The cut and cover method is proposed for construction.

Convention and Exhibition Zone

At convention and exhibition zone, exhibition halls and container stacking zones are alternatively arranged and transport tunnels pass through exhibition halls and container stacking zones in order; vertical transport shafts are erected in the center of container stacking zone to allow the crane to lift containers to the ground for devanning; containers are unpacked at the stacking zone and goods are sent via ground handling equipment to corresponding exhibition booths. Floor arrangement of UCFT convention and exhibition zone is shown in Figure 2.6.

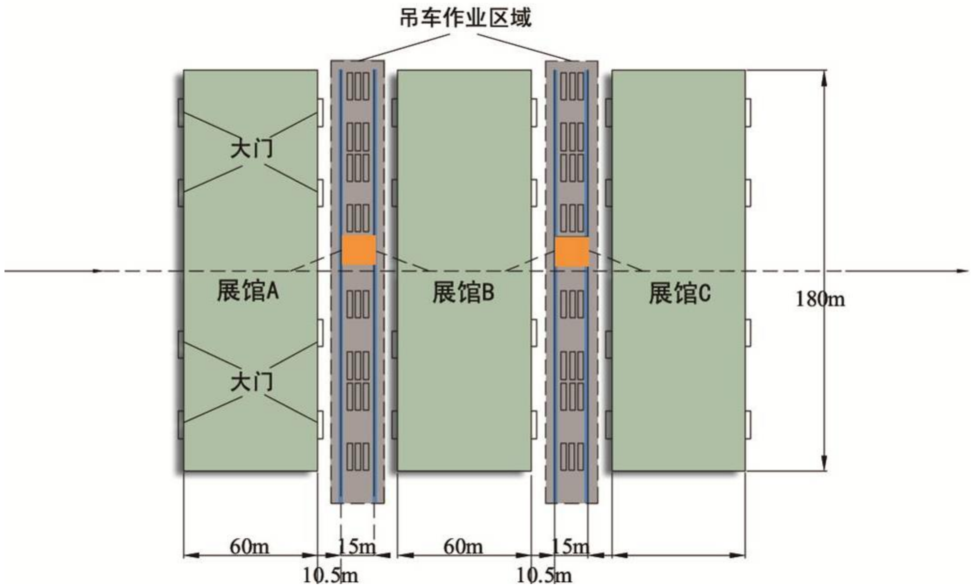


Figure 2.6. UCFT Convention and Exhibition Zone

Equipment of convention and exhibition zone falls into basic configuration and gross configuration, detailed as below:

Basic Configuration:

- Considering 6.0-minute loading/unloading cycle by gantry crane, 30,000 m^2 service area and the hoisting of 270 containers within 16 hours, hoisting speed of gantry crane shall be 3.5 minutes. Therefore, one vertical shaft shall be equipped with two gantry cranes.
- If the area of exhibition hall exceeds 30,000 m^2, the number of vertical shafts shall be increased.
- Given 90-minute devanning time limitation, 24 containers may be arranged at ground temporary freight yard beside shaft and on both sides of the doorway of exhibition hall.
- Two cranes may be deployed on both sides of the shaft. For double-layer arrangement, the cranes may be deployed in the upper and lower layers.

Gross configuration:

- Each vertical shaft is equipped with 1 crane and the number of containers that can be hoisted is: (16*60/6=) 160
- The number of vertical shafts required for the hoisting of 2500 containers at exhibition venue is: (2500/160=) 16, and 16 cranes need to be deployed
- Devanning time is 1.5h, and the number of devanning cycles that can be done at devanning site beside shaft is: (16h/1.5h) =11
- The number of containers being devanned simultaneously at exhibition venue: (2500/11~=) 230
- Supposing the footprint of each container is 50 m^2, the total area of devanning site is: (230*50=) 11500 m^2

Gross configuration is based on ideal conditions, but different exhibition halls have different area. Therefore, the configuration of facilities varies for various exhibition halls.

Relationship between Mainline Tunnel and Branch Lines of Convention and Exhibition Zone

The relationship between mainline tunnel and branch lines of UCFT convention and exhibition zone is shown in Figure 2.7.

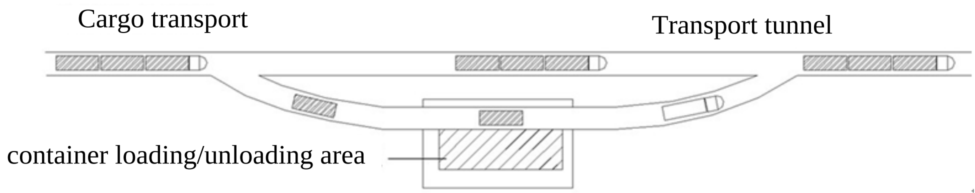


Figure 2.7. Mainline Tunnel and Branch Lines of UCFT

Mainline transport tunnel has branch lines; branch lines are connected to vertical transport shaft and intended for temporary emplacement of containers so that the crane can lift the containers to the ground for devanning; containers are unpacked and goods are unloaded at the stacking zone before being transferred via ground handling equipment to corresponding exhibition booths.

Conclusions

Based on freight transport requirement analysis of China National Convention and Exhibition Center and with due consideration of influencing factors like surrounding environment and road network, three logistic system technical schemes are put forward. Through scheme comparison and selection, the scheme featuring the underground container freight transport system is chosen due to its optimal effect. This shows traditional logistic schemes fail to meet the freight transport requirement of China National Convention and Exhibition Center and that the development of underground logistic system, a new mode of freight transport, has considerable comprehensive benefits: for Hongqiao CBD as a whole, the adoption of underground logistic mode to solve traffic problem of the exhibition center will help relieve the huge pressure of exhibitions on regional road transport; and this scheme will also greatly reduce carbon emissions, save energy and remarkably improve regional neighboring environment. For the convention and exhibition complex, orderly devanning organization will increase the efficiency of dismantling and arranging an exhibition; the setting of logistic park will not only deal with the storage of early cargo but also regulate peak value of freight transport requirement; due to the saving of supporting zone dedicated for unloading and forwarding, the entire scheme will considerably increase intensive land use.

The following points shall be paid attention to in future research of underground logistic scheme for convention and exhibition center:

(1) Convention and exhibition is not a sheer market or commodity economy but an experience economy. Its purpose is to secure exhibitors' participation in future exhibitions. Therefore, the analysis of customer value involves not just money cost and value but also time, spiritual, physical and psychological values.

(2) The advantages of the scheme on social environmental and other public benefits shall be highlighted.

(3) Scientific and objective evaluation of logistic schemes shall focus on comprehensive system analysis, which looks at the change in distribution of interests of the whole incurred by change in logistic link from the angle of the entire value chain.

(4) Underground convention and exhibition logistic system will be will be the first of its kind in China and elsewhere and require innovative containerization integrated technology and model of organization management involving convention and exhibition third-party logistics.

Postscript

This paper was finished in April 2011. After the completion of solicitation of schemes from home and abroad, the scheme is changed as follows: convention and exhibition complex is placed in the center of project site in a radial "four-leaf clover" pattern, which divides the site into 4 parts, namely eastern, western, southern and northern squares according to the relationship between building access and environment, as shown in Figure 2.8. Such change deviates from the foregoing design scheme but basic principles remain unchanged.

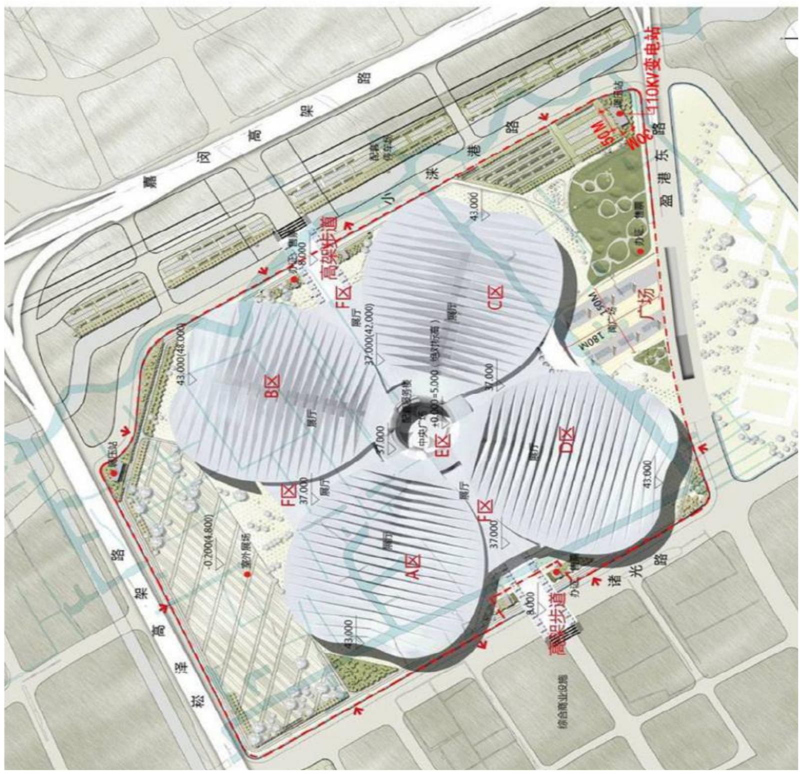


Figure 2.8. China National Convention and Exhibition Center

References

Qian Qihu, Guo Dongjun. Introduction on Urban Underground Freight Transport System [M].Beijing: The Communication press, 2007

Willy Winkelmans, "Redressing the Balance between Demand for Mobility and Supply of Transport by Means of New Modes of Transportation", ISUFT 2008, Arlington.

Willy Winkelmans and Johan Van Wassenhove, UCM (Underground Container Mover) (Denys NV) a technological and transport-economic solution for sustainable development of seaports, ISUFT2010, Shanghai.

Guo Dongjun, Yu Mingjian, Chen Zhilong, The Preliminary Study on Underground Container Transportation System(UCTS) for Yangshan Port in Shanghai, ISUFT 2008, Arlington.

Guo Dongjun, Chen Zhilong, Xie Jinrong, Zhao Ziwei, A comparison of different container transport modes in Yangshan deep Water Port, ISUFT 2010, Shanghai.

Yu, M.J., Fan, Y.Q., Plan and Conceptual Design of Urban Underground Domestic Waste Transfer Logistics System. ISUFT 2010, Shanghai.

Fan Yiqun 1, Pei Qi, Key Issues Studies in Design and Construction of Transfer Station and Terminal of Municipal Underground Environment Freight Transport System: a Case Study in Shanghai, ISUFT 2010, Shanghai.

Shanghai Municipal People's Government. The Detail Planning of China National Convention and Exhibition Center, 2012 Shanghai Municipal People's Government. The Structural Planning of Hongqiao Business District.

Paper No. 3

Pipeline Asset Management Specific to Gas Pipelines: Issues and Needs

Jonathan Faughtenberry, P.E., Senior Facility Engineer/Project Manager,
Oasis Petroleum, Inc., 1001 Fannin Street, Ste. 1500, Houston, TX 77002
Email: jfaughtenberry@oasispetroleum.com

Refer to Appendix A, Page A-25, for a copy of presentation

3. Pipeline Asset Management Specific to Gas Pipelines: Issues and Needs

Jonathan Faughtenberry, P.E., Senior Facility Engineer/Project Manager,
Oasis Petroleum, Inc., 1001 Fannin Street, Ste. 1500, Houston, TX 77002
Email: jfaughtenberry@oasispetroleum.com

Abstract

In the United States today there are over 210 natural gas pipeline systems which encompass over 305,000 miles of interstate and intrastate transmission pipelines. With this many miles of gas pipelines, there are over 11,000 delivery points, 5,000 receipt points, 1,400 interconnection points, 24 hubs or market centers, and 49 locations where natural gas can be imported/exported via pipelines throughout the U.S. If all the natural gas pipelines in the U.S. were connected to each other they would stretch to and from the moon almost three times. With this many miles of natural gas pipeline assets in the ground and flowing, there comes the requirements and challenges of trying to properly maintain these infrastructure assets. There are requirements for properly maintaining these assets as defined by the Department of Transportation (DOT) CODE 192, but any good pipeline operator will maintain these assets to insure a safe and suitable design pipeline system. The challenges of pipeline asset management present themselves in several different forms, but can be broken down in to 4 main threats which are external corrosion, internal corrosion, 3rd party damage, and construction defects. This presentation paper will discuss those threats, how and why they occur, what the current methods are for detecting and preventing these threats, and the current research needs for improved asset management of natural gas pipelines.

Introduction

Proper asset management of natural gas pipelines begins with following the DOT 192 and 195 minimum requirements for asset management of gas pipelines. The Pipeline and Hazardous Materials Safety Administration (PHMSA) is a branch of the federal government that is responsible for regulating and ensuring the safe and secure movement of hazardous materials to industry and consumers by all modes of transportation, including pipelines.

PHMSA is the author of the DOT 192 and 195 pipeline codes. DOT 195 is the code requirement for transportation of hazardous and/or combustible liquids by way of pipeline, and DOT 192 is the code requirement for the transportation of combustible and/or hazardous gases by way of pipeline. These codes are what set the minimum standards for proper asset management of gas pipelines and have set the standard for certain operational practices to be implemented in order for sufficient asset management of pipelines.

However, along with knowing the minimum DOT code requirements for asset management of gas pipelines, it is also very important to know the threats that endangers a gas pipeline system, how and why the threats occur, what the current methods are for asset management of a gas pipeline systems, and current research needs for asset management of a gas pipeline system. The top four threats to a gas gathering pipeline are internal corrosion, external corrosion, third party damage, and construction defects.

General Discussion & Case Studies

Internal corrosion is one of the main threats to a gas pipeline due to the compounds that are found mixed in with the natural gas. These compounds mainly consist of bacteria from the well flowback, saltwater from the ground formation as a result of the wellbore drilling, hydrocarbons, and oxygen. These four components can attack the inner walls of a pipeline if proper asset management techniques are not implemented. Case study A which is a 24" natural gas pipeline called the Winscott to Grace Lateral, is an example of what can happen to the inner walls of a gas pipeline if the proper facilities such as pigging are not in place to prevent bacteria and water build up in the pipeline.

After running an inline inspection tool (ILI) on the 24" Winscott to Grace pipeline, the results of the tool indicated 62% wall loss in over a hundred different locations throughout a one mile length of pipe (figure 1 & Figure 2). The cause of this wall loss has not been confirmed, but the initial investigation by the ILI tool indicates that the pipeline was installed without any pigging capabilities for 24 months. Since the pipeline was not pigged for over 24 months, the pipe set idle/dead leg and allowed bacteria scaling and water to build up in the pipe and corrode the inner walls of the pipe. This form of pipe design and installation is known as a dead leg because it does not have any pigging facilities to flush out water, and inject chemicals to kill bacteria. The solution to repair this issue was to replace a mile of 24" pipe.

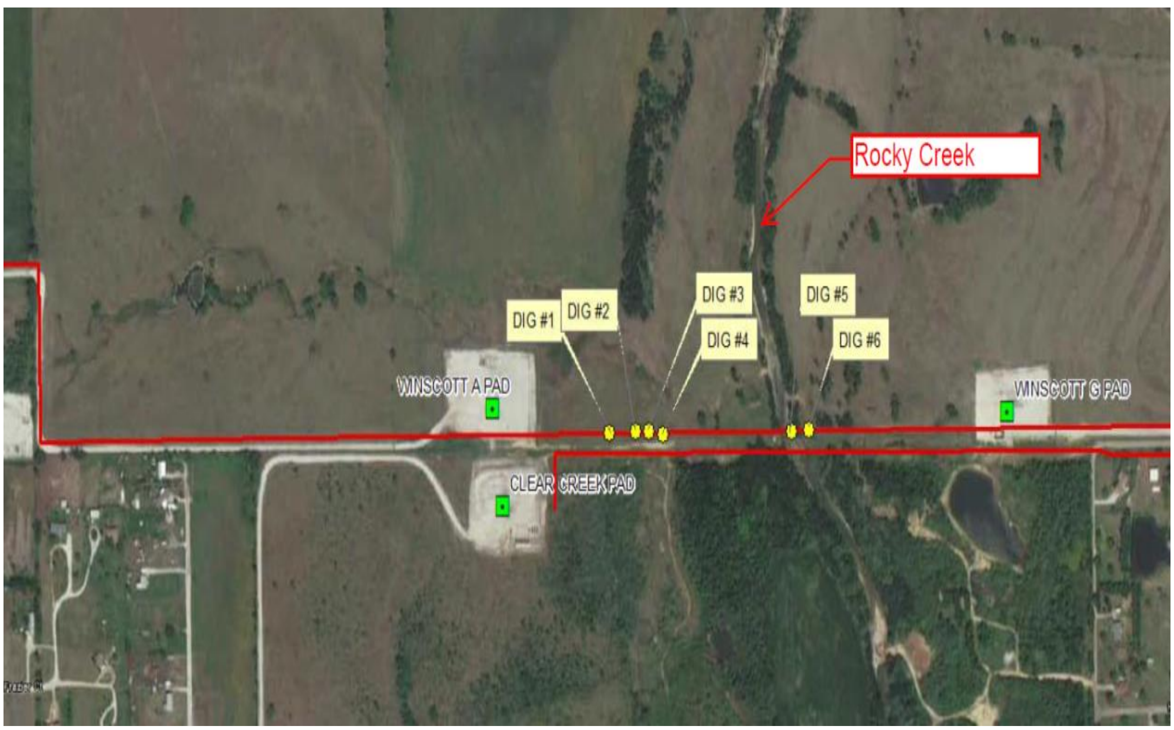


Figure 3.1. Results of the Tool Indicating 62% Wall Loss in Over a Hundred Different

Figure 3.2. Results of the Tool Indicating 62% Wall Loss in Over a Hundred Different

Case study B, is an example of internal corrosion that occurs when the proper asset management of facilities are in place, but not utilized. Case study B is four 12” pipelines, which were discovered to have 6 leaks after a pipeline patrol indicated a gas leak along the pipe right of way. Once the leak was detected during pipeline patrol, an ILI tool was run through the pipe and confirmed that the pipe had 6 leaks with defects up to 1” in width (figure 3 and figure 4). Since the pipeline had sufficient pigging facilities in place, it was determined that proper operation and maintenance activities were not being practiced for this stretch of pipe by verification of a lack of operation and maintenance records. The combination of low flows, non-pigging operation, and lack of chemical injection allowed the buildup of water and bacteria which ultimately corroded the pipe. The solution to repair this issue was to replace over a mile of 12” pipes.

Figure 3.3. Confirmation of the Pipe having 6 Leaks with Defects up to 1” in Width

Figure 3.4. Confirmation of the Pipe having 6 Leaks with Defects up to 1" in Width

External corrosion is another top threat to natural gas pipelines. The case study presented herein for external corrosion is an example of a 12" pipeline that was determined to have 50% wall loss after running an ILI tool through the pipe. After exposing the pipe at the location of the wall loss it was determined that the wall loss was due to improper application of joint weld coating. As shown in figure 5, the joint coating was not properly and adequately applied to the joint and/or the joints were coated to quickly causing hydrogen gas to build up during the drying of the paint not allowing a sufficient joint coating. Therefore, this lack of joint coating application exposed the iron pipe allowing a direct corrosion point. The proper asset management technique that could have avoided this situation is to have good field inspection and acceptance of field joint coating applications, and proper training of how to apply field joint coatings. The repair method for this corroded joint is a clock spring composite wrap (figure 3.6).

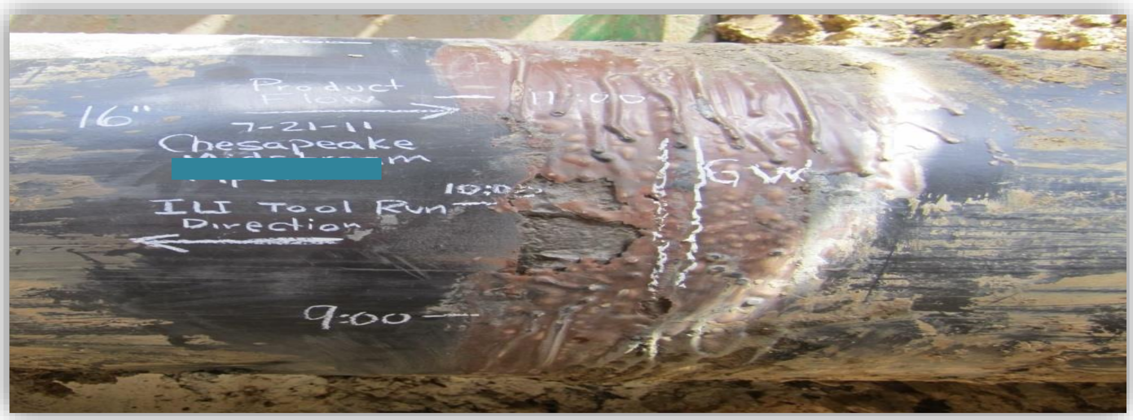


Figure 3.5. Joint Coating not Properly and Adequately Applied to the Joint

Figure 3.6. Repair Method for Corroded Joint

The third major threat to a natural gas pipeline is material defects. These material defects are due mainly to poor mill quality/production and/or poor handling once received at the construction site. Material defects such as cracked pipe or insufficient pipe coating can cause major problems to the pipe such as internal and external corrosion. Figure 3.7 and Figure 8 shows an example of poor pipeline coating during jeep testing that led to the discovery of a cracked pipe. It was concluded that there was insufficient mill quality oversight and testing due to a lack of inspection at the mill. The mitigation method for this insufficient pipe was to quarantine the pipe and send it back to the mill.

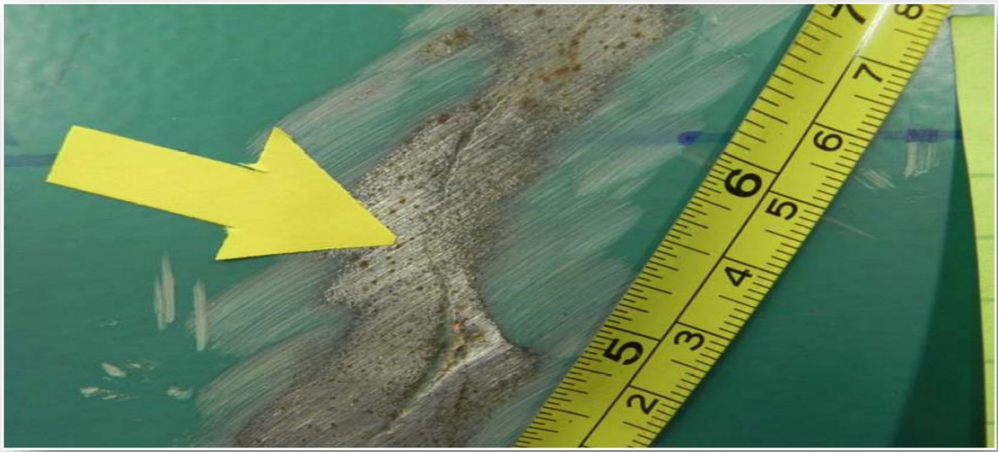


Figure 3.7. Example of Poor Pipeline Coating during Jeep Testing

Figure 3.8. Example of Poor Pipeline Coating during Jeep Testing

The fourth main threat to a natural gas pipeline system (if proper asset management operations are not in place for pre-construction activities) are construction defects. Figure 9 shows a pipeline that has been damaged due to a paralleling bore during the reaming stage. It was determined that a reamer caused the mechanical damaged during the reaming stage of a paralleling horizontal directional drilling installation of a 12" pipe. This could have been prevented by the use of proper field line locates and as-built records. The repair method for this damage was to replace 47.5 feet of 12" pipe. In addition, several other threats can be avoided which pose a problem to proper asset management of pipelines such as avoiding wyes which hinder sufficient pigging operations, fittings designed with radiuses less than 1.5 x D that hinder pigging operations, and random heavy wall pipes that hinder pigging operations. These type of defects can be avoided by proper design, oversight during purchasing, and good field inspection.

Figure 3.9. Pipeline Damaged due to a Paralleling Bore during the Reaming Stage

Another threat to natural gas pipelines is the formation of hydrates when hydrocarbon gases occur in the gas composition usually greater than 1180 British Thermal Units or BTU. When hydrocarbon gases greater than 1180 BTU occur in the gas composition hydrates can form when pressures increases, temperature decreases, and low flows occur. Under these circumstances, hydrates can form causing ice type crystals to form in the pipeline (figure 3.10). These hydrates clog the pipe, and cause for an insufficient pipeline system. Most hydrates are discovered when there is a pressure drop in the pipeline, low flows occur, or an ILI or pig run discovers the hydrates. Proper asset management to prevent these type of issues is to maintain low system pressures by adding adequate compression where needed, methanol injection, proper pigging, and to maintain temperature and pressure under the dew point requirement for the gas.

Figure 3.10. Formation of Hydrates Causing Ice Type Crystals to Form in the Pipeline

Causes of Pipe Rehabilitation

With each of the four threats presented, each case study required some type of pipe rehabilitation. To summarize what the causes of pipe rehabilitations are, they can be grouped into three main categories which are lack of field and procurement inspection, poor O&M processes, procedures, and documentation, and improper design of gas pipelines. Where most material defects occur are at the mill inspection level when there is a lack of mill inspection along with improper delivery documentation. If the proper delivery documentation is provided, then the checks and balances are in place to insure good quality assurance of mill inspections. In turn, materials then should not be delivered to the site with defects because proper mill inspection occurred.

If there is improper procurement inspection, and a defective material is delivered to the site, then a second quality assurance check and balances should occur and that is at the field level site inspection. These type of quality assurance checks and balances are in the form of an eye ball inspection, pipe jeeping, and non-destructive testing such as X-Ray and Hydro testing. However, even if an acceptable pipe is delivered to the site a lack of construction oversight on handling of the pipe can occur causing the pipe to be damaged. Therefore, good asset management of pipes is always having good inspections on the pipe assets at all times (procurement and field handling).

Poor O&M process, procedures, and documentation can endanger the quality of a gas pipeline. Good asset management of a gas pipeline system always involves a good O&M process, procedure, and documentation, and is a requirement by DOT 192 Code. The most common reason for poor O&M procedures is usually not having a regular pigging schedule or no pigging of the pipeline at all which allows for water, hydration, and bacteria build up, dead legs in the pipe system, poor system operation management, and no chemical treatment of the pipeline system to prevent bacteria or hydration formation build up.

Improper pipeline designs can lead to pipe rehabilitation. The more common improper pipe designs are fittings designed to a bend that is less than a 1.5 x the diameter of the pipe. A pipe bend that is less than 1.5 x the diameter of the pipe will not allow a pig to negotiate the turn and will get stuck at the bend. Wyes that have angles less than 30 degrees can make running a pig through the intersection very difficult if not impossible, this in turn creates an unpiggable section of pipe. Dead legs as discussed previously, are bad design standards that create major internal corrosion issues. The design of the pipe wall thickness should also incorporate some type of corrosion allowance which helps maintain the life of the pipeline. Also, there should be a consideration for temperature, pressure, and flows in the design of the pipeline to help with pipe flushing and hydrate formation. Good design practices are a critical piece to proper gas pipeline asset management.

Current Pipeline Maintenance & Inspection Methods

Good pipeline asset management involves knowing the latest technologies for maintenance and inspection. Current methods for gas pipeline maintenance are the following:

- **Pigging Procedures**
  - Pigging is a method where a brush/foam/heavy duty plastic tool is pushed down the pipe by using backpressure from the flowing gas.
- **Cathodic Protection**
  - The two main methods for gas pipeline cathodic protection are impressed current and sacrificial anodes.
- **Good O&M process, procedures, and documentation**
  - Best way to insure proper asset management of a pipeline system
- **Chemical Treatment**
  - Two main methods for gas pipeline chemical injection are methanol injection which prevents hydration build up, and anti-bacteria agents for preventing bacteria build up in the pipe.

Current methods for pipeline inspection are the following:

- **Caliper Pig**
  - Pigging tool that determines wall thickness and pipe ovality
- **Gyro Pig**
  - Determines pipe profile and bends through the use of a gyroscope. It helps to verify HDD bend radiuses, and determine exact profile of the pipe.

- **Gauge Plate**
    - Determines Pipe Ovality and Damage to Pipe Wall
- **Magnetic Flux Leakage**
    - Determines changes in wall thickness by inducing magnetic flux in in pipe to detect changes in amplitude due to wall thickness change, and it is an inferred measurement.
- **Ultrasonic**
    - Determines wall thickness by use of a transducer to send and receive sound waves. The difference in time of flight determines wall thickness.

Research Needs

Although there are several very sound methods for insuring good gas pipeline asset management, there is always room for improvement. There are current research needs in the following areas:

- More Research in Pigging Technologies
    - Develop pig designs that allows chemical batch treating for biocide and inhibitors that helps coat the entire internal circumference of the pipe.
    - More improved low flow/pressure pigs
- More research in developing better remote monitoring of rectifiers to assure consistent CP. Tie into SCADA.
- More research on improving design of system to alleviate Hydrate and Liquid build up.
- More advancement in remote pipe monitoring
- Ways to protect existing pipe from 3rd party damage
- Improvement in predicting bacteria build up in pipeline systems
- Research in best ways to optimize O&M on pipeline systems

Conclusions

In summary, the most current methods for proper asset management of gas pipelines are proper pigging procedures, proactive approach to O&M, good procurement and field inspection, acceptable ILI tools and operations, good design practices to allow for superior O&M procedures. Proper asset management of gas pipelines begins with knowing the DOT 192 code requirements, knowing the threats to a gas pipeline system, knowing how to prevent the threats to a gas pipeline, knowing the current methods and technologies for proper gas pipeline asset management, and knowing the future needs for developing new gas pipeline asset manage technologies.

References

U.S. Dept. of Energy, “About U.S. Natural Gas Pipelines (2007/2008)”, U.S. Energy Information Administration, Washington, DC.

Interstate Natural Gas Association of America, “Pipeline Facts 2013”, INGAA, Washington, D.C.

Paper No. 4

Improving Transmission Pipeline Design, Operations and Maintenance

David Marshall, Engineering Services Director
Tarrant Regional Water District, Fort Worth, Texas
Email: david.marshall@trwd.com

Refer to Appendix A, Page A-38, for a copy of presentation

4. Improving Transmission Pipeline Design, Operations and Maintenance

David Marshall, Engineering Services Director
Tarrant Regional Water District, Fort Worth, Texas
Email: david.marshall@trwd.com

The Tarrant Regional Water District is a raw water wholesale supplier in north central Texas, supplying 70 cities with a total population base of 1.8 million people. The District owns four reservoirs, uses three reservoirs owned by others and operates 187 miles of large diameter transmission pipelines. Almost 90% of the water delivered is to Tarrant County, encompassing Fort Worth and the surrounding metropolitan areas. This year we will deliver about 370,000 acre feet of water. About 70% of that water is delivered from two reservoirs 75 miles southeast of the county. The elevation increases by 440 feet through the pipeline route, requiring high horsepower pumping. The pipeline system has to be near 100% reliability to ensure there is no disruption in service.

The system has been built over the last 40 years, and the development and failures shown below.

Table 4.1. Developments and Failures

Pipeline	Year Finished	Diameter - length	Max Pressure, psi/ material	Number of failures
Cedar Creek	1972	72" – 68 miles 84" - 6 miles	225 psi/E301	9
Richland Chambers	1988	90" - 72 miles 108: - 6 miles	225 psi/E301	14
Benbrook	1998	90" – 11 miles	100 psi/E301	0
Eagle Mountain	2008	96" – 10.5 miles 84" – 10.5 miles	225 psi/Steel	0

Failures of the two lines were investigated, root causes found, and mitigated to the extent possible. Problems included high transient pressures, embrittlement of the prestressing wire, corrosion of the prestressing wire, and thrust restraint design. There are many damaged pipe in the system, and TRWD prioritizes pipe replacement based on damage, remaining strength and risk. Engineers from Simpson, Gumpertz and Heger developed models for TRWD to use to evaluate remaining strength and risk. To date, over 160 damaged segments have been replaced. There are over 800 damaged segments remaining, many which can provide service for some time to come.

Working through these problems, it became apparent that the design methodology developed in the AWWA standards and manual of practices in use at the time of design did not accurately predict the behavior of the pipelines. Working with the standards committee, the design of thrust restraint in M-9 was changed to a method that worked for the very soft soils in north Texas. The limit states design method in the current standard C-304 has been shown to be very effective, as shown in a study sponsored by the Water Research Foundation. The revised standard for prestressing wire, ASTM 648, ensures that embrittlement is no longer an issue. Solving our problems for thrust and determining remaining strength was done using finite element analyses using observed pipe condition and actual soil strengths.

Currently, TWRD is working on a joint transmission project with Dallas Water Utilities that consists of 84” to 108” diameter pipe over 149 miles. This project is through 20 different geologic outcrops along the alignment. The design is being developed for steel pipe and prestressed concrete cylinder pipe. We are working with the University of Texas at Arlington to explore using modified native backfills and controlled low strength materials developed from native soils. We are also working with them using finite element analyses to evaluate pipe and trench systems.

Based on the experience of TRWD, I offer these ideas toward improving the robustness of transmission pipelines:

Design – The design needs to balance reliability and cost. Transmission mains need to be very reliable. Equations for design are generally empirical, with coefficients estimated based on experience. The same equation is used for all diameters. Consideration should be given to develop standards for using three dimension finite element analyses for pie and trench systems. The software tools are available and there have been a great deal of studies published. Life cycle cost and reliability may be improved through enhanced structural design.

The applicability and performance of equations used to determine pipe wall thickness for static and dynamic loading needs to be explored to verify they produce the same degree of reliability for all pipe diameters and trench widths. Some questions to consider are:

Does ring theory apply to large diameter pipes or should they be treated as thin shells?
Will the deflection be elliptical or can there be local deformations?

Resistance to collapse from vacuum is calculated by ring deflection. If a pipe does not deflect as assumed through ring deflection, could collapse occur at a much lower vacuum?

Should the stiffness of the mortar lining be used? In 40 years will that mortar lining still have the same characteristics or will carbonation decrease the strength? Trench backfill system analysis needs to be site specific based on measured parameters. Trench wall material and support for large diameter pipe can vary widely both vertically and longitudinally. Work done by UTA on CLSM has shown that stopping the clsm at 70% of the pipe height creates localized stress points that may lead to snap buckling. Full scale testing should be developed to explore vertical changes in trench wall strength to help guide trench width. Some questions to consider are:

1. Will vertical trench wall material changes result in non-uniform soil reaction, especially for rock/soil interfaces in the trench wall and create high localized stresses on the pipe wall?

2. Can backfill be developed using differing materials in different vertical zones to improve performance and reduce costs?

3. Trench width generally has a minimum based on constructability. For softer soils, a wider trench is required. There should be a way to optimize sidewall strength while minimizing width.
4. Coatings

Coating systems determine the life of a pipe. As coatings age and become permeable, corrosion or corrosion mitigation requirements increase. Designing for a century of life of a transmission main requires the coating system to perform flawlessly as the system ages. Questions to consider are:

a) What measurement should be used for flexible coating acceptance? Pull offs measure adhesion but not permeability.
b) What tests can be used for estimating the coating life. Glass transition temperatures may bias results for many polymer coatings.
c) Will micro-cracking of mortar coating always heal, or will carbonation eventually make pathways of high permeability?
d) How does the grout perform in non-welded joints over decades? Would a shrink wrap system provide for a longer life?

5. Installation

Conservatism in design may be consumed by the installation. Uniformity in the trench bottom is assumed. Small variations will add to the stress in the pipe through beam action. Compaction is also assumed to be uniform. Haunch support is critical and is the most difficult to achieve with traditional backfill methods. Exploration of installation variation could benefit designers and owners to understand the degree of conservatism that should be placed in design and what alternative methods for installation could be cost effective. UTA will be piloting a system for high accuracy measurement of pipe deflection. If successful, this should be used to explore large diameter flexible pipe installations to document deflection as it is found in the field. This information then could be used in design to develop proper factors of safety for non-elliptical deflection.

6. Operations

Operational upsets lead to extreme conditions for pipelines. Overpressure from leaking isolation valves and operator errors can lead to damage to long lengths of pipe and failure. Power failures and equipment failures can lead to transient events. Designs must include some provisions to help mitigate overpressure. Surge valves or altitude valves at strategic locations would help insure low volume extreme pressure events could be mitigated. Performance of these systems needs to be documented to ensure recommendations work. Transient analyses provide some guidance for design. Transient models do not reflect the full event, just the first low pressure wave and returning high pressure wave. There is still room for improved transient wave analyses.

Right of ways do not remain static. During design factors such as right of way use and future land use need to be considered. Long term differential settling resulting in shear is a concern. Pipes enclosed in tunnels under roads naturally have a point exiting the tunnel where differential support over decades may create stress. When roadways are widened, the force points will change. In our clay soils, this settlement may take decades to stop. The San Jacinto Monument is a great case to observe settlement over time. Settlement was rapid over the first two years, and then proceeded linearly for the next 4 decades until finally slowing to a total displacement of about a foot. Studying installations would help define what needs to be accounted for in design.

Operating conditions change over time. Most pipelines see increasing demands resulting in higher pressures and flows increase over time. Internal surfaces become rougher, resulting in high friction. Designs need to account for the life of the line and planners need to understand the eventual reduced capacity and pressures that the line can withstand as it ages. Guidance based on actual systems need to be documented for improved design and planning.

7. Maintenance

Owners must take responsibility for an active maintenance program to make the system last. Funding is always an issue. Australia and New Zealand require asset management as part of their full cost of service. There are software programs available for guidance and numerous publications. There are still opportunities to refine best management practices looking solely at transmission mains and develop their cost to help support agencies to fully fund their systems.

Understanding what needs to be done needs to come from successful utilities. Support for this work needs to be developed in the industry. Data collection is always a hurdle. Defining practices and collecting the costs associated with them needs to be deliberate. Having staff time available to accumulate the information is always hard. A great deal of work needs to be done to define proper maintenance and justify the costs associated with it.

Transmission system reliability needs to be first and foremost in design, operation and maintenance. The failure of a system impacts a large population. The capitol costs for transmission is very high but failing to provide the proper factor of safety can plague a utility with interruptions. Transmission mains need to be considered as long term assets and designed sustainably, taking into account conductions that could occur decades from now. There is still a great deal to explore in large diameter pipe design that will optimize the resources required for a successful project.

Paper No. 5

Broadband Electro-Magnetics (BEM)

Martin Roubal (Geophysicist B.Sc. (Hons.)), Rock Solid Group Pty. Ltd.,
11/7 Commercial Court, Tullamarine, Australia 3043
Email: info@rocksolidgroup.com.au

Refer to Appendix A, Page A-45, for a copy of presentation

5. Broadband Electro-Magnetics (BEM)

Martin Roubal (Geophysicist B.Sc. (Hons.)), Rock Solid Group Pty. Ltd.,
11/7 Commercial Court, Tullamarine, Australia 3043
Email: info@rocksolidgroup.com.au

Abstract

How many different pipe condition technologies and corrosion experts do you have at your company? Ultrasonics, Magnetic Flux Leakage, Radiography, etc.…and all the different people and companies that are required to drive these service. I bet it's quite a list. But what if there was a technology and device which you could provide to a pipeline that would allow it to develop a virtual brain. Something that would allow the pipe to tell you how stressed it feels and more importantly warn you that it is coming to the end of its life and needs a revamp or a replacement? This presentation describes the integration of BROADBAND ELECTROMAGNETICS (BEM) into a pipeline network and the benefits of empowering pipelines for self-assessment. Create "THE INTERACTIVE PIPELINE".

Keywords: Non-Destructive Testing (NDT), Pipes, Bridges, Ferrous, Non-ferrous, Surface, Underground, Hardware, Software, Manager, Owner, Remote

Introduction

Pipelines are the lifeblood of industry supplying necessary products and materials as well as removing waste. These networks ensure efficient and environmentally sustainable means of transportation to and from destinations, some of which may even occur in treacherous and inhospitable environments, in relative safety.

As long as these arteries provide a dependable service, ensuring management, employees, customers, suppliers, and partners have access to products and materials wherever and whenever required, the business runs smoothly and efficiently.

However, allow one of these pipelines to fail unexpectedly and the whole operation will at best be disadvantaged, at worst will be brought to a standstill. Such an event can not only paralyze the operation but can also extend beyond the operation itself and cause untold harm if the failed system is not rapidly brought under control. Since pipes often lie in treacherous, inhospitable and difficult-to-get-to environments, taking action to contain or repair failures can be difficult. Proactive awareness is the best solution leaving little to chance.

Asset Management

Asset management or condition inspections are routinely undertaken within clear limits developed partly with the service provision and partly by the need to continue operation unabated. External and internal inspections and testing is classically undertaken with human intervention, thus commonly limited to locations which can be accessed by technicians, in-pipe inspectors or divers. In some cases humans have been replaced with remotely operated vehicles (ROV) or pipeline inspection gauges (PIG). These tools provide a means of delivering the inspection technology to specific locations. Where they are fitted with video cameras actual CCTV footage can be obtained for visual assessment at any location filmed. However, getting inspection teams, ROV's or PIG's to desired locations can be difficult, time consuming and costly.

The result of these inspections, especially where they are in locations, not easily to get or not accessible, means that little or no information is collected and asset managers have to make do with what they get. It is also quite impractical to undertake the inspections from inside the network because that slows down or stops transport of the conveyed product for a set period of time resulting in a drop in revenue or loss of service. Left unchecked the pipe owner is potentially left with predictably damaging results.

BEM Technology Background

BEM technology falls under the umbrella group of devices commonly referred to as 'pulse EM' systems. This technique is derivative of geophysical equipment which has been used in the Australian exploration industry for more than 90 years and is therefore based on well-established physics principles. RSG's background knowledge of this technology and experience in its use in the exploration industry has allowed it to modify the technology for NDT inspections, suitable for acquiring detailed information about the current condition of surface or sub-surface pipelines as well as other infrastructure such as tanks and bridges.

It can be said that the fields of geophysics and non-destructive testing has merge. The point of commonality is the field of physics. At one end are geophysical techniques such as seismology, magnetics and electromagnetics while at the other end are non-destructive testing techniques such as ultrasonics, magnetic flux leakage and eddy currents. From a physics view point these techniques are based on the same principles.

Although it may seem at first glance that material testing and mineral exploration are worlds apart, the fact is that identical physics is used for exploration geophysics as for non-destructive testing (NDT).

- Seismology = Ultrasonics
- Magnetics = Magnetic Flux Leakage
- Electromagnetics = Eddy Current

Having used and evaluated many of the commercially available devices, which make use of the physics principles described above (UT, MFL, Eddy Currents), and identifying the short comings of each technique, RSG embarked on a process of developing its own technology some 25 years ago.

The development of this BEM was not the result of wanting to develop technology for the sake of it. It costs many millions of dollars to bring technology to the market so it is not something considered lightly. BEM was developed because existing and available techniques and devices could not give the level of detail and data confidence required for assessments of assets without misrepresentation or unacceptable commercial risk.

Many of the devices used as NDT are actually destructive because they have some level of impact on the pipeline. Hence to call these techniques NDT is really a misrepresentation. To not remove coatings or linings or to not 'polish' surfaces for good sensor contact means yielding low confidence data. Furthermore, acquiring data using frequency dependent devices in regions know to be 'infested' with stray fields, potentially altering recorded frequencies unexpectedly, give rise to recording of inaccurate results. These limitations added up to unacceptable commercial risk for RSG.

External Inspections

External pipe wall condition assessments are typically carried out on all types of ferrous pipelines to explore the integrity of the ferrous pipe wall. Tunnel wall inspections have also been undertaken with this technology. Pipe scanning is undertaken using HSK (Hand Scanning Kit) non-destructive testing (NDT) technique. Individual readings are taken along the surface of a pipe. With the aid of a temporary paper grid wrapped around the outside of the pipe allowing for accurate positioning of each reading taken. Following post survey data processing this allows a presentation of results

Advantages

- Scanning is not limited by the diameter of the pipe or shape of the pipe component (egelbow).
- The equipment has the ability to survey through thick coatings (25mm+/1"+) of materials such as paint, tar or concrete commonly found on many buried and exposed pipelines.
- The line does not have to be taken off-line, as readings are taken from the outside of the pipe. The technique scans through the full wall of the pipe registering corrosion or flaws within the full wall thickness.
- Negligible effect of outside stray current fields potentially contaminating resulting data.
- Where stray fields are identified – these can be clearly seen in captured data – variations in
- Data capture parameters are possible since the device is non-frequency dependent.

In-Line Inspections

Internal pipe wall condition assessments have been carried out on any diameter of pipe 2" upwards. Continuous data can be recorded along extensive lengths of pipeline. During in-pipe data acquisition the NDT probes are either winched, rodded or manually pushed (where pipe diameter allows manned entry) through the pipe. Due to the large volumes of data recorded as part of any scan, distances surveyed along smaller diameter pipes are typically 1,000's feet per day while in large diameters only 100's feet per day can be scanned. Data acquired is generally represented graphically or as color contour plots. The graph below is actual data collected along a series of cast iron pipe sections.

Advantages

- Ideal for extensive pipe surveys where the probe can be inserted into pipe hatches or cuts eliminating the need for extensive excavations or physical pipe sampling.
- Typically the pipe needs to be dewatered, cleaned and off-line for surveys.
- In special circumstances the PIG can be operated in full or partially filled non-pressurized pipelines eliminating the need for total dewatering of the pipeline.
- Can survey through all known internal linings including thick layers of cement.
- Can survey through thick and uneven tuberculation in water pipes.
- Probes can be customized to fit a variety of pipe diameters starting as small as 2".

The Interactive Pipe

The scale of operations, length of pipeline networks and breadth of environments the networks are expected to operate in, make traditional inspection costly and often haphazard.

Equipping pipes with a means of being able to interact directly with their asset manager has the potential of reducing the need for arbitrary inspections or inspections in hostile environments while at the same time allowing inspections in places previously inaccessible. Smart computing will allow asset managers to be virtually everywhere along the network, virtually all the time.

Benefits of an Interactive Pipe

To anyone who's gone out to assess a pipeline, or tried to located that elusive corrosion location with a 10mm probe head and miles of pipe to inspect or has attempted to organize the inspection locations into a week's program, the benefits of pipes that continuously report their state will be apparent.

Sensor Installation

Antennae consist of sensors which emit or receive signal responses. These sensor are little more than coils of wire housed in a plastic casing. The size of the sensor can be altered depending on the size of the target or the pipe under inspection but essentially the antennae wrap around the outside of the pipe and can be permanently bonded to the pipe. There is no need to remove or damage the pipe coating and the antennae can be fitted to new pipes or existing pipes can be retrofitted.

Pipe Access

Unlike routine inspections, access to the pipe at any location is required only once at the time of initial installation. The pipe can then be submersed, buried, insulated, elevated high overhead, basically located anywhere without the need for further access. Installation can occur prior to pipe placement or laying where the pipe is new or a new section of pipe is being considered. If retrofitting is considered then one-off access to the desired location is required by manned access, divers, via excavations or when the pipe cladding is removed. At no time does the pipe need to be off-line so installation has little if any impact on service.

Full Circumferential Scanning

By strapping or attaching the antennae about the full circumference of the pipe information can be obtained for the entire circumference at each scan period. The positioning of the antenna ensures 100% surface coverage of the pipe section with BEM sensors. Data is available for the entire pipe for the section scanned.

Scanning Through Coatings

Since BEM is a truly non-destructive and non-invasive technique and does not require the metallic surface to be prepared or exposed in any way to allow for scanning, the technique is ideal for scanning through protective coatings. Even where the pipe is being retrofitted and surface corrosion products exist there is no need to remove these to allow for inspection by BEM signal. In many cases the removal of surface corrosion products can actually be detrimental to the pipe health because its removal exposes new fresh metallic surfaces to attack. Simply pick your location, undertake a superficial surface clean and the pipe is ready to start reporting on its state of health.

Frequency of Scanning

The frequency of scanning at any one location is driven by the asset manager who programs the activation software as desired. Corrosion, abrasion or alteration of pipe walls is a relatively slow process compared to the potential scanning frequency so it is reasonable to expect many hundreds or even thousands of scans to occur before pipe changes are recorded. However, because the scan is activated by the scanning software, emission and reception of the data is done by the permanently installed antennae, data is recorded automatically to a central PC by recording software, analysis software undertakes the basic analysis of the data and the system can issue regular plots and reports, the scanning frequency can be virtually continuous with the pipe reporting its condition somewhere along the pipe length all the time.

BEM Signal Emission & Reception

When it is time for the pipe to report its condition, the driving software MetCon©, which resides on the central PC, will issue a command to the electronics to send a pulse to the transmitter in a specific antenna. The transmitter emits the signal which 'energizes' the pipe wall under inspection (underneath the transmitter foot print). In a number of milliseconds the receiver, also housed in the specific antenna, responds to the emitted signal and sends the received signal back to the electronics where the data is digitized and send over 10's, 100's or even 1,000's of feet of cable to the central PC to be recorded and stored. This is all run and managed with the aid of MetCon©.

Data Processing & Analysis

When MetCon© receives and stores the recorded data on the central PC it proceeds to make a 'handshake' with MetProc©, the processing software. During this 'handshake' the recorded data is passed over for processing. MetProc© processes and analyses the captured data against imbedded databases of known and recorded samples of the pipe material.

Data Plotting, Reporting & Management

The processed and analysed data is now ready to be reported on. This is achieved by a 'handshake' between MetProc© and the plotting and reporting software MetPlot©. When the processed and analyzed data is received, MetProc© can provide the data in a number of graphical plots or models. These can either be made available to the asset manager or archived and MetPlot© can be programmed to sound the alarm when the recoded, processed, analyzed and modelled BEM response approaches or reaches a predetermined level or value.

Accessible 24/7 from Anywhere

The Pipe Awareness System is fully integrated and automated allowing the use of BEM technology to scan pipeline infrastructure anywhere at any time without the need for human intervention. The associated MetCon©, MetProc© and MetPlot© software activate the scanning process, record and process the captured data or analyze and report the results. All of this is done remote of the location where the scanning is taking place. The central PC can communicate the results via a cloud-based application that's accessible at any time, from any Web browser. You can instantly view the results and share them with colleagues, customers, suppliers, and partners. You can monitor pipe condition in real time on your smartphone or tablet, even if you're halfway around the world from the inspection site.

Scalable

Whether you are looking to monitor a 6" or 60" ferrous pipe, the empirical components of the system can be scaled to suit. No matter how many pipes of varying diameters you have, the

BEM system can be scaled up or down to meet your requirements. There's no limit to the number of antennae you can connect together at any location.

Conclusion & Summary

In order to meet today's demands for non-destructive, accurate, cost-effective methods of evaluation, a clear understanding of a broad range of NDT methodologies is essential to allow one to take advantage of what the technologies offer. Using existing, modified and new techniques, such as BEM, an appropriate and cost-effective assessment program can be designed to suit a range of under and above-ground pipes, conduits, tunnels, and other structures. BEM is now commonly applied to studying and assessing ferrous water main supply pipes, sewers and gas lines. It can be used in both surface, and in-pipe systems. One of the main benefits provided by this technique is its ability to survey *through* ferrous pipe external coatings or internal linings. To date, successful surveys have been conducted through coatings in excess of 4" thick.

Recent enhancements to the BEM technologies have also increased their sensitivity. New probe configurations for medium-large diameter pipes are becoming available as the inventory of probe increases allowing for detailed in-pipe inspections and the possibility to construct a project specific probe is there. A need to understand the condition of extensive pipeline assets at any given moment can be met by a BEM system having the attributes to allow for this. With years of global application in pipeline inspections this tested technique is now supported with software allowing for the scanning and data collection, processing, analysis and reporting of any pipe anywhere at any time.

It is now possible to equip a critical network with an inspection capability for pipelines to virtually report their bill of health, regardless of whether the asset owner or manager is on site or on the opposite side of the world. The time for 'THE INTERACTIVE PIPE' is here.

Paper No. 6

Pipe Condition and Earthquake Damage The Information That Is Not Currently Recorded

J R Black, Technical Principal, Pipeline Materials
Opus International Consultants Ltd, Christchurch New Zealand
Email: John.r.black@opus.co.nz

Refer to Appendix A, Page A-54, for a copy of presentation

6. Pipe Condition and Earthquake Damage The Information That Is Not Currently Recorded

J R Black, Technical Principal, Pipeline Materials, Opus International Consultants Ltd, Christchurch, New Zealand
Email: John.r.black@opus.co.nz

Introduction

In the aftermath of any major earthquake event, there is immense pressure on utilities and their operators to make repairs and to get systems working again. At these times, pipe failure repairs are undertaken by multitudes of contractors, many totally unfamiliar with the normal procedures and record keeping. In the haste to make essential repairs and restore service, some unique opportunities to investigate pipe condition, cause of failure and failure modes can be lost. Also, little (if any) information is recorded, especially during the initial response phase.

The damaged pipes are loaded directly on trucks and consigned to landfill or they are stockpiled in random heaps for disposal. By then, it is usually too late to identify where they came from and impossible to tell what is earthquake damage and what is damage caused by excavation and repair works.

There is much valuable information on failure modes and cause of failure that can be gained from even a brief, informed examination of the failure as it is exposed and repairs are made. Photographic records of failures is generally poor and many photographs that are taken are out-of-focus and under-exposed.

This writer’s opinion is that that with only minimal additional cost, a significant amount of valuable information could be recorded that could lead to improved designs and better selection of pipe materials and jointing systems. How this information can best be recorded appropriately is a subject for further research.

Detailed Examination of Failed Pipes & Fittings

Only a few Christchurch earthquake damaged pipes and fittings failures were examined and investigated in reasonable detail by the writer and no others carried out any of this work. The examinations that were undertaken showed that there were other significant contributing factors that resulted in failure, aside from the direct earthquake effects. These examinations also highlighted that many of the pipe failures that occurred could have been easily prevented and the amount of earthquake damage minimised.

These other factors include:

- The pipes were of poor quality and probably should never have escaped the manufacturer’s quality assurance checking,
- The pipes have been poorly installed,
- The design did not have sufficient flexibility and allowance for differential movement.

Poor Installation

Pipeline Inventory Records

When checking the details of failed pipelines in the GIS system (e.g. year installed, pipe material and recorded diameter), a number of anomalies were found which indicate a need to check and verify the GIS data. Even well managed networks can have significant numbers of anomalies in their asset records.

Earthquake response and recovery repair works provide a unique opportunity to gather information on large tracts of the piped networks over a relatively short period of time. Provided the repair data is complete, reliable and consistently recorded, the information can be used to confirm and/or revise the records.

All utilities have their own standard systems and forms, be they paper copy or in electronic format. The prime goal is to keep them simple and to minimize the amount of unnecessary data generated. Sometimes essential data is not recognized on the paper forms or when using electronic data capture, there may be insufficient fields for the range of information needed for out-of-the-ordinary issues.

It is not uncommon to find in pipeline inventory records that similar pipe materials are identified in many different ways. As an example, polyethylene pipes in New Zealand can be called up in GIS systems as any of the following; PE, HDPE, Alkathene, polythene, poly pipe, PE 80, PE 100. Sometimes these descriptors are "correct" (e.g. Alkathene [LDPE], PE 80 and PE 100) but more often than not, they are just different generic descriptors that have been used for PE pipe. Similar issues also exist for most of the other common pipe materials.

Therefore, an essential first step in rationalizing record keeping is to standardize on materials identification and making sure that staff have the training necessary to reliably record the information.

Pipe material identification can also be a source of problems. It is frequently assumed that it is easy to distinguish between the different pipe materials. Nothing could be further from the truth for many pipe types. Without appropriate training and experience it is easy to get-it-wrong and even experienced maintenance operators do not know the difference between some of the trickier pipe materials.

Some General Observations and Comments

Based on over 40 years of experience with piped network design, operation, maintenance, condition assessment and cause of failure investigations, it is the writer's opinion that:

- Field record forms are usually inadequate for dealing with anything that is out-of-the-ordinary and earthquake response and recovery work certainly falls into this category.
- When it comes to recording pipe failures (be they routine maintenance or emergency repairs) there is rarely a process in place to adequately record what happened or guidelines for retaining samples for future examination.
- Photographs of sufficient quality of the failed pipe or fitting are seldom taken.

- It is usually assumed that maintenance personnel fully understand all of the pipe materials in the networks they are maintaining and that they will make the right decisions without fail.
- Maintenance operators are usually under-valued and under-trained.
- There is an industry need (world-wide) to train key maintenance personnel in these areas:
    - Ways to reliably identify pipe materials,
    - How to record information gained from repair works,
    - Basic condition assessment principles, ,
    - How to decide when to take samples for expert examination,
    - How to package such samples for safe transit (if they need to be forwarded for assessment).

Research Needs

Improvements to processes for recording pipe failures can usually be made in even the "best" utility systems. A research program, carried out jointly with utilities asset management and maintenance personnel, would help to improve data capture as well as improving preparedness for the next earthquake emergency. The training needs for maintenance personnel (including the need for "refresher" coursed to keep up to date with new pipe materials and equipment) should also be considered.

The outcomes of this research would also benefit day-to-day operations and could be used to provide information for reliably updating and correcting asset inventory records as well as providing valuable resource material for future research.

Some of the aspects that the research could address include:

- Checking of asset inventories for reliability and consistency (by interrogating and challenging existing records).
- Rationalization of pipe descriptions in the inventory (eliminate multiple names for the same material).
- Confirmation of pipeline install dates (sometimes a default date is used in data entry and is rarely corrected).
- What information should be recorded by maintenance personnel? (Remember to keep it simple, so don't record unnecessary data).
- How should it be recorded? (Paper copy or electronic format).
- How much checking is necessary before changes to asset inventories should be made?
- How to set up appropriate systems to change incorrect records? (Consider who owns the data and who can make changes).
- Determine if maintenance personnel need additional training.
- Find out if suitable training courses are available and if not, it may be necessary to start your own using suitably experienced and qualified experts who understand all of the pipe materials.
- Identify who should be trained (e.g. leading hand, foreman, or overseer?)

Conclusions

By implementing the outcomes from such a research and improvement program, utilities should be able to keep better records of the next emergency. The knowledge available from better record keeping will also be useful for future earthquake damage research. Serious consideration should also be given to identifying appropriately experienced pipe experts (pipe whisperers) that can be used during the response and recovery phases to assist with the assessment of pipe condition and cause of failure.

Paper No. 7

Pipeline crisis: Why Research Matters

Neil S. Grigg, Professor, Department of Civil and Environmental Engineering
Colorado State University, Fort Collins, CO 80523
Email: neilg@engr.colostate.edu

Refer to Appendix A, Page A-67, for a copy of presentation

7. Pipeline crisis: Why Research Matters

Neil S. Grigg, Professor, Department of Civil and Environmental Engineering
Colorado State University, Fort Collins, CO 80523
Email: neilg@engr.colostate.edu

A crisis in pipelines?

If a crisis is a crucial situation or a turning point, then the slow-changing condition of pipelines may not qualify as one, but the term "creeping crisis" might apply because, if nothing is done to improve the overall condition of pipelines, the consequences will be significant. What would these consequences be? Increasing water main breaks, sewer failures, gas main explosions, and bursts in oil pipelines are a few examples. If you add up the potential consequences of inaction, the condition of pipelines is seen as needing attention to avoid undue risk to the public and environment and a buildup of financial commitments for future generations.

Whose job is it to fix this problem? Should it be by federal action, both by appropriations and regulations? Should it be local responsibility? What role should industry play? As in other infrastructure issues, it is really "all of the above" because the pipeline industry has many parts and scenarios.

Will research be useful to resolve the problem?

It will take a lot of money to make progress on this issue, but can research help as well? Some may argue that pipeline issues involve mainly practical problems and don't require research as much as they do good and skillful work. Others will say that pipelines are increasingly high tech and high risk, and that research is needed to push the envelope. Both answers will be correct, and therein is the riddle of pipeline research.

Pipeline research is like that in other fields which require complex equipment to meet multiple needs and requires attention to technology, management, materials, equipment, scenarios, rules and procedures, and risks. A few examples of these fields include medical research to develop tools and methods, product development and marketing, transportation systems to improve mobility, and social research to strengthen families. In all cases, the key issue is *integration* of discoveries and practice. It is really just an extension of the maxim that it is easy to develop ideas, but the hard part is putting them into practice and making a profit at it.

This also raises the question of whether pipeline research is basic or applied, comprises research *and* development, and is adequate along the spectrum of research-to-practice? To make research management adequate, what is the best model? Should it be government research? After all, the technology for the Internet was developed this way? Should it be academic research? Should it be industry cooperative research, as for example the WaterRF, WERF, or EPRI?

It is difficult to answer that question because pipeline research involves multiple players, including federal agencies, water and gas and oil associations, vendors who develop products and services, and consultants who seek improved tools to apply to client work, among others.

Trends in the organization of industry cooperative research

People have always studied problems to find solutions and better methods. The experiments of Benjamin Franklin and Thomas Edison with electricity should be known to every school child. However, as increasingly-complex technological problems emerged, it became clear that new approaches to the organization of research were required. One of these was the creation of the National Science Foundation, which followed World War II development of advanced weapons systems. Vannevar Bush's book *Science, the Endless Frontier* tells this story.

As a result of WWII research, the nation started to seek organized research approaches to other problems, such as in the Water Resources Research Act of 1964, which created a new intergovernmental research program. In that same decade, AWWA initiated its research foundation, now named the WaterRF, and the electric power industry was soon to launch EPRI, in 1973. EPA was created from existing programs in 1970, and its research program grew to embrace multiple media and regulatory missions. WERF came in 1989 to address water quality and related issues. The Gas Technology Institute was created by merger of the GRI, created in 1976, and the Institute of Gas Technology, which had been created in 1941. PHMSA was created in 2004. Clearly, these cooperative research programs, ventures and partnerships are continuing to emerge. What will be next? What kind of payoffs come from this approach to research?

It is difficult to pinpoint major advances, but areas of work familiar to me are asset management, causes of pipe breaks, corrosion mechanisms, surveys and inquiries about pipeline issues, tools for condition assessment, accounting methods for water losses, management frameworks, like "knowledge management," and BMPs, such as distribution systems optimization. While most of these involve synthesis of work, rather than fundamental new advances, they create knowledge and make it available to the pipeline community.

Is the knowledge useful? Some allege that researchers don't care about usefulness, and are unconcerned with messy details. The researchers might complain that practitioners ignore research and refuse to implement reforms, but the practitioners might counter by deriding the research as ivy tower. Is it a fundamental problem, or simply a misunderstanding? Given the divergent incentives of researchers and practitioners, the conclusion seems to be that it is fundamental and that research-practice gaps will be difficult, but important, to overcome. Of course, there are always technology agents, who see both the need for research and for its application.

Another important issue in cooperative industry research is competition. How do you juggle the tension between shared knowledge to advance the public interest and proprietary knowledge to advance the profit motive?

What to do?

If pipeline research can make a difference in mitigating problems and avoiding consequences, what should be done? Obviously, it depends on which industry and which role to play. In the case of the water industry, we see slow change but high stakes in public health and deferred maintenance. In oil and gas, we see aging infrastructure, environmental conflicts, and increasing networks of pipelines that track today's energy boom.

Depending on who you are, you must first determine the boundary conditions of the problems you address. As a researcher, mine are defined by areas where I might succeed in research. If you are a research organization, then the boundary conditions are formed by your industry and its major issues. In any case, we must identify problems clearly to find solutions.

Should we try to make it happen or let it happen? Whose job is it to figure that out? In any case, we must make a business case for our research programs by identifying the important problems, recruiting industry advocates, getting good researchers, and planning research-to-practice transitions.

Rather than a cost-benefit calculation, it will be success stories that carry the day. Champions are needed, like Harry Hopkins, who headed up FDR's WPA program. It is the job of research organizations to bridge the gaps and organize the advocacy.

At the end of the day, research matters because society depends on technology advancement. Pipeline work is a shared inter-industry activity for both profit and public good. It deals with many subjects, synthesis and basic work. It should be innovative but practical. To succeed we should foster cooperation and work through the challenges. It is important work and worth doing.

Paper No. 8

Integrity Management in Piping Infrastructure Systems

Ernest Lever, R&D Director, Infrastructure
Gas Technology Institute, Des Plaines, IL 60018
Email: Ernest.Lever@gastechnology.org

Refer to Appendix A, Page A-81, for a copy of presentation

8. Integrity Management in Piping Infrastructure Systems

Ernest Lever, R&D Director, Infrastructure
Gas Technology Institute, Des Plaines, IL 60018
Email: Ernest.Lever@gastechnology.org

GTI is the leading research, development and training organization addressing energy and environmental challenges to enable a secure, abundant, and affordable energy future. For more than 70 years, GTI has been providing added value to the natural gas industry and energy (nuclear water pipes) markets by developing technology-based solutions.

General

- GTI and its predecessor research institutes have been serving the gas market since 1941
- GTI commercialized over 500 products, provided over 750 licenses and produced over 1,200 patents

GTI Structure

- GTI research program is aligned with the industry's value chain from exploration to delivery infrastructure
- GTI has trained and certified over 60,000 energy professionals in gas distribution and transmission and in ASME nuclear water piping systems and others
- GTI has about 250 employees with 60% scientist and engineers and 44% with advanced degrees

GTI Focus on Piping Infrastructure and Integrity Management

- GTI customers include local distribution companies and the government agencies that regulate the activities of gas and nuclear water utilities.
- GTI has developed a full understanding of the performance characteristics of steels and plastics in:
    - Oil and gas gathering lines
    - Oil and gas transmission lines
    - Processed water lines
    - Gas distribution lines
    - Water lines in conventional and nuclear power plants.
- GTI continues to develop integrity management and risk assessment systems for all the above applications.

GTI Expertise in Polyethylene

- As early as 1952, GTI performed research on plastic pipe and on metal pipe for utility use.
- GTI published 237 reports and software packages on plastic pipe use in gas distribution systems (1997-2005).
- GTI was among the early drivers of advancement in polyethylene science along with Osaka Gas, Tokyo Gas, British Gas and Gaz de France.
- The gas industry focus on public safety and in-field failure modes of polyethylene lead to millions of dollars being channeled to research projects carried out by the above listed organizations.

- GTI research programs led to the full understanding of the behavior of Polyethylene materials and led to the continuous improvement and understanding of its material properties.
- Key to this understanding was the understanding of the Slow Crack Growth (SCG) failure mechanism and the development of the PENT test to quantify a polyethylene material's SCG resistance, all carried out under GTI research projects.
- All of the polyethylene knowledge developed by the gas industry has made its way into potable water applications through ASTM, ASME, ISO and AWWA standards.

Current State-of-the-art in Gas Piping Integrity Management

- Focus research programs on developing detailed understanding of the causal mechanisms in system failure
  - Basic scientific research to understand the physics and chemistry
  - Intelligent use of existing data
  - Develop probabilistic models for each failure mechanism
- Define the correct datasets needed to properly determine the likelihood of failure in the piping system

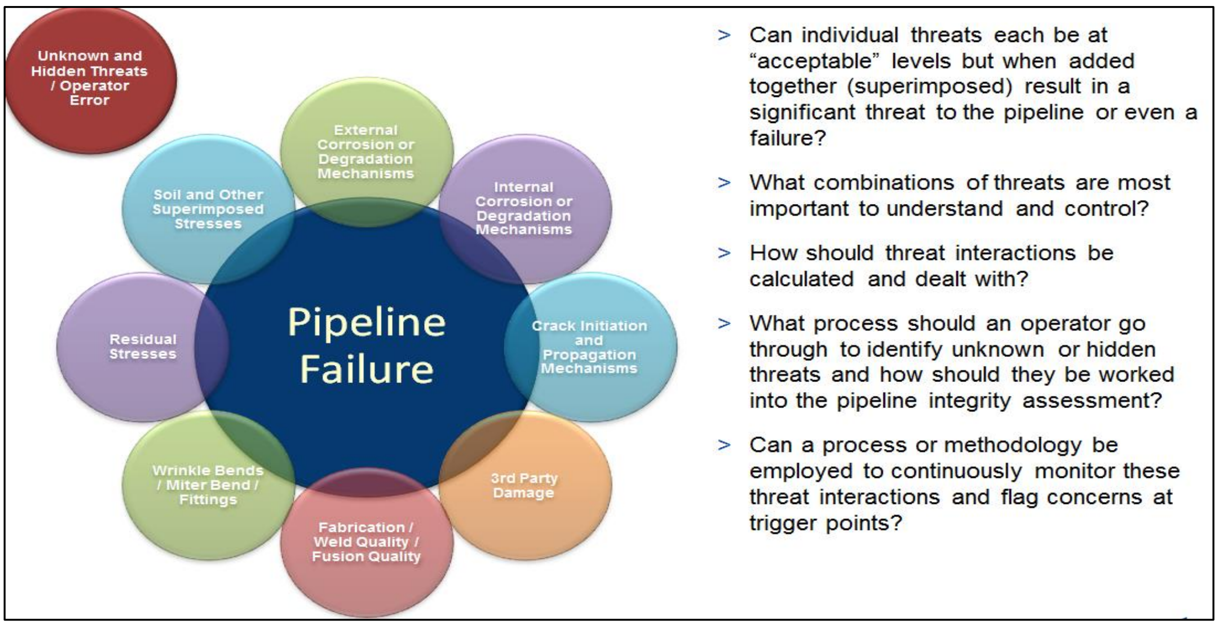


Figure 8.1. Datasets Needed to Properly Determine the Likelihood of Failure in the Piping System

- Rigorously address threat interactions
  - Develop proper calculus to properly combine multiple threat mechanisms acting simultaneously

– Combine consequences of failure with likelihood of failure to determine the risk associated with each section of the system

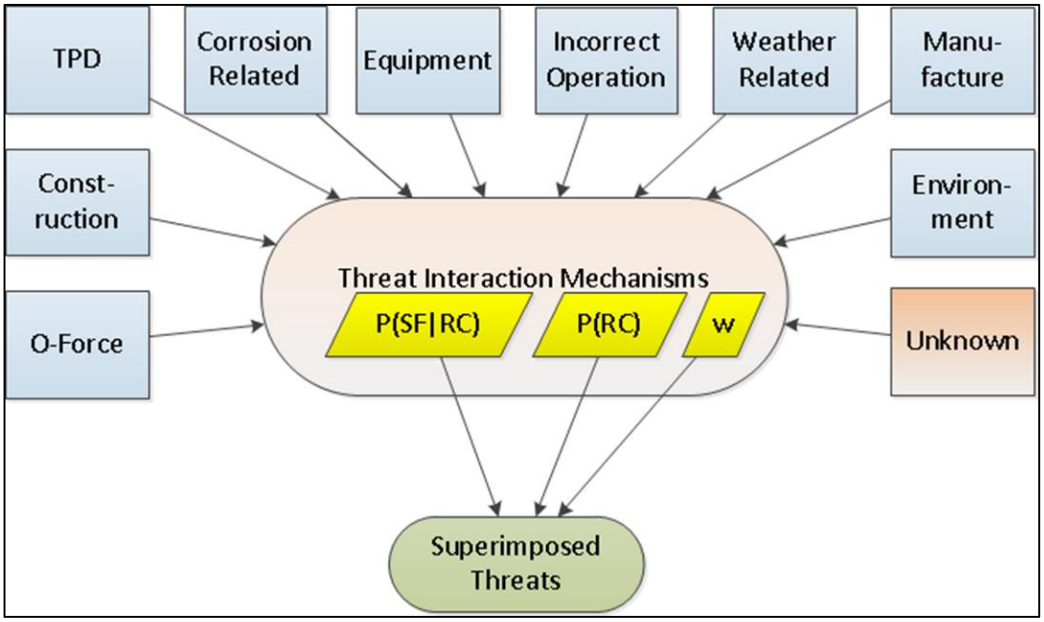


Figure 8.2. Threat Interaction Mechanisms

– Run scenario analysis to determine the most effective risk management strategy

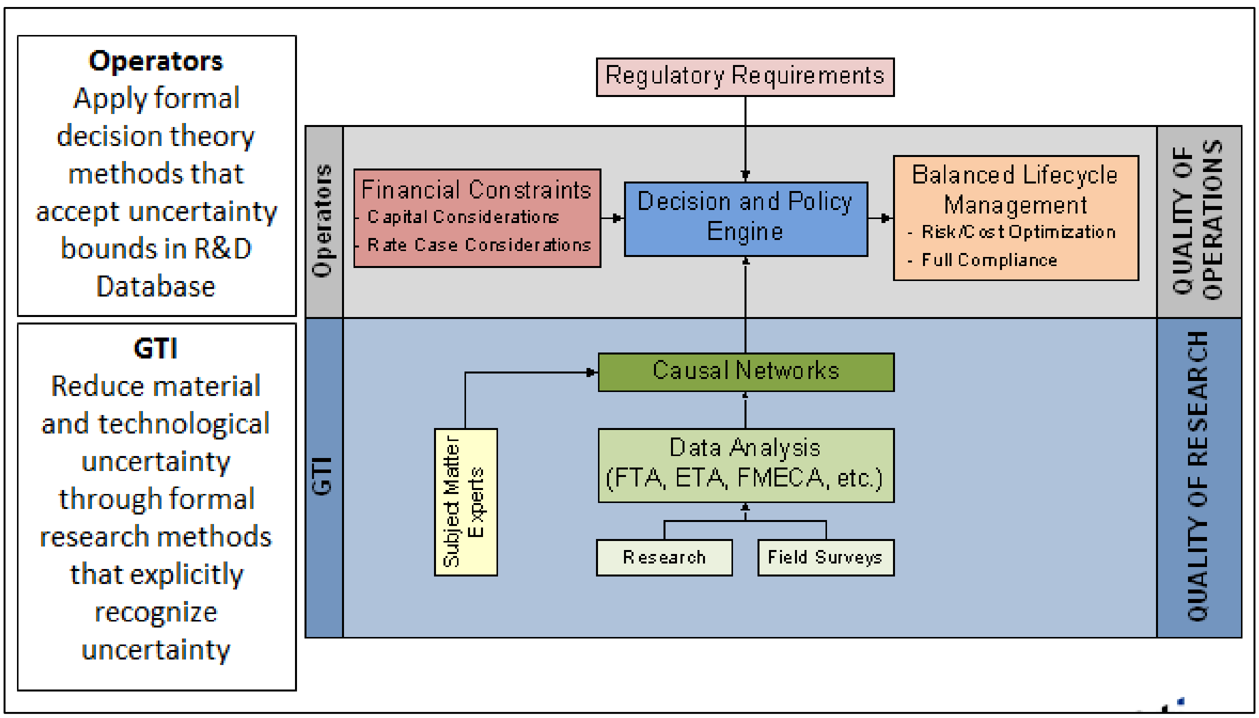


Figure 8.3. Scenario Analysis to Determine the Most Effective Risk Management Strategy

Conclusions

- Balanced lifecycle management demands a full understanding of risk inherent in the system.
- Uncertainty needs to be explicitly addressed.
- Proper data needs to be collected.
- Intelligent probabilistic models are needed to support decision making processes in complex piping systems subject to multiple threats, constraints and sometimes conflicting objectives.

Paper No. 9

Pipeline Research Needs: Material Properties and Operational Surge in Pipeline Failures

Graham E.C. Bell, PhD, PE, HDR|Schiff, 431 W. Baseline Rd,
Claremont, CA 91711
Email: Graham.Bell@hdrinc.com

Refer to Appendix A, Page A-91, for a copy of presentation

9. Pipeline Research Needs: Material Properties and Operational Surge in Pipeline Failures

Graham E.C. Bell, PhD, PE, HDR|Schiff, 431 W. Baseline Rd,
Claremont, CA 91711
Email: Graham.Bell@hdrinc.com

Abstract

The forensics and investigations of pipe breaks focuses on strength of materials. Pipe breaks or failures have more to do with fracture mechanics and loading than is generally recognized in the industry. Pipeline design focuses on strength of materials and forensics assumes that material strength is a good predictor of material failure. This paper highlights the need to research and understand pipe materials, fracture mechanics and surge loading in order to understand and ultimately prevent pipeline breaks and failures.

Pipe Failures/Breaks and Material Properties

Pipelines leak, blowout, or catastrophically fail when the mechanical/structural demands of the system exceed the mechanical/structural capacity of the pipeline at the time when the leak or blowout occurs. When a pipeline is new, catastrophic failures are not common because design practices use known design conditions along with engineering safety factors to insure that capacity exceeds demand when the pipeline is fabricated and installed. By definition, prior to the failure, the capacity always exceeded demand. Over time, both demand and capacity change. Damage to the pipeline during installation, operation, and interaction with the internal and external environments accumulates over time and reduces pipe capacity. Damage accumulation as a function of time reduces capacity of the system.

Demand generally increases with community development and time. We demand more of our aging pipes and infrastructure as the age. Capacity decreases as material properties and condition deteriorate due to environmental and operational degradation mechanisms. For example, from the soil environment, corrosion removes sound metal and reduces the mechanical/structural capacity of the pipeline where the corrosion occurs. From the operation standpoint (depending on the pipe material), pressure transients, spikes, or surges can result in damage accumulation and reduction of mechanical/structural capacity.

Many engineers make the assumption that material strength relates to pipeline failure or breaks. Strength of materials is useful for design purposes, but not necessarily to predict failure. In design, the "material strength" of a material is reduced by the factor safety to give the design allowable stress. The assumption is that the factor of safety contains sufficient margin to prevent failure of the system during its lifetime. However, the time dependent failure of pipes is due to the non-uniform accumulation of damage which reduces the local capacity of the pipe. Whether loss of local capacity results in eventual failure is determined by the fracture mechanics and the properties of the pipe material.

Fracture mechanics is the field of mechanics concerned with the study of the propagation of cracks in materials. It uses methods of analytical solid mechanics to calculate the driving force on a crack and those of experimental solid mechanics to characterize the material's resistance to fracture and failure.

Fracture mechanics was developed during World War I to explain the failure of brittle materials. Experiments on glass fibers suggested that the fracture stress increases as the fiber diameter decreases. Hence the uniaxial tensile strength, which had been used extensively to predict material failure, could not be a specimen-independent material property. A.A. Griffith suggested that the low fracture strength observed in experiments, as well as the size-dependence of strength, was due to the presence of microscopic flaws in the bulk material.

Cast iron (CI) is a brittle material. Cl is a more brittle material compared to steel or ductile-iron pipe materials. Brittle materials are not necessarily “weak” or lacking in strength. That is to say that when uniaxial tension is applied in a uniform fashion, the stress required to failure the material is not necessarily small by comparison to other materials. However, the amount of energy (force times displacement) required is much less than other more ductile/less brittle materials. There are two primary types of breaks that occur on CI pipe, so called beam or “circular” breaks and longitudinal splits or breaks. The type and morphology of each type of break is consistent with the loading and brittle failure characteristics of the material. Fundamentally, cracks propagate perpendicular to the applied stress. For a circular break, the applied stress is vertical (beam loading) and the crack will propagate circumferentially around the pipe creating a circular profile.

For steel pipe, the material properties are such that beam breaks are much less likely, since the thin and flexible steel pipe wall tends to locally buckle (rather than cause a circumferential crack to form and propagate). When steel pipe loses vertical support, the pipe defects from a circle to an oval and then eventually locally buckles and may “pull away” from rivets or push on type joints. In general, steel pipes do not suffer from circular beam breaks.

Longitudinal splits or breaks are the result of internal radial pressure resulting in longitudinal crack growth from an initiating flaw location. For cast iron, as for any brittle material, a critical flaw or initiation site is needed along with corresponding stress intensity. Internal pressure generates radial stresses, which once above the critical stress intensity cause longitudinal crack growth. Flaws are initially due to casting imperfections which do not change over time. Corrosion is not uniform and external corrosion flaw sizes increase over time and eventually reach critical flaw size and limit pipe life.

The same general morphology of longitudinal splits applies to steel pipe breaks. In general, thinning of the steel usually due to external or internal corrosion creates an initial flaw. Internal pressure provides radial stress that propagates along the longitudinal crack. However, steel is usually not a brittle material so the crack propagates a short distance and then runs out of energy. The process is repeated over time until stresses build up locally or, due to operations or surges, allow further propagation and eventual failure.

Although some research has been done on fracture mechanics and tolerance of pipe line materials (Ivanova, 1978; Habibian, 1994; Atkinson et al., 2002), more is need to relate the microscopic material conditions to the macroscopic behavior observed as individual leaks and patterns of breaks in systems (Agbenowosi, 2000; Andreou, 1986; Bardet, et al., 2010).

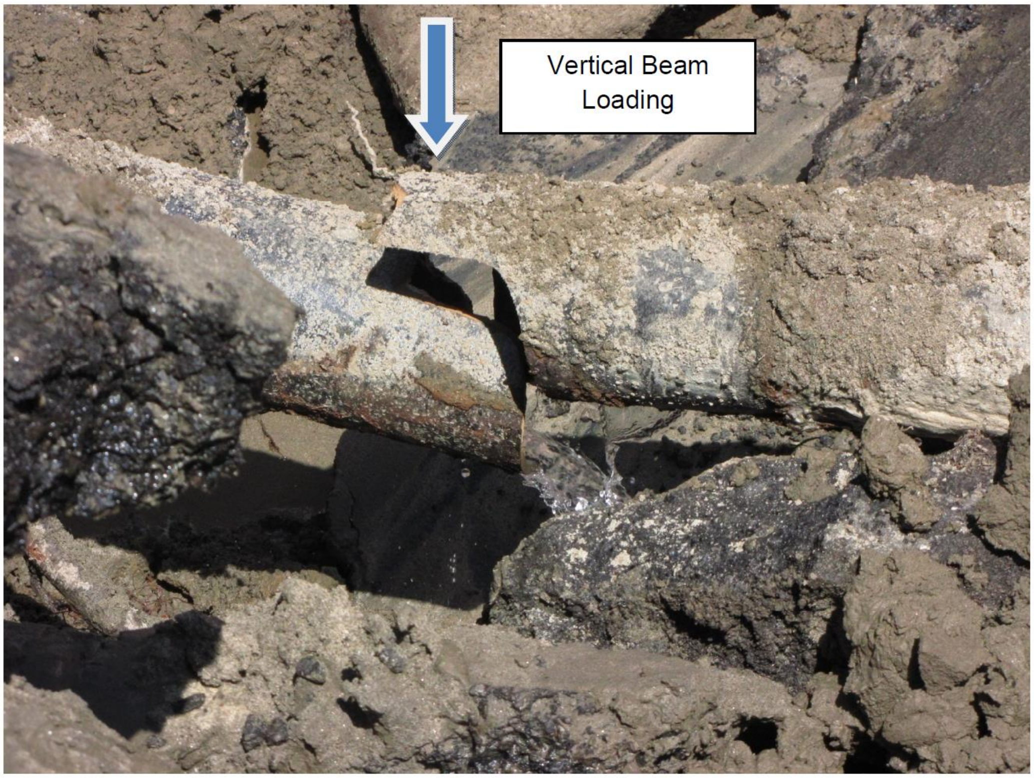


Figure 9.1. Vertical Loading and Loss of Pipe Support Leads to Circular or Circumferential Break in Cast Iron Pipe

Surge and Pipe Failures

Similar to the assumption that material strength is sufficient to understand failures there is a general belief that pressures and loads inside and outside of pipes are constant and that surge is an aberration. Typical water industry instrumentation has insufficient temporal response to accurately record surge events. Within the last 10 years, rapid response transient pressure monitoring systems have been developed to give pipeline operators detailed information about transient pressures within a pipeline. Allowing operational impacts to be noted and could be used in conjunction with other pipeline monitoring systems to prevent accumulation of pipeline damage (Stroeble et al., 2010). Research, development and implementation of these monitoring technologies may be our best program for understanding and ultimately mitigating pipeline breaks and failures.

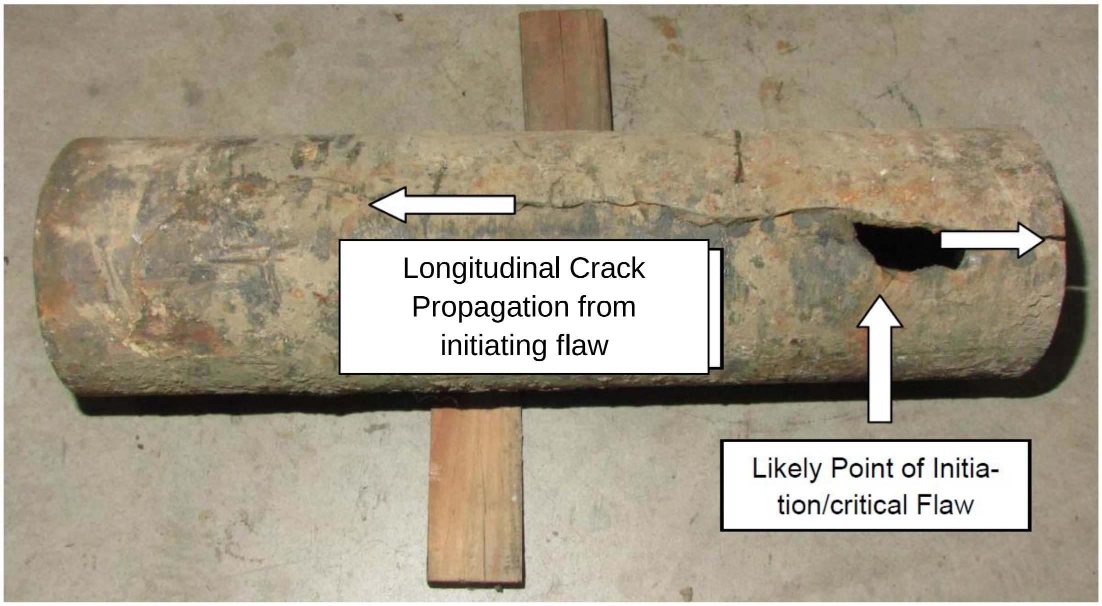


Figure 9.2. Internal Pressure Increase and/or Surge Leads to Longitudinal Crack Propagation from Corrosion Flaw in Cast Iron Pipe

Figure 9.3. Longitudinal Split of Rivet Steel Pipe

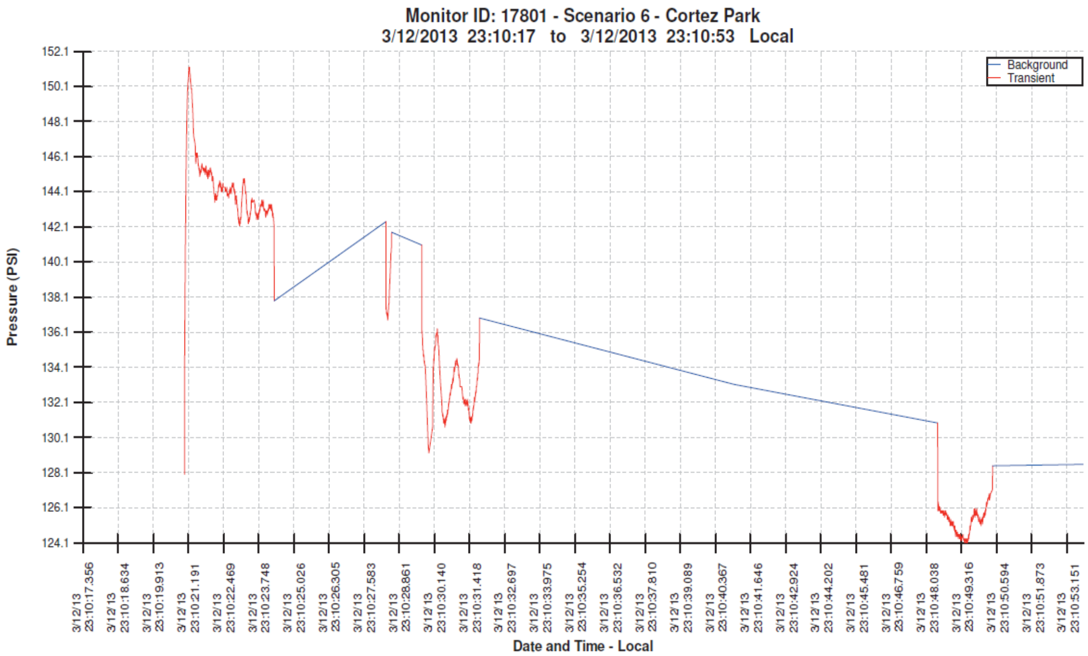


Figure 9.4. Surge Events due to Valve Closing on Prestressed Concrete Cylinder Pipe

References

Agbenowosi, N. 2000. "Mechanist Analysis Based on Descision Support System for Scheduling Optimal Pipeline Replacement," *Ph.D. Dissertation, Virginia Polytechnic Institute and State Univeristy*. Blacksburg, VA.

Andreou, S.A., D.H. Marks and R.M. Clark, 1986. "Predictive models for pipe break failures and their implications on maintenance planning strategies for deteriorating water distribution systems," *Ph.D. Dissertation. Massachusetts Institute of Technolog*y. Cambridge, MA.

Atkinson, K., J.T. Whiter, P.A. Smith and M. Mulheron. 2002. "Failure of Small Diameter Cast Iron Pipes," Urban Water, 4, p. 263.

Bardet J.P., D. Ballantyne, G. Bell, A. Donnellan, S. Foster, T. Fu, S. Foster, J. List, R. G. Little, S. Palmer, and T. D. O'Rourke, 2010. "Expert Review of Water System Buried Pipe Breaks in the City of Los Angeles." *USC Center on Megacities,Sonny Astani Department of Civil and Environmental Engineering Viterbi School of Engineering,* University of Southern California.

Habibian, A. 1994. "Effects of temperature on water main breaks," *ASCE Journal of Transportation Engineering*, Vol. 120, No. 2, pp. 312-321.
Ivanova, N.G. 1978. "Resistance to Fracture of Gray Cast Iron Pipe," *Metallovenenie I Termischeskaya Obrabotka Metallov*, No. 7, pp. 25-28.

Stroeble, A., G.E.C. Bell, and P. Paulson. 2010. "PCCP Damage During Depressurization/Pressurization Cycles," Proceedings of ASCE Pipelines Conference, Keystone, CO.

Paper No. 10

Staged Construction Modeling of a Large Diameter Steel Pipe Using 3-D Nonlinear Finite Element Analysis

Ali Abolmaali, Mojtaba Salehi Dezfooli, Mohammad Razavi

Author did not submit the paper

Refer to Appendix A, Page A-100, for a copy of presentation

10. Staged Construction Modeling of a Large Diameter Steel Pipe Using 3-D Nonlinear Finite Element Analysis

Ali Abolmaali, Mojtaba Salehi Dezfooli and Mohammad Razavi
The University of Texas at Arlington, TX, 76019
Email: abolmaali@uta.edu

Studying the pipe behavior during backfilling is one of the priorities before designing and installing pipelines. Design limitations are introduced by American Water Works Association (AWWA) for flexible and rigid pipes. These limitations are for both service and ultimate designs. Several backfill and embedment material are used in different conditions. Estimating pipe behavior in different backfill conditions during installation is an essential task to accomplish.

This study, in general, targets prediction of the performance of a steel pipe during backfilling and after the installation, using developed Finite Element Analysis model. Thus far, the results of developed FEM model for different trench condition show that the FEM model can predict the behavior of the steel pipe in field test.

Several steel pipes were instrumented and installed in soil box (rigid trench) to evaluate the pipe behavior. Then the FEM model was developed using the data obtained from soil box tests. The FEM analysis algorithm considered material, geometric, and contact nonlinearities. The material non-linearity consisted of elasto-plastic constitutive law for steel. The geometric non-linearity included the large deformation analysis for soil and steel pipe materials. Finally, the contact nonlinearity included the contact elements used at the interface between the pipe and soil and different soil layers during sequential layered construction. The analysis algorithm accommodated the time dependent response of soil-pipe model. This was done by using scaled mass dynamic analysis through total Lagrangian formulation.

Based on the results, three field tests (flexible trench) were designed with different trench width and backfill material. The developed FEM model successfully predicted the field test results. Ultimately, the essential design parameters selected for sensitivity study and the developed FEM model will be used to generate different trench and backfilling condition to evaluate pipes performance. The results of sensitivity study will be used to develop design equations and nomographs for different conditions.

Paper No. 11

Future Conveyance System and Asset Management Research Needs through the LIFT Program

Walter Graf, Program Director, Infrastructure Management Water Environment Research Foundation Alexandria, VA
Email: wgraf@werf.org

Author did not submit the paper

Refer to Appendix A, Page A-149, for a copy of presentation

Paper No. 12

Water Conveyance Infrastructure Research Needs: An EPA/ORD Perspective

Michael D. Royer, Physical Scientist, Urban Watershed Management Branch, Water Supply &
Water Resources Division National Risk Management Research Laboratory
U.S. Environmental Protection Agency Edison, NJ 08837
Email: Royer.michael@epa.gov

Author did not submit the paper

Refer to Appendix A, Page A-160, for a copy of presentation

Paper No. 13

Energy Pipeline Challenges & Related Research

Robert Smith, Research Program Manager, U.S. DOT/PHMSA
Email: robert.w.smith@dot.gov

Author did not submit the paper

Refer to Appendix A, Page A-171, for a copy of presentation

Paper No. 14

Pipeline Corrosion Prevention What is Needed?

James A. Hart, Program Manager NACE International Oil & Gas Industry
Email: jim.hart@nace.org

Author did not submit the paper

Refer to Appendix A, Page A-184, for a copy of presentation

Paper No. 15

Pipeline Research Needs for Future Practice Improvement-A Designer's Perspective

Sri Rajah, Ph.D., P.E., P.Eng., M.ASCE, HDR Engineering, Inc., Chair, Pipeline Location & Installation Technical Committee
Email: sri.rajah@hdrinc.com

Author did not submit the paper

Refer to Appendix A, Page A-187, for a copy of presentation

Paper No. 16

Development of Asset Management Certification and a Living Lab

Dr. Tom Iseley, P.E., Professor, Purdue School of Engineering & Technology,
IUPUI Chair, Buried Asset Management Institute-International
Email: dtiseley@iupui.edu

Author did not submit the paper

Refer to Appendix A, Page A-195, for a copy of presentation

Paper No. 17

14th International Trenchless Technology Research Colloquium Lab

Dr. Mark Knight, University of Waterloo Centre for Advancement of Trenchless Technologies
Email: maknight@uwaterloo.ca

Author did not submit the paper

Refer to Appendix A, Page A-202 for a copy of presentation

Appendices

Appendix A

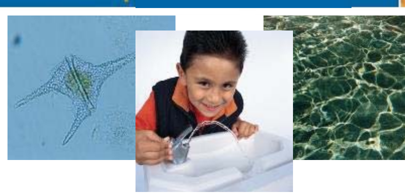
Presentations

Water Research Foundation Pipeline Research: Ongoing Work, Future Directions

Frank J. Blaha, P.E., and Jian Zhang, Ph.D., P.E.,
Water Research Foundation

June 22,2013

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM



WaterRF

Mission: Advance the science of water to improve the quality of life

- **Centralized research program for drinking water utilities**
  - Sponsor research
  - Develop knowledge
  - Promote collaboration
- **Agenda is planned and guided by drinking water utilities**
- **Broad research agenda**

  ~160 active projects

  Much of our work is water quality oriented

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

The Water Research Foundation (WaterRF)

…. is a member-supported, international, nonprofit organization that sponsors research to enable water utilities, public health agencies, and other professionals to provide safe and affordable drinking water to consumers.

Our members, "subscribers," are largely North American municipal water utilities.

ASCE PIPELINE RESEARCH NEEDS SYMPOSIUM

"…that sponsors research…"

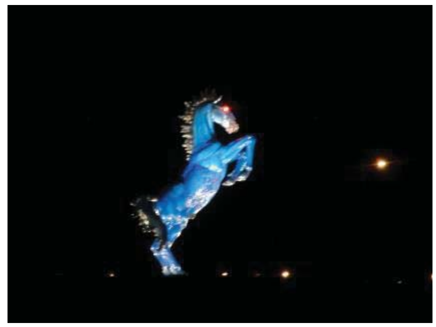
- **Research project identification is driven by the expressed concerns of utilities, typically through a volunteer group that we work with**
- **We coordinate and leverage research resources (especially money) - with other interested parties:**
  - **Utilities**
  - **Other research groups**
  - **AWWA**
  - **Environmental Protection Agency**
  - **Bureau of Reclamation**
  - **NOAA**

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Background History

- Located in Denver
- Work/Fund internationally (typically)
- Co-located AWWA
  - Former AWWA division
  - Independent since the mid-1980s
  - Separate funding mechanism
  - Similar "clients"



Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Foundation Long-Term Track Record on Infrastructure

- ~25% of overall funding into infrastructure work
- 1986 for first infrastructure project report – Report still has relevance
- Synthesis of knowledge from these projects is under-emphasized
- Greater unity of ideas and approaches would increase the value of our work

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

General WaterRF Infrastructure Research

These Pipes:

1. Cast Iron
2. Ductile Iron
3. Steel
4. PCCP
5. Asbestos Cement
6. PVC
7. PE

This Knowledge:

1. Break Rates/Longevity
2. Deterioration Mechanisms/Failure Modes
3. Assessment Capabilities
4. Renewal Methods

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Infrastructure Research Puzzle Considerations

Some pipe materials widely used:

- Cast iron
- Ductile iron

Others more unique:

- PCCP
- Bare (no CML) cast iron

Many can work on the puzzle!

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

Primary Funding Programs

- Focus Area Projects (solicited) – 60% of funding
- Tailored Collaboration – 20% of funding
  - Funding expended for 2013
  - Two to one matching in 2014
  - Utility lead
- Emerging Opportunities Program – 20%
  - Smaller, shorter projects
  - Typically solicited RFP advertised

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Water Utility Infrastructure Focus Area: Applying Risk Management Principles and Innovative Technologies to Effectively Manage Deteriorating Infrastructure

By 2017, provide utilities with tools and strategies to optimize the use of condition assessment and risk management in making infrastructure renewal decisions and the use of innovative renewal techniques.

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

Focus Area Objectives

1. Increase the use and understanding of risk assessment approaches
2. Increase the use and understanding of condition assessment approaches
3. Provide research on improved condition assessment technologies
4. Increase the use and understanding of the full range of renewal technologies
5. Increase the understanding of deterioration mechanisms of different assets
6. Aid the field testing and case study documentation

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Focus Area Dynamic Balances

- Multiple Focus Areas (ours is one of ten!)
- Limited funding – project or two started per year under focus areas
- We have “learned”
  - Can be difficult to justify CA to decision-makers
  - Capitalizing CA work is valuable
  - Can negotiate with accounting departments
  - Improvements to the technologies also desireable

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Condition Assessment/Risk Management Context

- Condition Assessment (CA) can be costly and difficult….and pipe is the same at the end
- Condition Assessment: risk management exercise
- Risk = Probability (likelihood) x Consequences
- CA can inform *Likelihood* of failure
- *Consequences* are why CA is of interest - Vehicles work better out of the water

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Consequences and "Large" vs. "Small" Diameter Pipe

- Real issue is "criticality" of the pipe
  - "Small" diameter pipe is often not critical
    - These failures are generally manageable
    - These failures are routinely managed
    - One large utility: ~735 failures (leaks & breaks per yr.)
  - "Large" diameter pipe is typically critical
    - These failures are of high priority and frequently a crisis
    - Same large utility: ~5 large diameter (16-inch and larger) failures per year
- Typical small breaks: ~$5,000 direct cost, ~$5,000 societal

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

"Critical" or "Large" Pipe Management and Failures

- Failures can be spectacular
- "Consequences" can be substantial (losing cars in the hole!)
- Failures are far less frequent
- Statistics not useful for management

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Large Diameter Failures

- Re-constructed total costs from 30 examples (20-inch diameter and larger)
  - Range of \$6,000 to \$8.5 million
  - Average cost of \$1,700,000 per failure
  - Geometric mean of \$500,000 per failure
  - ~Half of total costs paid by the utility – direct costs

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

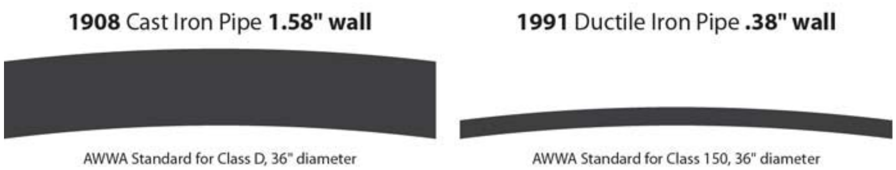
ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Age is Often Not the Prime Factor

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Material: Iron Pipe Wall Thickness



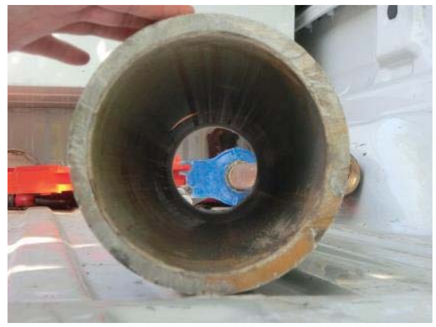
Pipe wall thickness based on withstanding internal and external pressures.

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

An Example North American Utility

- ~3200 miles of pipe
  - 400 miles 16-inch and larger diameter – critical pipe (12.5%)
  - 2800 miles of smaller than 16-inch diameter – small pipe (87.5%)
  - Estimated life: 100-120 yrs.
  - Average age: 68 years



Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Another Example

- **Miami-Dade**
  - 120 miles PCCP became worrisome
  - Hundreds of millions of dollars to replace
  - CA inspection of 70 miles at $15M with rehab
    - Less than 1% of segments severely deteriorated to be replaced
    - Mostly carbon fiber rehab of severely deteriorated sections
  - Estimate $25M total to CA inspect and rehab 120 miles PCCP

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

A Third Example

- **WSSC**
  - 145 miles of 36-inch diameter or larger PCCP
  - Based on inspection of 65 miles of 48” and larger PCCP
    - 1.5% of pipes requiring repair
    - 4.8% of pipes with some distress and not repaired
    - 93.7% of pipe without any distress
    - Acoustic fiber optics deployed
    - Only one failures on inspected pipes – in the last month
  - Effective program at 6% of replacement value

Large Diameter Failure & Consequence Avoidance - Example

- Miami-Dade
  - PCCP Failure – Hyaleah Street
  - Utility direct cost $2.5M
  - $100,000 - estimated cost of renewal prior to failure
    - Not all failure will have a 1 to 25 factor of replacement costs to failure costs, but some central tendency may be found in Project 4451

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

If not Age, What?

- **Pipe material, types of failure**
- **Soil and moisture conditions**
- **Bedding of the pipe**
- **Traffic loading**
- **Pipe/utility specific factors dominate**
- **Condition Assessment**

EACH AN AREA OF RESEARCH!

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Risk Management, Condition Assessment: Continuing Work

Risk Management

- Consequences: helps differentiate similar pipes
- Limited information on consequences
- “Understand” events that have not occurred

Cond. Assessment

- Likelihood: Informs this term
- Improved technologies desired
- Limited application and use
- Case studies important

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Impediments to Use of CA

- Some attempts to understand utility perspective on CA
  - Perceived high cost and cost uncertainty
  - Limited budgets for CA
  - Difficulties in gaining access to pressurized lines
  - Concern about equivocal data
  - Some wish to wait for improved technologies
  - No single technology universally useful in potable water systems
  - Limited use and case studies

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Some Ideas for Further Development

Much of the pipe being replaced is suitable for further service

- Deterioration is not uniform – ID deteriorated areas and fix those
- Improve understanding of “avoided consequences”

Renewal is not necessarily like for like

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Distribution Systems and Risk

- National Academy of Sciences Report on Distribution System Risk
  - Factor in Revised Total Coliform Rule (RTCR)
  - Factor in development of Research and Information Collection Partnership (RICP)
- Partnership for Safe Water
  - Distribution system excellence expansion - based on a WaterRF study
  - Voluntarily utility participation
  - Evolution of program expected

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Distribution System Excellence

- Requires consistent terminology
- Requires consistent definitions - to make comparisons on similar factors
- Encourages collaboration in research
- Synthesizes existing knowledge
- EPA encourages, utilities adopting
- Buried infrastructure renewal a key factor

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

CHARGING TOWARDS THESE MESSAGES:

Deterioration is not uniform

Prevention is better than failure for critical pipes

Condition Assessment can be valuable/economic

Distribution system excellence programs can provide a context for more practical application of our knowledge

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Thank You!
Questions?

Frank J. Blaha, P.E.
Senior Research Manager
Water Research Foundation
6666 W. Quincy Avenue
Denver, CO 80235
Phone: 303-347-6244
Email: fblaha@waterrf.org

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

SHANGHAI MUNICIPAL UNDERGROUND CONTAINER FREIGHT TRANSPORT SYSTEM OF CHINA NATIONAL CONVENTION AND EXHIBITION CENTER

by
Kesi You

Shanghai Municipal Engineering Design Institute (Group) CO.LTD

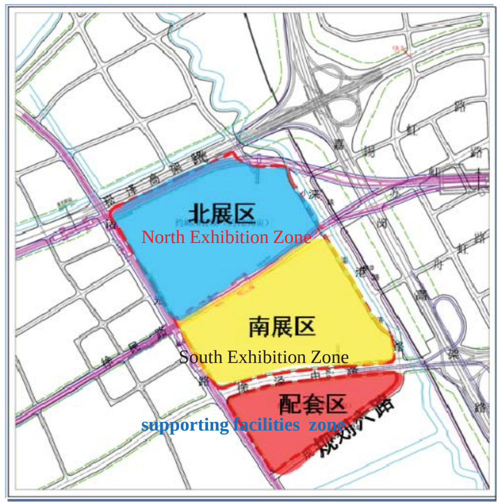
06/22/2013

Contents

1 Introduction

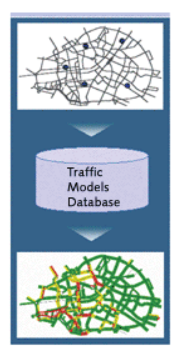
China National Convention and Exhibition Center (CNCEC)

- Located in Hongqiao CBD, Shanghai
- Consisting of exhibition venue, comprehensive supporting facilities and logistic support facilities
- **The world's largest exhibition** (An area of 500,000 m^2)



ASCE PIPELINE RESEARCH NEEDS SYMPOSIUM

- Traffic volume prediction
  - In the worst scenario, China National Convention and Exhibition Center will receive the transportation of 200,000 persons and 3,000 trucks each day
- Traffic organization of exhibition visitors and goods is rather difficult.



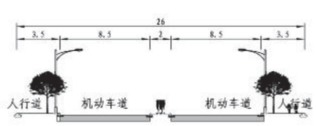
Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

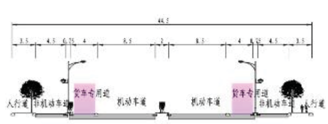
- Large quantities of freight transport will inevitably
  - generate a great deal of exhaust gas and noise
  - increase carbon emission
  - increase traffic pressure on road network
- It is especially important to conduct research to guarantee efficient transport of exhibition logistics and reduce environmental impact.

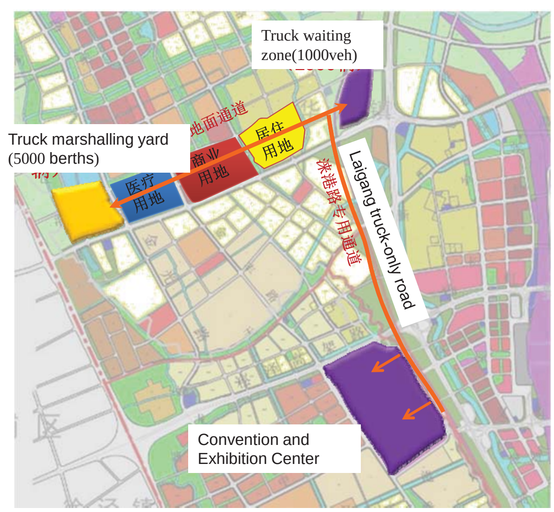
2 Logistic Proposals for China National Convention and Exhibition Center

Proposal 1: Truck-only ground road

Truck marshalling yard + Minbei truck-only road + truck waiting zone + Laigang special road



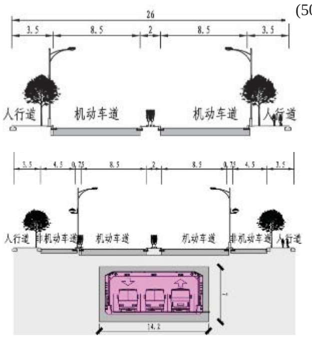


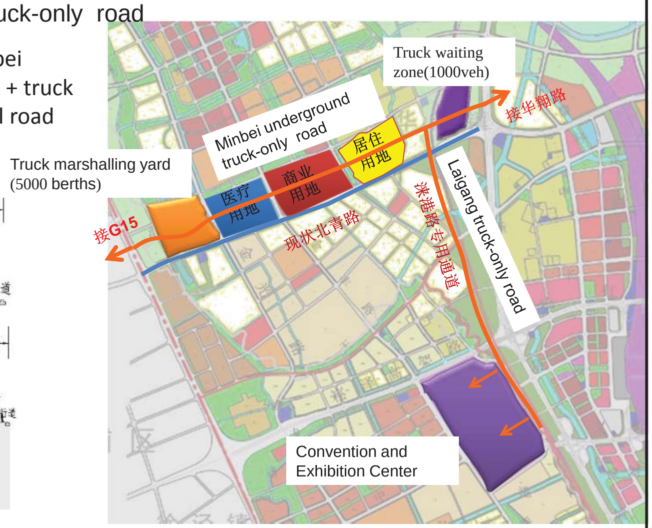


ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Proposal 2: Underground truck-only road

Truck marshalling yard + Minbei underground truck-only road + truck waiting zone + Laigang special road



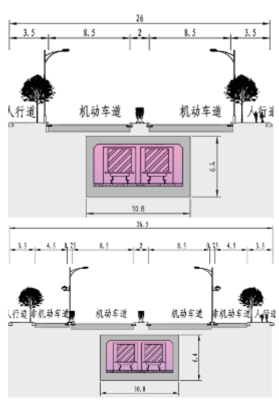


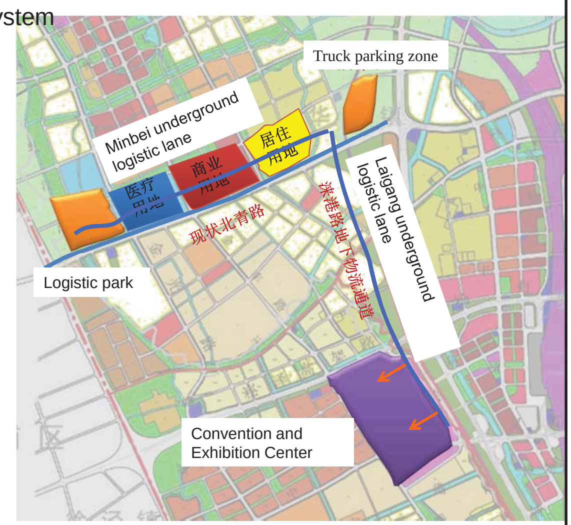
Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Proposal 3: Underground logistic system

Logistic park + underground logistic system + facilities in convention and exhibition zone + parking zone + Laigang special road





Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

Comparative analysis of the three proposals

Proposal 3 has the optimal effect!

Occupation of land	Proposal 1 truck-only ground road	Proposal 2 underground truck-only road	Proposal 3 underground logistic system
Occupation of land	Total area: 728,000 m² ① ground road: 128,000 m² ② Truck marshalling yard: 500,000 m² ③ Truck waiting zone: 100,000 m²	Total area: 704,000 m² ① ground road: 104,000 m² ② Truck marshalling yard: 500,000 m² ③ Truck waiting zone: 100,000 m²	Total area: 304,000 m² ① ground road: 104,000 m² ② Truck marshalling yard: 100,000 m² ③ Truck waiting zone: 100,000 m²
Environmental impact	Big environmental impact ① Exhaust gas, vibration and noise from trucks will impact greatly on CBD ② Annual carbon emissions of 89000t ③ impact on the goal of building a national low-carbon CBD	median environmental impact ① lower impact on CBD ② Annual carbon emissions of 89000t ③impact on the goal of building a national low-carbon CBD	Lowest environmental impact ① No impact on CBD ② The near-term annual carbon emissions of 58000t ③ impact will be negligible given high cargo containerization in the long run.
Efficiency	Low	Low	High
Investment (unit: hundred million yuan)	0.82	6.69	11.91
Risk	High operating risk, low technical, organizational management risk	High operating risk, low technical, organizational management risk	High technical, organizational management risk, low operating risk

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

3 Conceptual Design of Convention and Exhibition Center's Underground Container Freight Transport System

Previous research on Underground Container Freight Transport System

- Most of earlier researches on underground logistic transport system are restricted to the application of small-diameter pipeline logistics.
- Recent years, toward the development of large-diameter underground tunnels
  - conceptual design : Port of New York and Port of New Jersey in the US, Port of Antwerp in Belgium, Port of Tokyo in Japan and Ruhr Industrial District in Germany
- In China, Shanghai Municipal Engineering Design Institute
  - During 2006~2008, a flexibility study for developing underground container freight transport system for Shanghai Yangshan Port
  - During 2008~2010, a study was conducted for using underground container freight transport system for transporting garbage or trash in Shanghai.

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

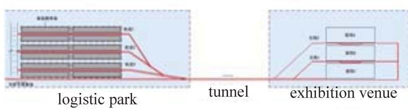
3 Conceptual Design of Convention and Exhibition Center's Underground Container Freight Transport System

General layout of Underground Container Freight Transport System

- The underground container freight transport (UCFT) system of China National Convention and Exhibition Center **comprises three subsystems including logistic park, transport tunnel and exhibition venue**
- Freight vehicles gather at logistic park--- Containerized cargo is unloaded in logistic park--- being transferred via UCFT to the Center for devanning.

Horizontal routes of underground container freight transpor

- UCFT
  - logistic park
  - transport tunnel
  - exhibition venue



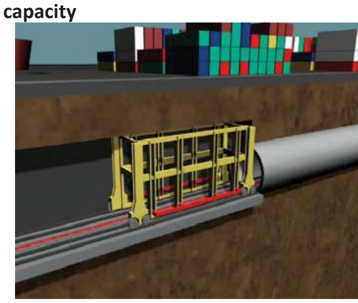
Underground container freight transport (UCFT) system

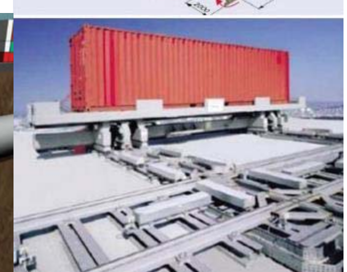
ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

3 Conceptual Design of Convention and Exhibition Center's Underground Container Freight Transport System

Delivery Ways of UCFT

- Tractor + semitrailer
- Motor tractor + container flat car
- Battery driven AGV
- Motor driven container railway transportation equipment
- Linear motor driven container railway transportation equipment **(recommended)**
  - **Excellent climbing capacity**
  - **Small curve radius**
  - **Flexible route**
  - **Low pollution**

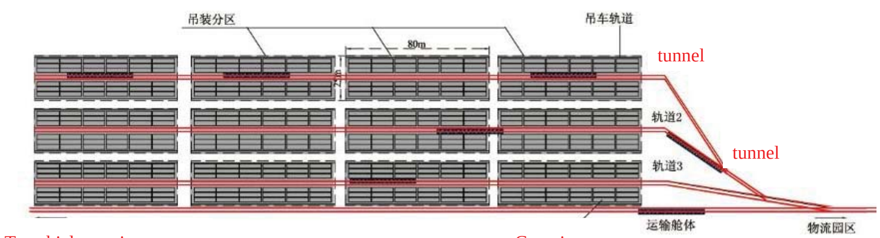




3 Conceptual Design of Convention and Exhibition Center's Underground Container Freight Transport System

Logistic park

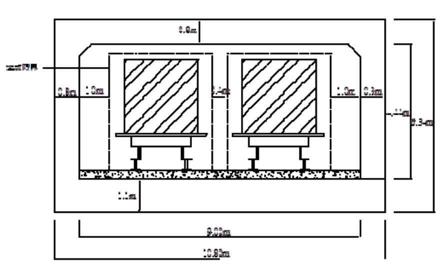
- Comprising freight yard, transit zone, comprehensive supporting service zone, parking lot and vehicle repair zone



ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Transport tunnel

- The cut and cover method is proposed for construction, two ways



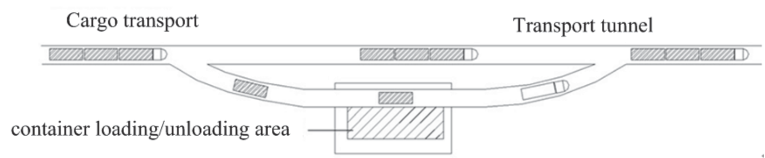
Cross-section of UCFT tunnel

Existing Road

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

Mainline Tunnel and Branch Lines of Convention and Exhibition Zone

- Mainline transport tunnel has branch lines
- Branch lines are connected to vertical transport shaft and intended for temporary emplacement of containers
- The crane can lift the containers to the ground for devanning
- Containers are unpacked and goods are unloaded at the stacking



ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

4 Conclusion

- Traditional logistic proposals fail to the requirement of huge convention center, especially like China National Convention and Exhibition Center, and may also bring adverse aspects.

- **Underground container freight transport system is a** new mode of freight transport, and has considerable comprehensive benefits:
  - relieve the huge traffic pressure
  - greatly reduce carbon emissions
  - save energy and land occupation
  - improve regional environment

- **Prospect**
  - in China, the land resource is limited, and people are paying more and more attention on the environment
  - Underground container freight transport system is very suitable for the condition of China.
  - For us, will continue the further research , and turn it into reality in the future.

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

Thank You!

Pipeline Asset Management Specific to Gas Pipelines: Issues and Needs

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

PIPELINE FACTS

1. More than 210 natural gas pipeline systems.
2. 305,000 miles of interstate and intrastate transmission pipelines
3. More than 11,000 delivery points, 5,000 receipt points, and 1,400 interconnection points that provide for the transfer of natural gas throughout the United States.
4. 24 hubs or market centers that provide additional interconnections
5. 49 locations where natural gas can be imported/exported via pipelines
6. If all the natural gas pipelines in the U.S. were connected to each other they would stretch to and from the moon almost three times.

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

PIPELINE FACTS

1. **Pipelines are constructed using different material depending on their size, pressure requirements and use. Transmission pipes, the pipes used to transport gas from supply areas to distribution centers, are made of 0.25-inch to 0.5-inch thick steel and have a special coating to protect against corrosion. Prior to steel, cast iron was widely used for pipeline construction. For distribution pipelines, especially lines which operate at less than 100 pounds of pressure, plastic is used because of its resistance to corrosion, flexibility, and cost-effectiveness.**

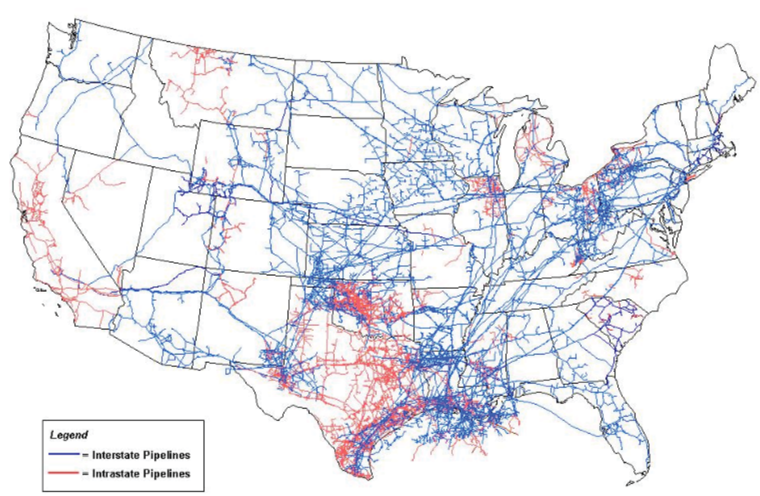
2. **Transmission pipelines are protected by an electrical shield called cathodic protection.**

3. **98 percent of the natural gas used in the U.S. comes from North America**

4. **When natural gas is first transported through transmission lines it can be passed through at pressures up to 1500 psi. By the time it reaches a household piping system, pressure has been reduced to under 0.25 psi – or less than the pressure created by a child blowing bubbles into milk through a straw.**

ASCE PIPELINE RESEARCH NEEDS SYMPOSIUM

U.S. Natural Gas Pipeline Network, 2009



Source: Energy Information Administration, Office of Oil & Gas, Natural Gas Division, Gas Transportation Information System

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

REQUIRED REGULATIONS

- DOT 192 Transportation of Natural Gas Pipelines:
  - API RP 80 – Determines Gathering Line Regulation
  - Dry and Wet Gas
    - Wet Gas > 1180 BTU Content (Ethane/Hydrocarbon Gases)
    - Dry Gas < 1180 BTU Content
  - Class 1 Pipelines
    - 10 or less buildings intended for human occupancy or an offshore area.
    - Except State of Ohio

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

REQUIRED REGULATIONS

- DOT 195 Transportation of Hazardous Liquids Pipelines
  - Transporting of any volatile liquid
    - API RP 80 – Determines Gathering Line Regulation
    - Corrosive or Flammable
    - Crude Oil

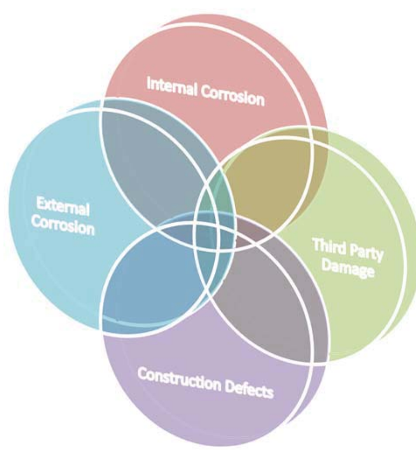
Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

TYPES OF GAS PIPELINES

- Gathering
  - From Wellhead to Compression or Sales Point
- Transmission
  - Compression to Sales Point
  - Higher Pressures
- Distribution
  - From Transmission to Sales Point
  - Usually Gas Pipeline to Your House

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

TOP 4 THREATS TO A GAS GATHERING SYSTEM



…AND CASE STUDY EXAMPLES

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

INTERNAL CORROSION CASE A

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

INTERNAL CORROSION CASE A

Type of Defect

- Internal Corrosion
- 62% wall loss detected by tool

Discovery Method

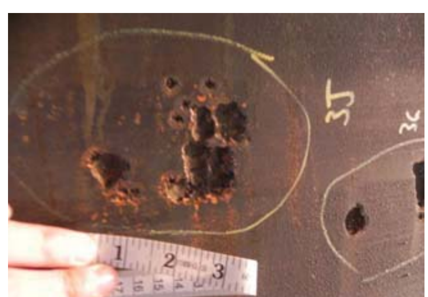
- In-Line Inspection tool (ILI)
- Hundreds of similar defects found in adjacent pipe

Mitigation Method

- Pipe replacement

Likely Cause of Defect

- Pipeline deadleg
- Possible anodic corrosion



Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

INTERNAL CORROSION CASE A

WHAT WENT WRONG:

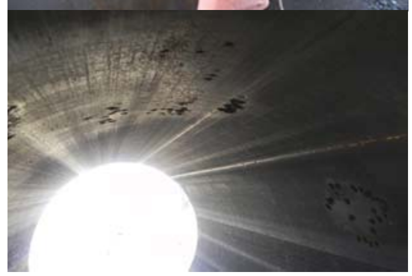
- The cause of these defects is still being investigated
- Both of the suspected causes (bacteria, and scale causing an anodic condition) are related to the deadleg condition the pipe was in during construction
  - *Deadleg is a length of gas pipelines not able to be pigged.*

Preventive Activities

1. Pipeline pigging and chemical injection
2. Reducing time that pipeline is placed in deadleg service
3. Treating pipelines prior to placing them in a deadleg state

Mitigation Method

1. Pipe replacement



ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

INTERNAL CORROSION CASE B

Type of Defect

- Internal Corrosion
- 6 leaks discovered on 4 pipelines
- Majority of pipeline had severe defects located at bottom of pipe, up to 1” wide

Discovery Method

- Pipeline patrol, ILI, hydrostatic test (defects were found in-service and during pipeline assessment)

Likely Cause of Defect

- Lack of O&M activities (pigging and chemical treating)

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

INTERNAL CORROSION CASE B

WHAT WENT WRONG

- Low flow conditions and lack of pigging allow water to build up and bacteria to harbor
- Low flow conditions prevent chemicals intended to kill bacteria and inhibit corrosion from being spread throughout the pipeline

Preventive Activities

- Follow a pigging program
- Follow a chemical injection program

Mitigation Method

- Pipe replacement
- Reduced MAOP and hydrotest to confirm fitness for service

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

EXTERNAL CORROSION

Type of Defect

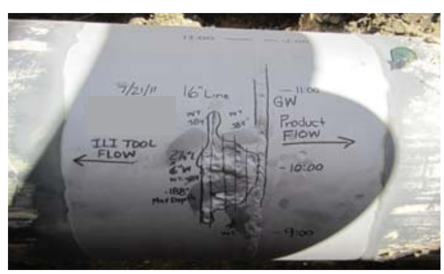
- Joint Weld External Corrosion
- 50% wall loss
- 40 mill/year growth rate

Discovery Method

- In-Line Inspection Tool
- Called as 48% defect

Likely Cause of Defect

- Improper application of joint weld coating



Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

EXTERNAL CORROSION

WHAT WENT WRONG

- Most joint weld coatings fail due to issues with preparation of pipe, training of personnel, or lack of inspection
- Could be due to hydrogen gas building up because joints are coated too quickly

Preventive Activities

- Training on coating application
- Inspection of applied coating

Mitigation Method

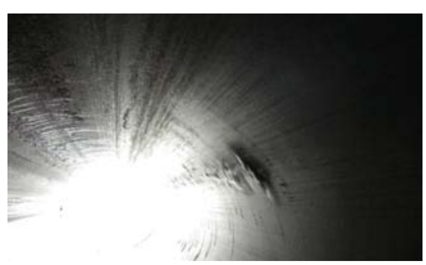
- Clockspring composite wrap

See: *Joint Weld Coating Advisory Bulletin*

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

CONSTRUCTION DEFECTS

- **Located in Bore section of a paralleling 12" pipe**
- **Paralleling line's pilot drill or reamer drill may have been the cause of mechanical damage to line**
- **47.5 ft of pipe was cut out and replaced**



Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

CONSTRUCTION DEFECTS

Wyes

- Prevents In-Line Inspection
- May not be fit for service if designed incorrectly
- Need to Design for Adequate Pigging and ILI inspection

1.5 D Fittings

- Can cause damage to inline inspection tools
- Need 2 – 3 D Fittings

Random Heavy Wall

- Can cause damage to inline inspection tools
- Need to use same wall thickness through out pipe.

Preventive Activities

- Better oversight during purchasing and construction
- Need Good Inspection

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

MATERIAL DEFECTS

Type of Defect

- External Manufacturing defects

Discovery Method

- Pre-installation pipeline inspection (jeeping)

Likely Cause of Defect

- Poor inspection at mill
- Lack of control over material quality

Preventive Activities

- Provide oversight at the mill level

Mitigation Method

- Quarantine unused pipe if possible
- Spike test pipe post-construction to ensure defects are not injurious

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

OPERATIONAL ISSUES

HYDRATE FORMATIONS

- Form at certain temperatures, pressure, and composition
- Formation occurs with a mixture of hydrocarbons, water, low temperatures, and high pressure.

DISCOVERY METHOD

- Pressure Drops
- Low Flows
- ILI
- Pig Runs

PREVENTATIVE ACTIONS

- Maintain Low System Pressures (Compression)
- Methanol Injection
- Maintain Temp & PSIG under dewpoint
- Proper Pigging

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

CAUSES OF PIPE REHABILITATION

LACK OF FIELD AND PROCURMENT INSPECTION

- **PROCUREMENT INSPECTION**
  - Mill Inspection
  - Poor Delivery Documentation and Inspection
- **FIELD INSPECTION**
  - Jeeping
  - Site Inspection
  - Lack of Construction Installation Oversight
  - Poor Non Destructive Testing (NDT) Procedures and Oversight

POOR O&M PROCESS, PROCEDURES, AND DOCUMENTATION

- No Pigging Procedures or Plan
- No ILI Procedures
- Poor System Operation Management
- No chemical treatment of Pipeline System

IMPROPER DESIGN OF PIPELINE

- 1.5 D Fittings
- Unpiggable Wyes
- Deadlegs
- Pipe wall thickness does not incorporate a corrosion allowance
- No consideration for temperature, pressure, and flows in design of pipe for flushing and hydrate formation.

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

CURRENT METHODS FOR PIPELINE MAINTENANCE & INSPECTION

- MAINTENANCE
  - PIGGING
    - Brush/Foam pigs to clean the pipe
    - Heavy Duty Plastic Pigs to Sweep the pipe of Hydrates or Liquid build up in the pipes.
  - CATHODIC PROTECTION
    - Help prevent external corrosion and monitor external wall corrosion
  - GOOD O&M PROCESS, PROCEDURE, AND DOCUMENTATION
  - CHEMICAL TREATMENT
    - Methanol
    - Anti Bacteria Agent

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

CURRENT METHODS FOR PIPELINE MAINTENANCE & INSPECTION

- INLINE INSPECTION (ILI)
  - **CALIPER**
    - Determines wall thickness & Pipe Ovality by use of caliper tool to read pipe ovality and wall thickness changes.
  - **GYRO PIG**
    - Determines pipe profile & bend through the use of a gyroscope. Verify fitting and HDD bend radiuses, and determine exact profile of pipe in ground.
  - **GAUGE PLATE**
    - Pipe Ovality & Damage to Pipe Wall
  - **MAGNETIC FLUX LEAKAGE**
    - Determines changes in wall thickness by inducing magnetic flux in pipe to detect changes in amplitude due to wall thickness change.
    - Inferred measurement
  - **ULTRASONIC**
    - Determines wall thickness by use of a transducer to send and receive sound waves. The difference in time of flight determines wall thickness.

CALIPER PIG

GYRO PIG

GAUGE PLATE

MAGNETIC FLUX

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

RESEARCH NEEDS

- **More Research in Pigging Technologies**
  1. Pig design that allows chemical batch treating for biocide and inhibitors that helps coat the entire internal circumference of the pipe. Currently in the works.
  2. Better Low Flow/Pressure Pigs
- **More research in developing better remote monitoring of rectifiers to assure consistent CP. Tie into SCADA.**
- **More research on improving design of system to alleviate Hydrate and Liquid build up.**
- **More advancement in remote pipe monitoring**
- **Ways to protect existing pipe from 3rd party damage**
- **Improvement in predicting bacteria build up in pipeline systems**
- **Research in best ways to optimize O&M on pipeline systems**

Pipelines and Trenchless Construction & Renewals: A Global Perspective **June 22, 2013, Ft Worth, TX**

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

CONCLUSIONS

BEST INDUSTRY PRACTICES:

- *PROPER PIGGING OPERATIONS*
- *PROACTIVE APPROACH TO O&M/R&I*
- *GOOD FIELD AND PROCURMENT INSPECTION AND PROCESSES*
  - PIPE JEEPING
  - FIELD INSPECTION
  - PROCURMENT INSPECTION
  - NDT TESTING
- *GOOD ILI TOOLS AND OPERATIONS*
- *DESIGN PIPELINES FOR A SUPERIOR O&M SETUP*
  - NO HYDRATES
  - ADEQUATE PIGGING
  - FITTINGS
  - WYES

Pipelines and Trenchless Construction & Renewals: A Global Perspective **June 22, 2013, Ft Worth, TX**

QUESTIONS?

U.S. Dept. of Energy, “About U.S. Natural Gas Pipelines (2007/2008)”, U.S. Energy Information Administration, Washington, DC

Interstate Natural Gas Association of America, “Pipeline Facts 2013”, INGAA, Washington, DC

IMPROVING TRANSMISSION PIPELINE DESIGN, OPERATIONS AND MAINTENANCE

David Marshall

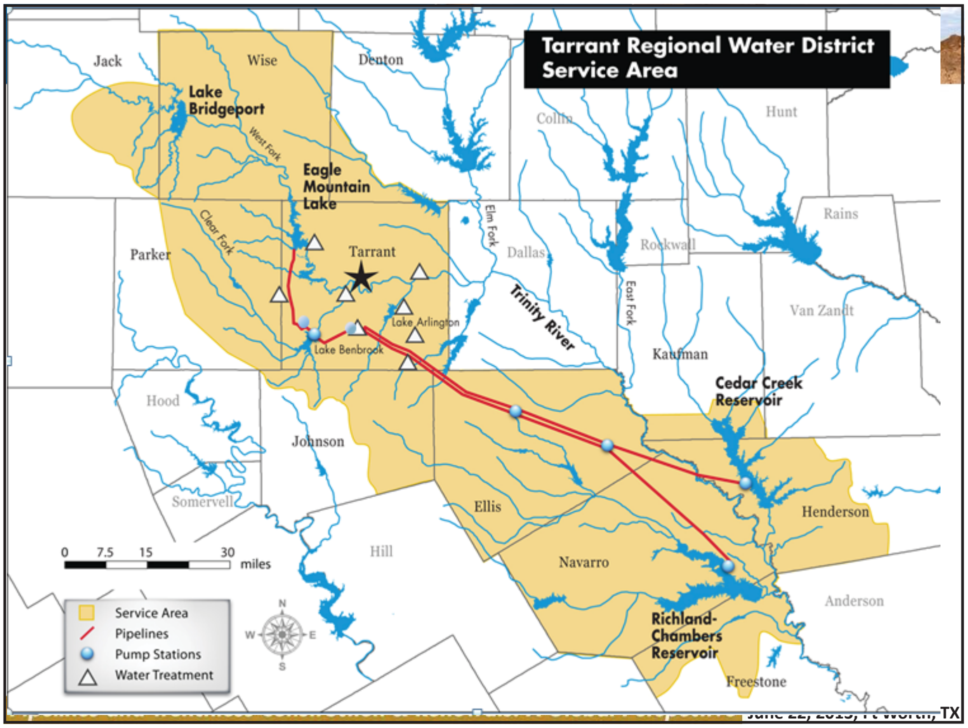
Tarrant Regional Water District

ASCE PIPELINE RESEARCH NEEDS SYMPOSIUM

TRWD System

- We operate a transmission system with 187 miles of large diameter pipe (72”to 108”) driven by 9 pump stations
- About 70% of the water used in the Fort Worth area is supplied by the system
- Reliability is the most important element in the system – most delivery is real time

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX



ASCE | **PIPELINE RESEARCH NEEDS SYMPOSIUM**

TRWD Issues

- Most of the system is PCCP
- Problems include:
  - Corrosion
  - Hydrogen embrittlement of the prestressing wires
  - Thrust restraint
  - Shear failure
  - Valve casting defects
- Resolution has been through a root cause failure analysis and mitigation

Solutions

- Hire experts and listen to them
- Transient mitigation/pressure management
- Rigid manufacturing and installation inspection
- Cathodic protection
- ASTM 648 change
- C301, C304 changes
- M9 changes

ASCE PIPELINE RESEARCH NEEDS SYMPOSIUM

Research for the Integrated Pipeline Project

- Texas soils are great for cotton but not for transmission pipelines
- Use FEA to verify design would work with these soft soils
- I also wanted to take advantage of recent advances in using modified native backfills and CLSM if they proved economical
- We are working with UTA on guidance

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

Large Diameter Transmission Pipe

- Most equations were developed from tests for smaller diameter pipe
- Scale up for pipes two or three times the test diameter may not perform the same
- Don't trust any equation over 30

Steel Pipe Transmission Design Improvements

- Trench sidewall and trench bottom support
  - Trench bottom, bedding, backfill and trench walls need to be designed as a system
  - Vertical changes in trench wall materials
  - Materials required for backfill
- Pipe Wall Thickness
  - Will large diameter pipe act according to ring theory?
  - Will local stress deform the pipe leading to a possible vacuum collapse?

Steel Pipe Transmission Design Improvements

- Coatings
  - For polymer coatings, what should be the test for acceptance?
  - How should accelerated performance tests be conducted?
  - For microcracking of mortar, will the healed cracks perform over the life of the pipe or are they more susceptible to dissolution over time and in acid soils?
  - Long-term, would heat shrink sleeves help extend the life of grouted joints?

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Transmission System Installation

- A robust design can be changed to a marginally reliable system if installation is not well inspected.
- Periodic inspections could help improve design
  - Areas susceptible to changed loading may show increased deflection
  - Slip joints may show areas of movement
  - Cracking may show areas with insufficient support

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Transmission System Operations

- Operations experience needs to be folded into design philosophy
  - Transient and operations error pressure increases need to be mitigated
  - Changes in static and dynamic loading need to be considered, especially at highway crossings
  - Long term soil consolidation needs to be considered
  - Aging pipe needs to be considered in planning

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Maintenance

- Funding for transmission system maintenance is always an issue
  - Management needs to understand the critical nature of the assets
  - Full cost of service should be how the rate structure is developed
- Maintenance practices vary utility to utility
  - Best management practices need to be collected and documented
  - Costs associated with the BMPs need to be captured to help with rate development

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Transmission Systems

- Reliability and cost need to be balanced in design
- Modeling behavior and performance will help establish reliability
- Large diameter full scale testing and inspection of installed systems will help calibrate pipe behavior
- The critical nature of a transmission system needs to be considered in every aspect of its life.

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

Broadband Electro-Magnetics BEM

The Interactive Pipe

The Technology

BEM Overview

BEM Signal Penetration

BEM Signal Characteristics

BEM Results

BEM Overview

- Derivative of the 'pulse eddy current' system

  Established geophysical exploration technology

  Modified for NDT inspections of metallic infrastructure

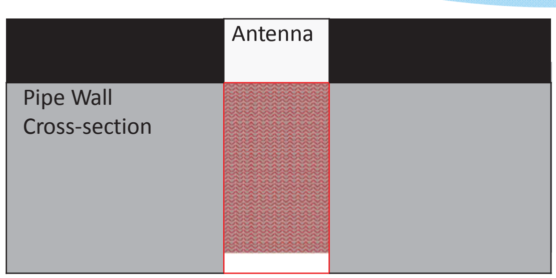
  Non-frequency dependent

  Ability to scan through thick coating / lining (1" +)

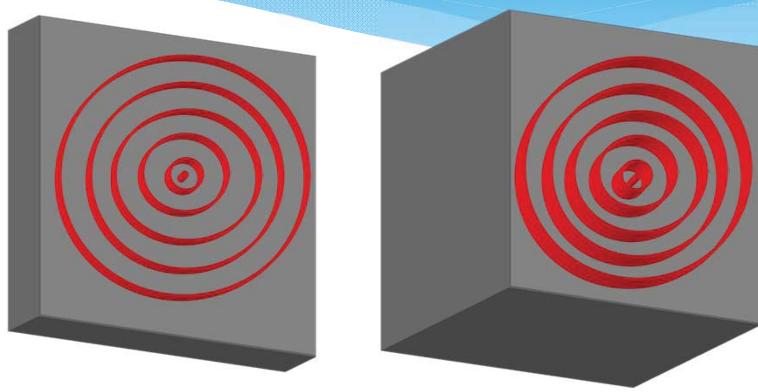
  Contact with metallic surface not required

  Patented Technology

BEM Signal Penetration

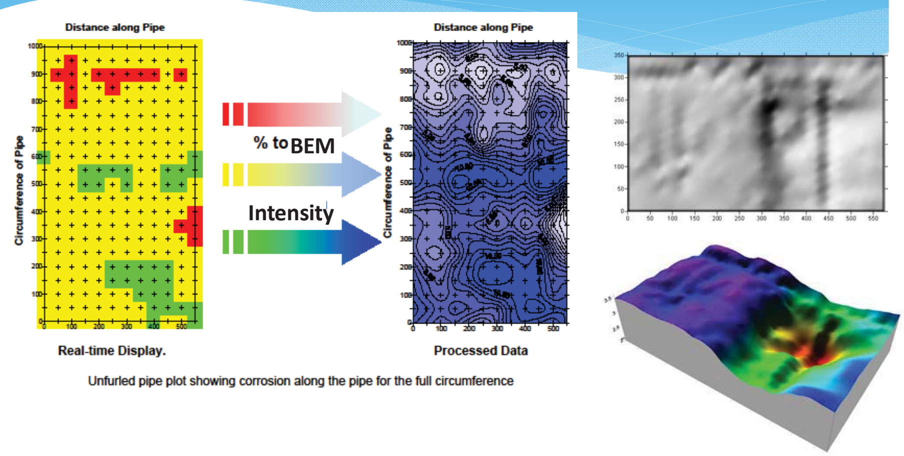


BEM – Signal Characteristics



The Interactive Pipe – June 2013

BEM Results

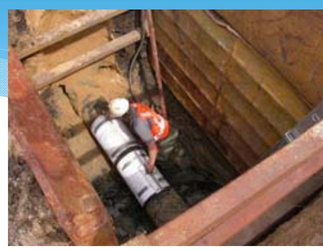


The Interactive Pipe – June 2013

Current Modes of Application

Hand Scanning (HSK)
Inline Inspections (PIG)
Crown Assessment Probe (CAP)
Keyhole Inspection System (KIS)

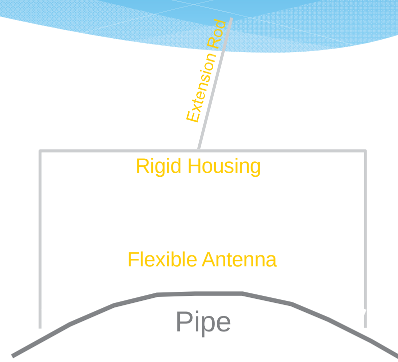
Hand Scanning Kit (HSK)

In-Line Inspections (PIG)

The Interactive Pipe – June 2013

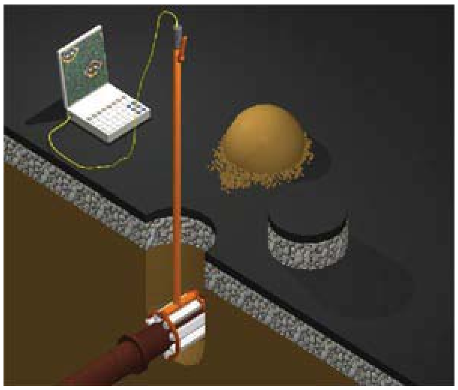
Crown Assessment Probe (CAP)



The Interactive Pipe – June 2013

10

Keyhole Inspection System (KIS)



The Concept of the Interactive Pipe

Technical Components

System Installation

Data Collection & Reporting

System Management

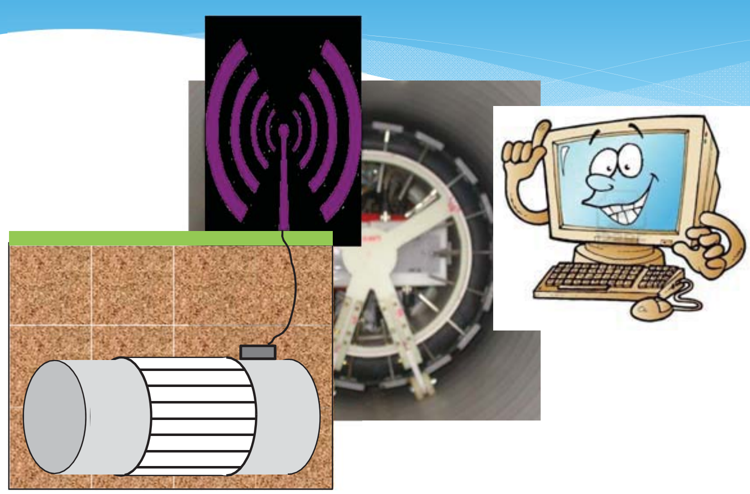
The Interactive Pipe – June 2013

Technical Components

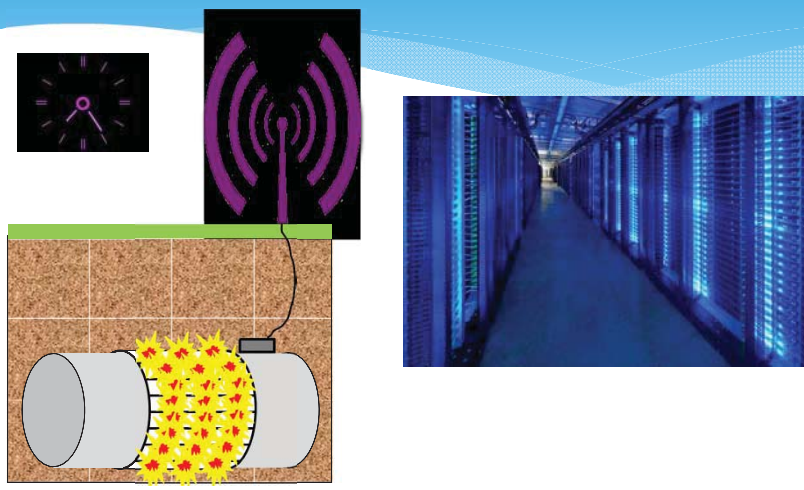
SOFTWARE

MetCon© → MetProc© → MetPlot©

System Installation



Data Collection & Reporting



The Interactive Pipe – June 2013

System Management

The Interactive Pipe – June 2013

The Interactive Pipe

The Interactive Pipe – June 2013

Contact Us

www.rocksolidgroup.com
info@rocksolidgroup.com.au

ROCK SOLID GROUP

Non-Destructive Testing
Geophysical
Geotechnical

The Interactive Pipe – June 2013

The Interactive Pipe – June 2013

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

PIPE CONDITION AND EARTHQUAKE DAMAGE

WHAT INFORMATION IS NOT CURRENTLY RECORDED?

By J Black – Chief Whispers to Pipes

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

The Christchurch Earthquakes Sept. 2010 to Dec. 2011

- After a major and damaging EQ, there is extreme urgency to restore services
- Exhumed pipes were stockpiled and then dumped

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Exhumed Pipes Consigned to Landfill

- AC pipes – what failed?

Pipeli ... orth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Exhumed Pipes Consigned to Landfill

- PVC Pipes – low pressure water main exhumed, broken and dumped – what failed?

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

The Christchurch Earthquakes

- Valuable asset information was being uncovered on an unprecedented scale (failure mode, condition, pipe size, type and with knowledge of pipes approx. year installed)
- Repair record forms are designed for day-to-day maintenance works (not major catastrophes)
- Information on what failed seldom recorded
- A data collection opportunity was lost
- Few useful photographs of failures were taken
- Most photos were of the repaired pipe in the ground (to ensure that contractors were paid).

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Pipe Condition and EQ Damage

I was not directly involved with the response and recovery work but since so much valuable information was being lost, I used every opportunity to look at failed pipe samples

Some general observations were:

- Brittle pipe materials are more vulnerable to EQ damage than ductile and semi-ductile pipes.
- Deteriorated (poor condition), brittle pipes are even more vulnerable

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Pipe Failure Examples Examined

- I could only examine a few pipe failures in any detail
- My examinations identified other factors that contributed to/caused the failures, aside from the earthquakes
- What was surprising was that many of the failures I inspected were preventable
- The earthquake was just the catalyst for failure

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Other EQ Damage Factors

The other factors that were identified were:

- Pipe quality
- Installation quality
- Pipeline design and provision of flexibility
- Many of these factors can only be identified by suitably experienced and skilled people
- These can have a very strong influence on EQ damage

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Quality Issues – 1937 Cast Iron Pipe

Also, the minimum pipe wall thickness is only 85% of the Standard minimum

n & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

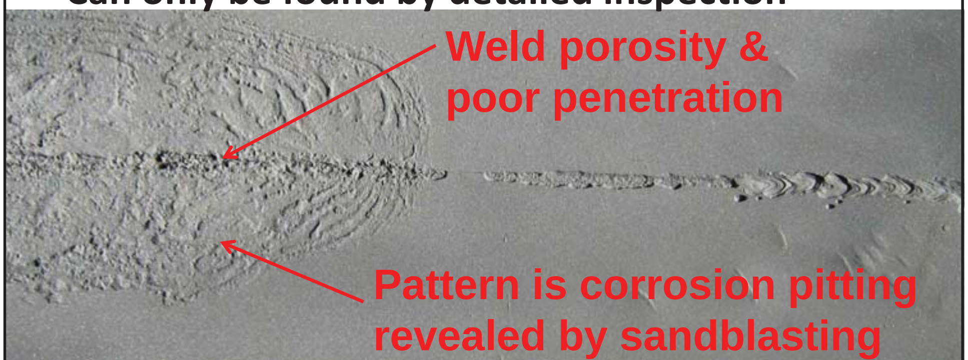
ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Quality Issues – PVC Pipe

- **Poorly processed (low toughness) PVC pressure pipes are susceptible to failure by longitudinal splitting (brittle fracture) – this pipe did not meet the standard requirement for ductile fracture**

Quality Issues – Steel Pipe

- Lack of weld penetration & porosity on hand weld of longitudinal seam (the concrete lining was thin and water was seeping through the wall)
- Can only be found by detailed inspection



ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

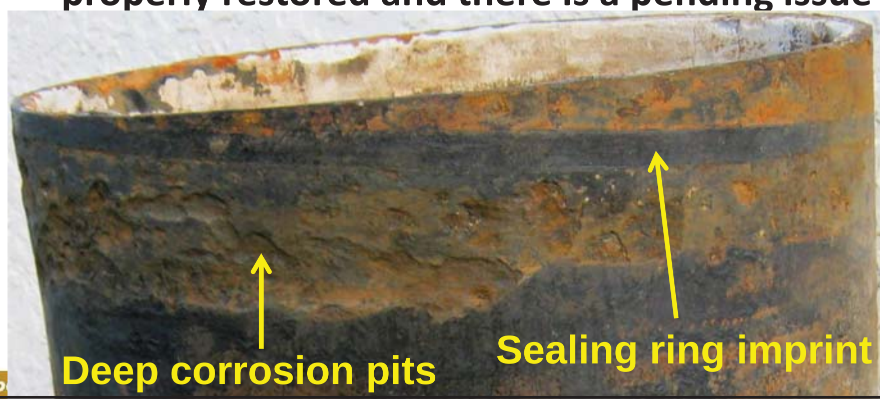
Installation Issues – Cast Iron Pipe

- View of a broken 6” 1880’s Cast Iron pipe that had been laid on a large rock
- Vertical acceleration was nearly 2 x g – the only failure in 650’ of pipeline
- This information was not recorded – obtained directly from the repair gang foreman

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Installation Issues – Steel Pipes

- A 1969 24" steel pipe laid with a deflection of >5°. Only ½" of movement caused leakage
- The corrosion protection system was not properly restored and there is a pending issue



ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Pipeline Design Issues

- Designs often allow insufficient flexibility at anchorage points
- Traditionally, only allowance for minor settlement was made (maybe ±½ -1")
- In an EQ event, the relative movement can be 5-10 times this (or more)
- The length of "rocker" pipes is usually far too short (if they exist at all)
- Record forms could provide for comment on lack of flexibility

Inflexible Design 27” Cast Iron Pipe

- Some pump stations had no flexibility at all between pump station and valve chamber.

Asset Inventory Records (GIS)

- Many of the failed pipes examined were incorrectly or (at best) inconsistently recorded in the GIS system
- Most GIS systems contain errors and anomalies - even in well managed systems
- Earthquake response and recovery repair works provide a unique opportunity to gather information on a vast scale that can be used to verify/correct GIS records
- Complete, reliable and consistent records needed

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Consistent identification of Pipes

- It's common to find inventory records with similar pipe materials identified in different ways
- Rationalisation of pipe descriptors is essential in improving record keeping
- Training of Key personnel is needed as reliably identifying pipe materials can be difficult
- Even a pipe whisperer can get it wrong
- GIS records frequently don't have sufficient data fields for important sub groups of pipe materials

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

General Observations & Comments

- After an earthquake, the first consideration is recovery of survivors of damage
- Almost simultaneously, restoration of water supply and sewerage services begins
- The urgency to make repairs means existing resources are overloaded and assistance from outside is needed
- Contractors unfamiliar with systems are brought in to assist with the recovery

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

General Observations & Comments

- Field record forms are usually inadequate for anything but routine work
- Photographs of sufficient quality of what failed are rarely available
- Unusual damage samples are not retained
- It's assumed that maintenance crews can reliably identify all pipe materials
- GIS records don't recognise some important sub-sets of materials

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Example of Incorrect Asset Detail

- A section of 1930 4" spiral riveted steel pipe with 5 separate repairs within 900mm
- The GIS showed 1987 PVC-U for this main
- This type of pipe not recognised in the GIS record

After sandblasting

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

General Observations & Comments

- There is an industry need (world-wide) to train key maintenance personnel in:
  - o Ways to reliably identify pipe materials, - sounds easy but it's not. Try distinguishing between the PE's, the PVC's and AC types
  - o How to record information gained from repair works,
  - o Basic condition assessment principles, and
  - o To give guidance on how to recognise failures that could benefit from expert examination, and
  - o How to package such samples

Research Needs

My point here is that record keeping is so apparently simple and basic that it is largely ignored

- Most current repair record forms do not allow for some important data capture
- Research focussed on data capture and reporting would have benefits for day-to-day operations as well as emergency preparedness
- Input is needed from all stakeholders, asset owners, maintenance personnel (who have to record the information, technical experts, etc

Research Needs

- Key aspects that the research should address (at least) include:
  - Asset inventories reliability & consistency
  - Rationalisation of pipe descriptions
  - Confirmation of pipeline install dates (often only a [misleading] default date is used
  - What information should be recorded & how?
  - Training needs for maintenance personnel?
  - Updating records when pipelines are renewed or others decommissioned
  - All very basic stuff!!

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Conclusions

- Better record keeping is possible and will facilitate improvements to asset inventories as well as preparedness for an emergency
- Better records will be useful for future earthquake damage research
- Appropriately experienced pipe experts should be engaged at an early stage in the emergency recovery

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE PIPELINE RESEARCH NEEDS SYMPOSIUM

Thank you for your attention

ANY QUESTIONS?

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Pipeline Crisis

Why research matters

Neil Grigg, Colorado State University

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Pipelines 2013 Topics

- Infrastructure
- Planning and Design
- Safety, Risk, and Condition Assessment
- Trenchless Installation
- Location and Installation
- Oil & Gas: Design, Installation, Safety and Risk

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

Evidence of a pipeline crisis?

- ASCE Report Card?
- Water main breaks?
- PG&E? Exxon? Gulf blowout?
- Many kinds! Add it up.

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Why does a pipeline crisis matter?

- Risk to public
- Risk to environment
- Service levels
- Financial impacts

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

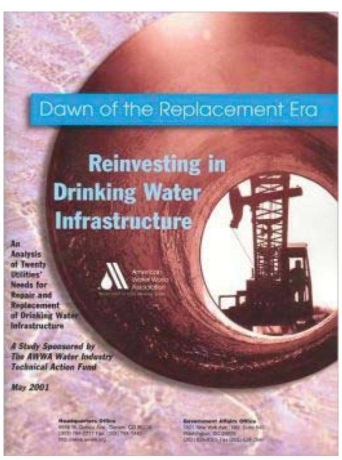
Slow renewal of pipes

- Once in 200 years— Does it make a crisis?

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

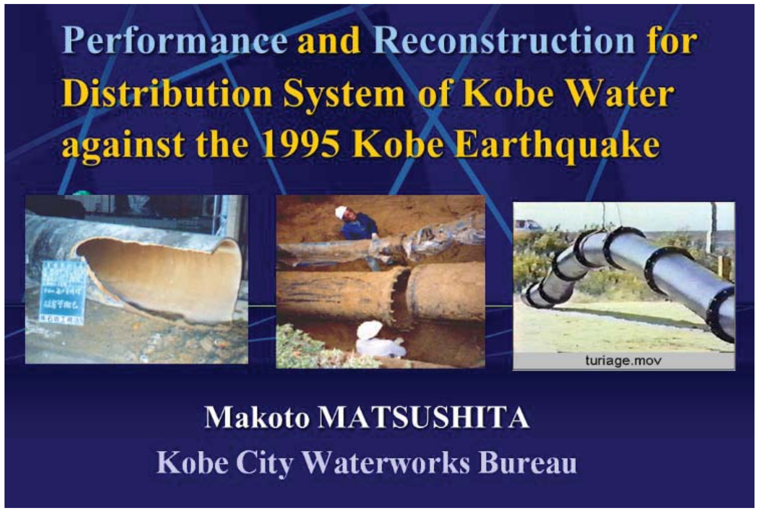
Money and aging infrastructure



Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Seismic failures



Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Add it up

- The problem has many parts
- It is a creeping crisis
- Important but easy to ignore—
- Until disaster strikes

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Whose job to fix it?

- Washington DC?
- EPA?
- Water and wastewater utilities?
- Gas and oil industry?
- PHMSA? Other regulators? PUCs?
- Taxpayers?
- All of the above?

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

About the pipeline industry

- Many disparate parts
- Lot of scenarios and types of pipes
- Lot of owners and fragmented responsibilities
- Aging pipes, new pipes
- Uncertain pipeline conditions
- Lot of conflicts, some danger
- Many routine situations
- Interdisciplinary and inter-industry

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

Does research matter?

Scenarios:

- Pipelines involve a lot of practical issues and don't require research—they just require good and skillful work
- Pipelines are high tech with a lot of management challenges—research is needed to push the envelope

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Pipeline research

- Is pipeline research about technology, management, or all of the above?
- Pipelines require practical knowledge, skills, abilities
- They also require materials, equipment, scenarios, rules and procedures, risks

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

What does it compare to?

- Medical research to extend life?
- Environmental research about nature?
- Product development for problem-solving (saline water) or profit (I-Phone)?
- Defense research for weapon systems?
- Transportation to improve mobility?
- Social research to strengthen families?

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Models?

- Basic or applied?
- R *and* D?
- Product development?
- Research-to-practice (education, child welfare, medicine, public administration)?
- Government research (ARPA-NSF, Internet)?
- Academic research?

- Best model: Industry cooperative research? – WaterRF, WERF, GRI, EPRI, CII, ...

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

Trash research?
Golden Fleece Awards

- NSF: compare aggressiveness in sun fish that drink tequila instead of gin
- NIH: Peruvian brothels (researchers made repeated visits for accuracy)

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Fund research no matter what?
Golden Goose Award 2012

- Charles Townes—1950s—laser technology—no known application—Nobel Prize 1964
- Several—study of tropical coral 1960s—Ideal bone graft material
- Shimomura—how jellyfish glow in the dark—used in pharmaceutical and biotechnology industries—Nobel Prize for Chemistry in 2008

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Who does research?

- EPA?
- WaterRF?
- WERF?
- PHMSA?
- Vendors to develop products?
- Utilities who never publish?
- Consultants to get work?

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Best examples of payoffs?

- Asset management?
- Pipe break causes?
- Condition assessment? Corrosion control?
- Water loss accounting?
- Frameworks, like “knowledge management?”
- BMPs? Like DSO?

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Gap—research to practice?

- Researchers unconcerned with messy details
- Complain that practitioners ignore research
- Practitioners deride research as ivy tower
- Gap caused by misunderstanding?
- Or fundamental—knowledge and skill sets differ?
- Research-practice gap difficult to overcome

An example from the computer industry
http://jnd.org/dn.mss/the_research-practice_gap_1.html

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Let it happen? Or make it happen?

- Innovation to practice is complex
- Requires problem recognition and importance
- Requires context-sensitive solutions
- Funders emphasize evidence-based strategies
- Adoption more than passing information to practitioners
- New knowledge-to-practice is a process
- Funders for public health may prefer 'making it happen'

http://www.communitysystemsonline.com/LinkClick.aspx?fileticket=STpRl5%2BH7zA%3D&tabid=708

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

Many faces of research

- What is it? Research-to-practice?
- Industry where it occurs?
- Who is responsible?
- Government or association-funded?
- Consultants to carve out niches?
- Vendors to develop products?
- Unfunded writers? Researchers?
- Kaleidoscope!

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Competition and trade issues?

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

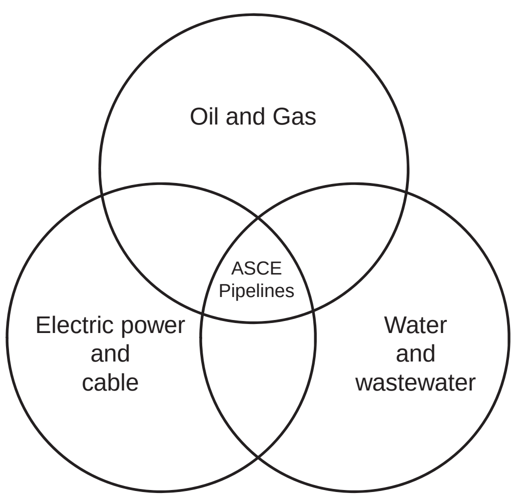
ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

What to do?

- It depends—your industry, your role
- Water industry—slow change, high stakes
- Determine boundary conditions
- Identify problems clearly
- Find solutions
- Make it happen? Whose job?

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM



Public sector—private sector
Regulated—unregulated
Oil and water
Different incentives/agendas
CEs, MEs, EEs and ChEs

From this…
progress and
advancement of knowledge!

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Business case for research?

- Identify problems
- Recruit industry advocates
- Get good researchers
- Plan research-to-practice
- Prepare success stories
- Champion research (like Harry Hopkins)

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

The ties that bind

- Technological gate keepers
- Change experts
- Imbedded technology agents
- People who stick with it (like with SWMM)

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

Why pipeline research matters

- Society without technology?
- Shared inter-industry activity
- Profit or public good?
- Many subjects
- Synthesis or basic work?
- Innovative but practical
- Foster cooperation
- Important work, keep at it!

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Thank you!

Neil Grigg
neilg@engr.colostate.edu
970-491-3369

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Integrity Management for Piping Infrastructure

Ernest Lever

R&D Director, Infrastructure

Gas Technology Institute

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Who is GTI?

- Not-for-profit research, with 70 year history
- Facilities
  - 18 acre campus near Chicago
  - 200,000 ft^2, 28 specialized labs
  - Other sites in DC, CA, MA, PA, and Alabama
- Staff of 250
  - 170 scientists and engineers covering all fields
  - In-house Contracts, Licensing

Offices & Labs

Flex-Fuel Test Facility

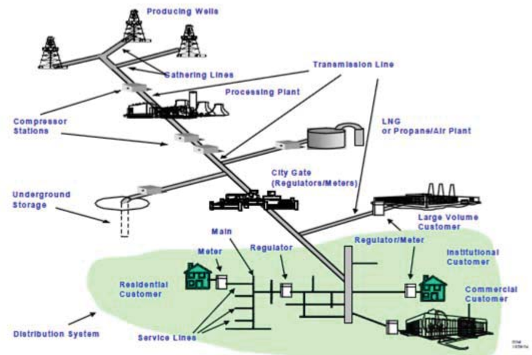
Energy & Environmental Technology Center

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Size of the US Natural Gas Piping System

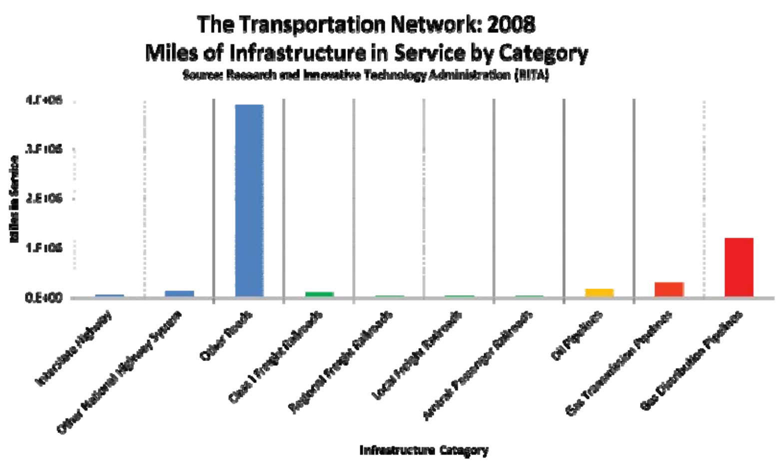
- In 2008 the US natural gas transportation system comprised :
- ~ 300,000 miles of transmission pipelines
- > 1.2 million miles of distribution pipelines



Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Natural Gas Transportation Network Compared to Other DOT Regulated Transportation Networks

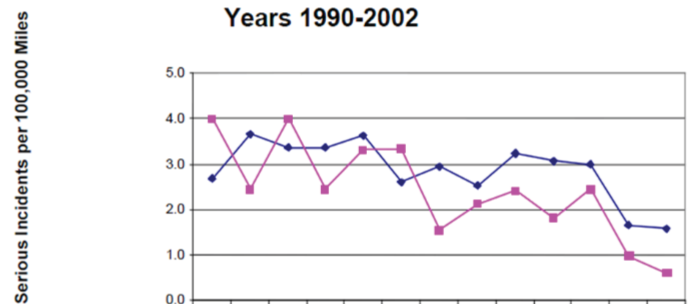


Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

PIPELINE RESEARCH NEEDS SYMPOSIUM

Continually Improving Integrity Management and Public Safety

Distribution Serious Incidents vs. Transmission Serious Incidents Years 1990-2002



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Distribution F&I Incidents	2.7	3.6	3.4	3.4	3.6	2.6	2.9	2.5	3.2	3.1	3.0	1.7	1.6
Transmission F&I Incidents	4.0	2.4	4.0	2.5	3.3	3.4	1.6	2.1	2.4	1.8	2.5	1.0	0.6

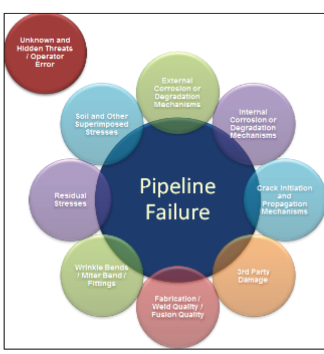
Source: Safety Performance and Integrity of the Natural Gas Distribution Infrastructure, American Gas Foundation, January 2005

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

PIPELINE RESEARCH NEEDS SYMPOSIUM

Integrity Management Principles

- Know the System
- Identify Threats
- Evaluate Risks
- Mitigate Risks

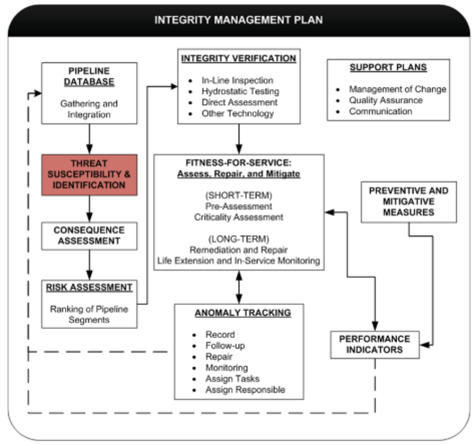


- Can individual threats each be at "acceptable" levels but when added together (superimposed) result in a significant threat to the pipeline or even a failure?
- What combinations of threats are most important to understand and control?
- How should threat interactions be calculated and dealt with?
- What process should an operator go through to identify unknown or hidden threats and how should they be worked into the pipeline integrity assessment?
- Can a process or methodology be employed to continuously monitor these threat interactions and flag concerns at trigger points?

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

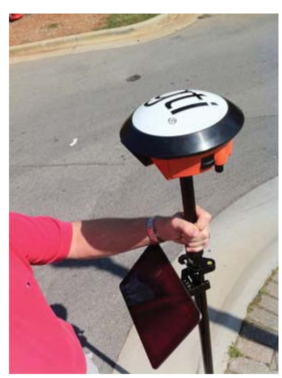
Know the System

- Location, properties, condition, environment . . . all data related to risk!
- Utility companies must collect information during installation and through routine operations to create data sets for integrity management and asset management in the future
- Installation is the optimal time to collect data
- Examples
  - GPS As-Builts
  - Tracking and Traceability with Barcodes



GPS As-Builts

- Integrated external high accuracy GPS receivers with tablet computers
  - Sub-foot quality data in real time
  - No need for post processing or a base station
  - Field data directly inserted into the GIS
  - Modular architecture allows integration of multiple GPS receivers
    - Navcom
    - Geneq
    - Trimble



Asset Tracking and Traceability

- GIS-centric data collection process
  - Barcode scanner
  - Sub-foot accurate GPS receiver
  - Tablet device with GIS-based data collection software
  - Application to convert barcode into asset attributes to auto populate the GIS

ASCE PIPELINE RESEARCH NEEDS SYMPOSIUM

Identify Threats

- Combine data from installation, operations and industry knowledge to identify trends
- Continuously monitor assets
- Understand trigger events that require enhanced monitoring
- Examples
  - GPS-Based Excavation Encroachment Monitoring
  - LiDAR for Post-Disaster Assessment

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

GPS-Based Excavation Encroachment Monitoring

- GPS tracks excavation activity and continuously sends positional information to a central repository
- Software sets up geo-boundaries around pipelines and monitors for encroachments
- Warnings are sent to pipeline operators and excavator

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

LiDAR for Post-Disaster Assessment

- LiDAR detects changes in the built environment that could impact pipe integrity (soil erosion, flooding, etc)
- Changes are used to model new risk profiles of pipelines
- Resources can be deployed to the highest risk pipe segments after a natural disaster

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

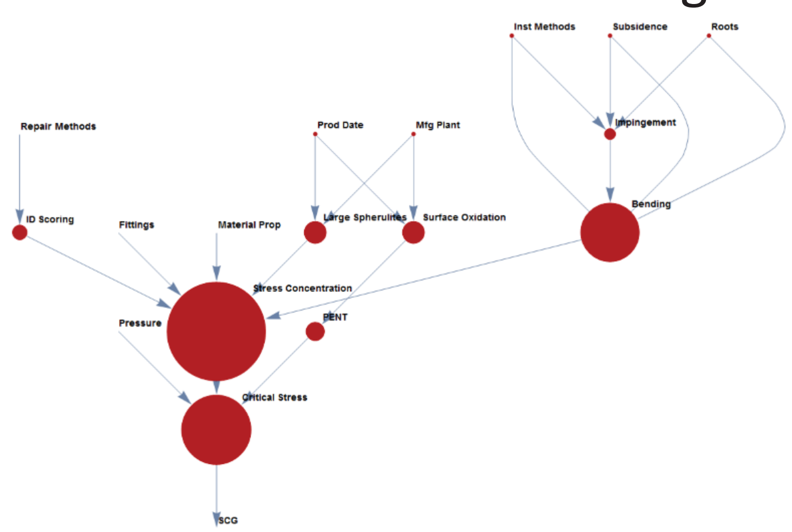
Assess Risk

- Determine probability of failure
- Determine consequence of failure
- Identify high risk pipe segments
- Examples
  - Probabilistic risk modeling for vintage pipe materials
  - More than 70 years of research experience and knowledge
  - Detailed understanding of risk drivers

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

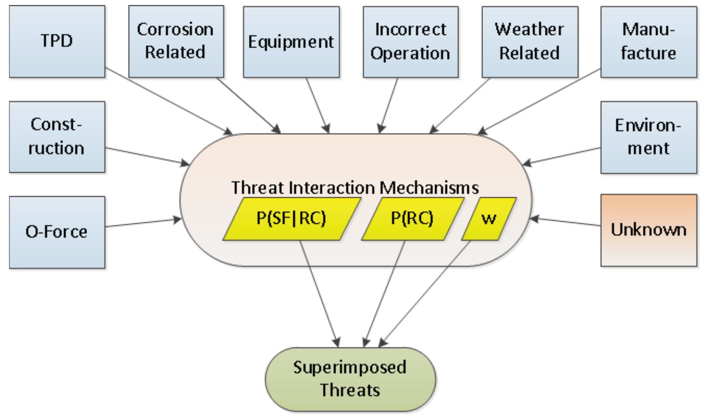
Probabilistic risk modeling



Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

Threat Interaction Mechanisms

- Absolute risk + rank for each *Circumstance*
- Risk hot-spots
- Parameter gradients
- Sensitivity analyses



ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Mitigate Risks

- Implement measures to reduce the probability of occurrence and/or reduce the consequence of occurrence
- Pro-actively survey and monitor
- Repair, rehabilitate, replace
- Examples
  – Remote Quality Monitoring
  – Cured-in-Place (CIP) Lining
  – Composites

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

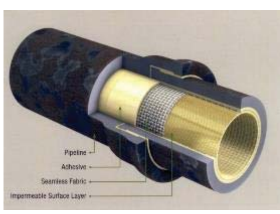
Remote Quality Monitoring

- Smart phones are used to take pictures during construction
- Pictures are GPS and time stamped
- Pictures are sent in real-time to the back office
- Monitor the progress of construction from the office
- Monitor important steps in the construction process
- Maintain QA/QC records

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

CIP Liners and Composites

- CIP liners can repair or rehabilitate aging infrastructure and provide a new service life
- Composites can provide external spot or complete internal repairs

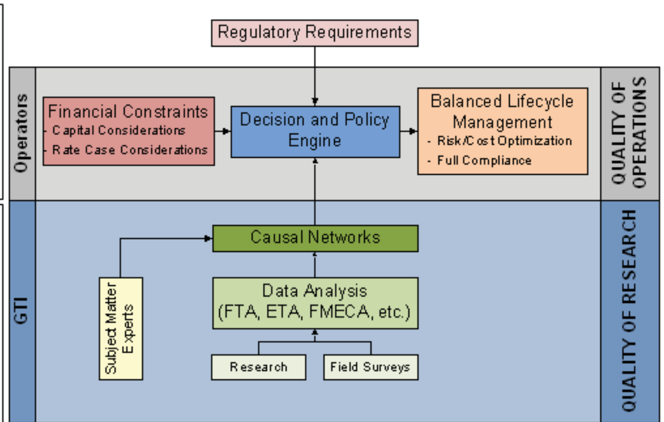


ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Pull it Together

Operators
Apply formal decision theory methods that accept uncertainty bounds in R&D Database

GTI
Reduce material and technological uncertainty through formal research methods that explicitly recognize uncertainty



Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Thank You

Questions?

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

Research Needs for Material Properties and Operational Surge in Pipeline Failures

Dr. Graham E.C. Bell
HDR|Schiff
Saturday June 22, 2013
PIPELINES RESEARCH NEEDS SYMPOSIUM

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Some of the fundamental assumptions that we make about our pipes are inaccurate

- Round & Straight
- Loads Constant
  - Internal
  - External
- Material Strength Determines Failure

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

Tensile testing and crush strength are not related to fracture mechanics

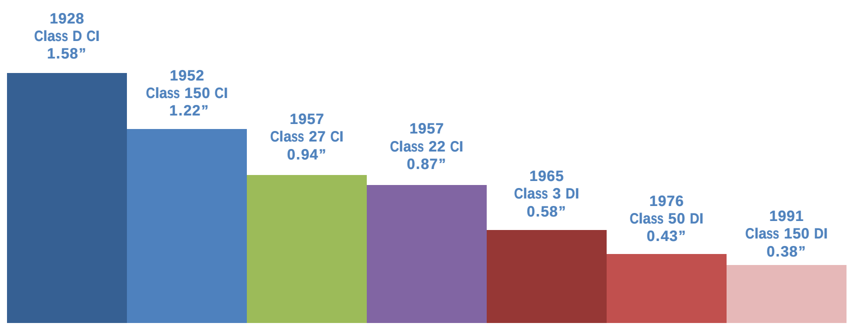
- Nonstandard samples
- Composite materials
- Crush loading is not related to pipe failure mode
- Need fracture mechanics information to relate microstructure, chemistry and break # and rate information.

Simplified History of Small Diameter Water Mains

1880 to 1925	1925 to 1940	1940 to 1970	1970 to 1995	1995 to 2011
Pit Cast Iron (unlined)	Spun Cast Iron (unlined)	Spun Cast Iron (factory lined)	Ductile Iron	
		Asbestos Cement	Polyvinyl Chloride	
				High-Density Polyethylene

Modern Pipe

Typical Iron Pipe Wall Thickness Decrease Over The Years



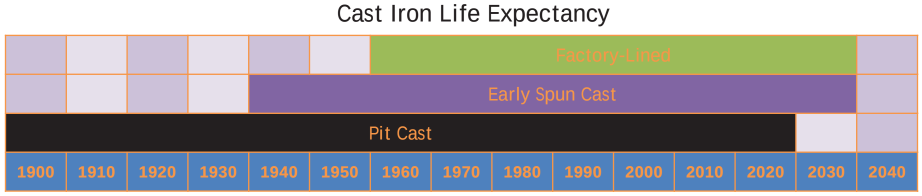
Example for Minimum Wall 36-Inch Iron Pipe

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

As Cast-iron Pipe Got "Better"…Lives Got Shorter

- Typical Industry Expectations
  - 120 years for pit-cast iron (1880 – 1925)
  - 100 years for unlined spun cast (1925 – 1945)
  - 75 years for factory lined cast iron (1945 – 1970)

Cast Iron Life Expectancy



Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

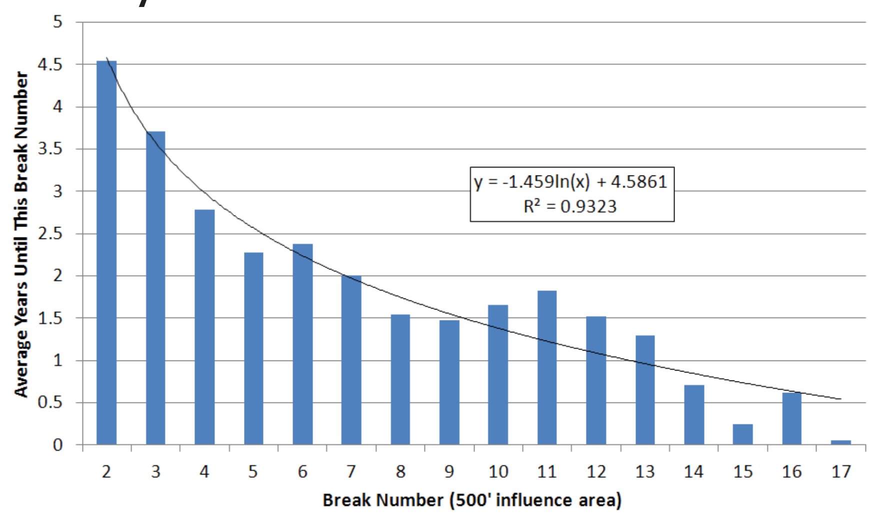
Fracture Mechanics is Important

- **Fracture mechanics** is the field of mechanics concerned with the study of the propagation of cracks in materials.
- The prediction of crack growth is at the heart of the damage tolerance discipline.

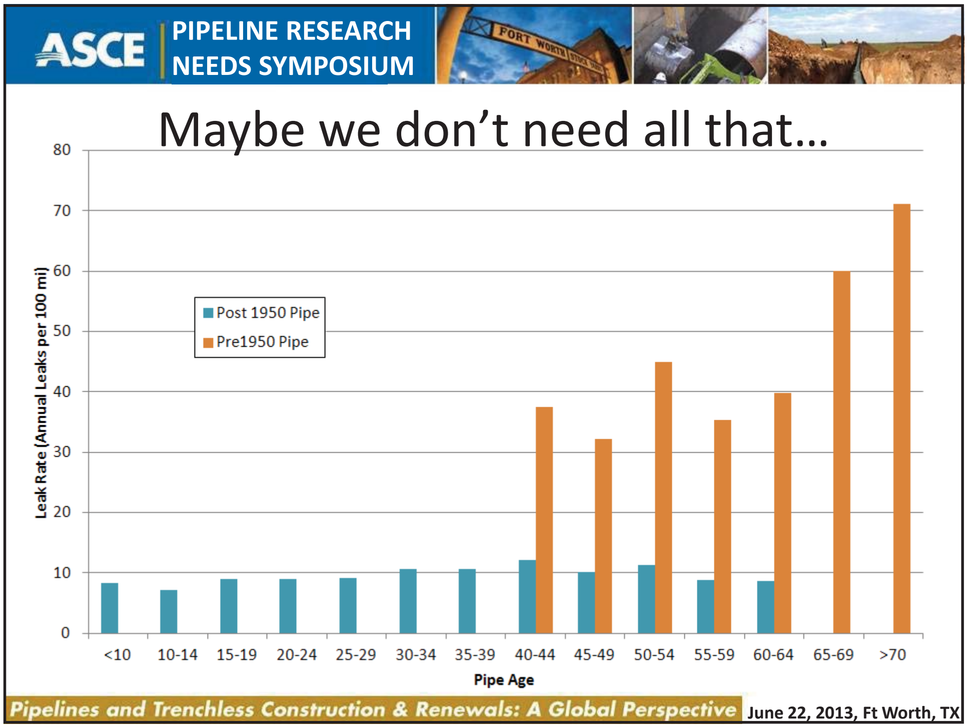
Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

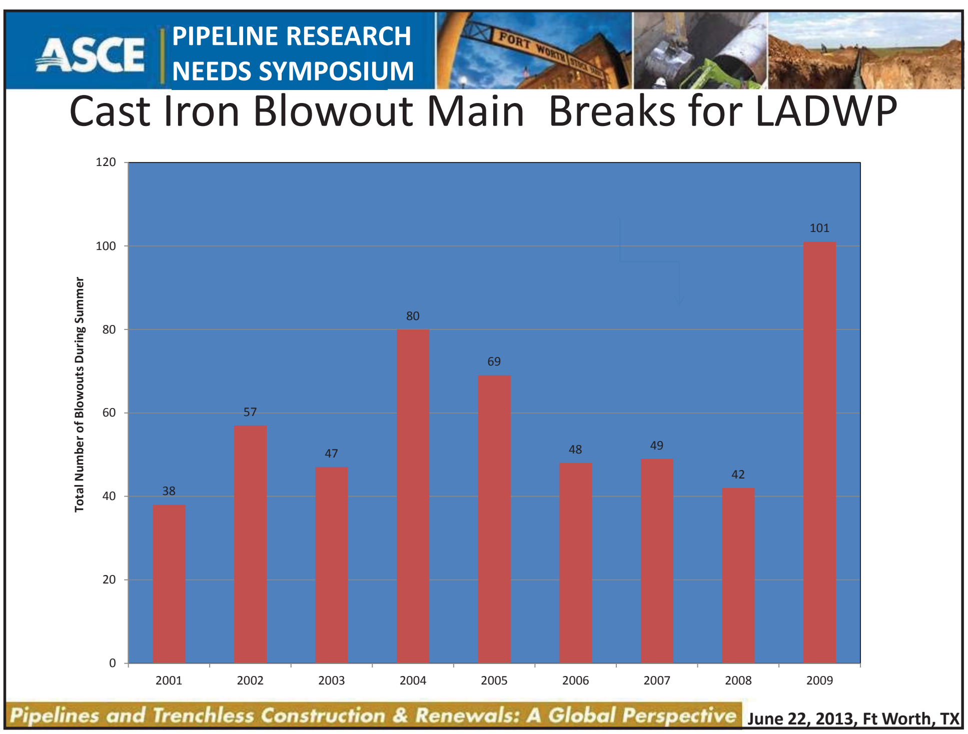
ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Maybe we don't need all that…



Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX


ASCE
PIPELINE RESEARCH
NEEDS SYMPOSIUM
Maybe we don't need all that…
Leak Rate (Annual Leaks per 100 mi)
80
70
60
50
40
30
20
10
0
Post 1950 Pipe
Pre1950 Pipe
<10
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
>70
Pipe Age
Pipelines and Trenchless Construction & Renewals: A Global Perspective
June 22, 2013, Ft Worth, TX


ASCE
PIPELINE RESEARCH
NEEDS SYMPOSIUM
Cast Iron Blowout Main Breaks for LADWP
Total Number of Blowouts During Summer
120
100
80
60
40
20
0
38
57
47
80
69
48
49
42
101
2001
2002
2003
2004
2005
2006
2007
2008
2009
Pipelines and Trenchless Construction & Renewals: A Global Perspective
June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Blow outs and breaks were longitudinal cracks

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

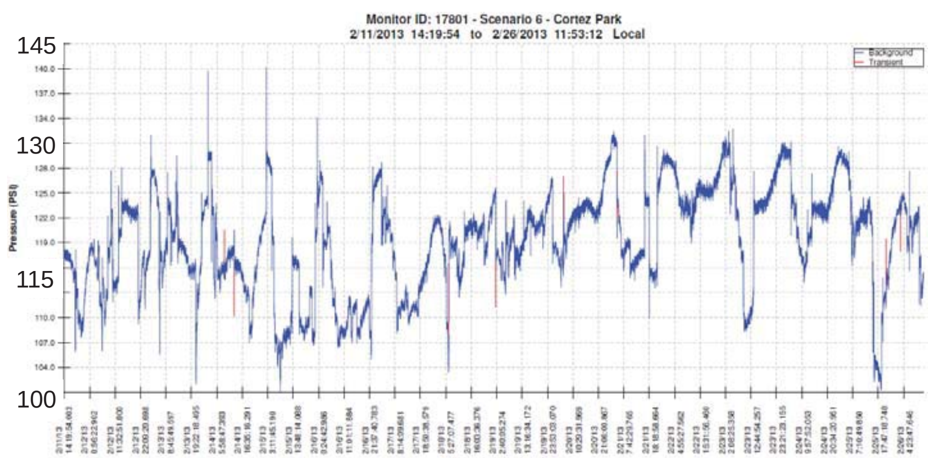
Long story short….

- In early 2009, LADWP institutes watering restrictions (every other day)
- 2009, cast iron blow outs increase dramatically.
- Root cause was that operational change due to water restrictions resulted in cyclic fatigue of aging brittle pipe material (cast iron) which leads to failures.
- 2010, even addresses water on even days, odd addresses water on odd days.
- Pipe breaks reduced back to previous levels.

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

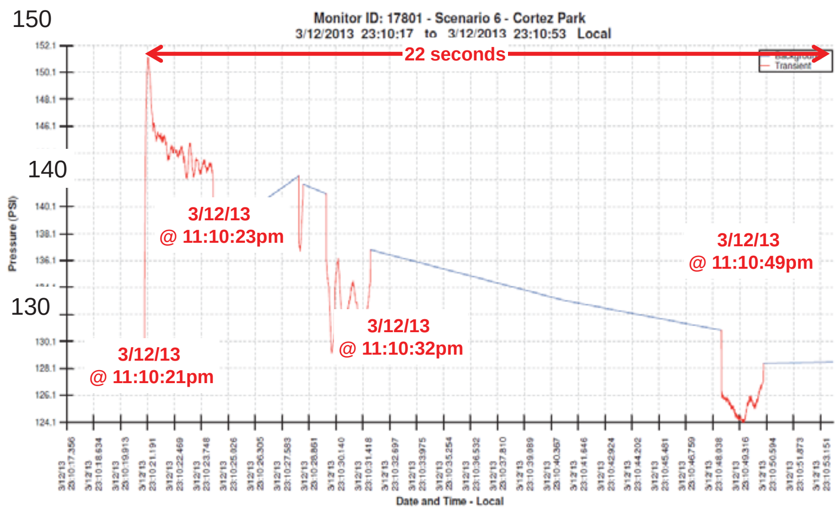
ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM



Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Scenario 6 Surge Event (PRV closing)



Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Research Needs

- Understand material fracture mechanics
  - Break morphology
  - Break frequency
  - Break mechanics
- Surge
  - Role in materials and pipe failure
  - Reduction
  - Analysis

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE PIPELINE RESEARCH NEEDS SYMPOSIUM

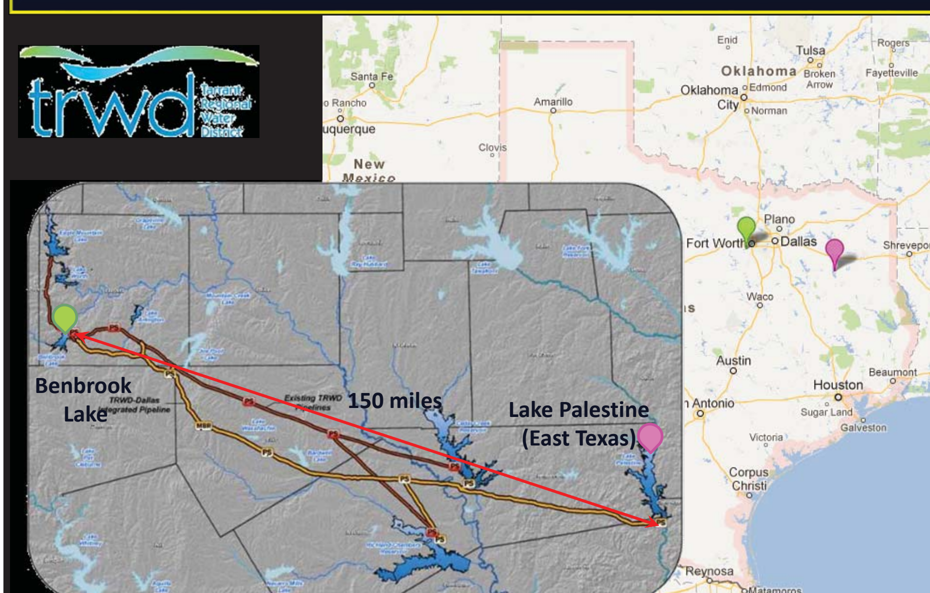
STAGED CONSTRUCTION MODELING OF A LARGE DIAMETER STEEL PIPE USING 3-D NONLINEAR FINITE ELEMENT ANALYSIS

PREPARED BY:
CENTER FOR STRUCTURAL ENGINEERING RESEARCH/ SIMULATION
PROFESSOR ABOLMAALI
MOJTABA S DEZFOOLI
MOHAMMAD RAZAVI

THE UNIVERSITY OF TEXAS AT ARLINGTON
DEPARTMENT OF CIVIL ENGINEERING

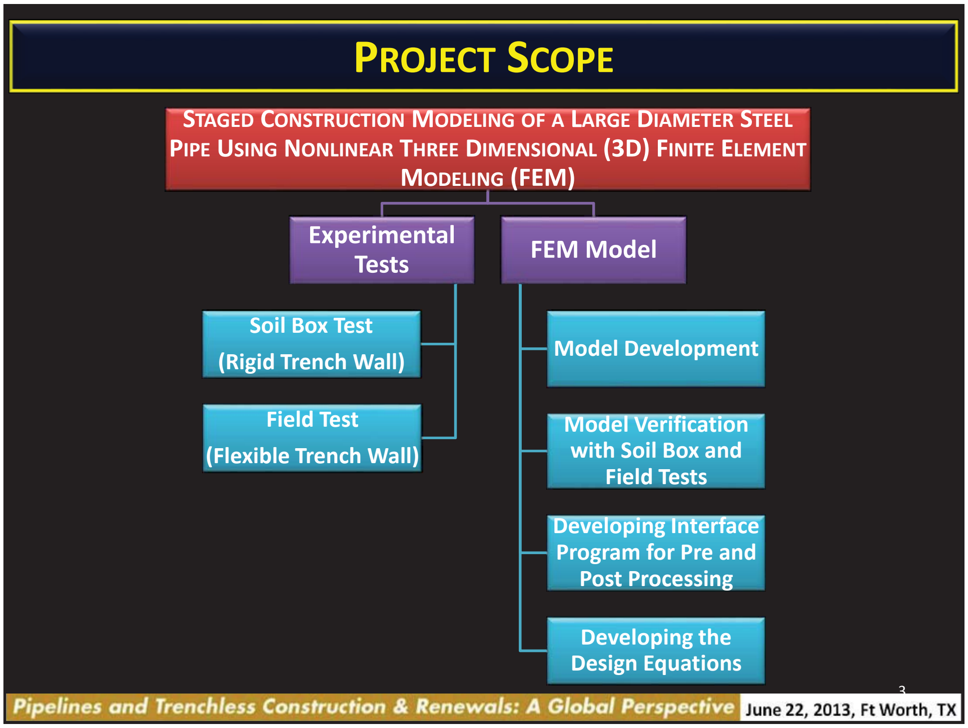
Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

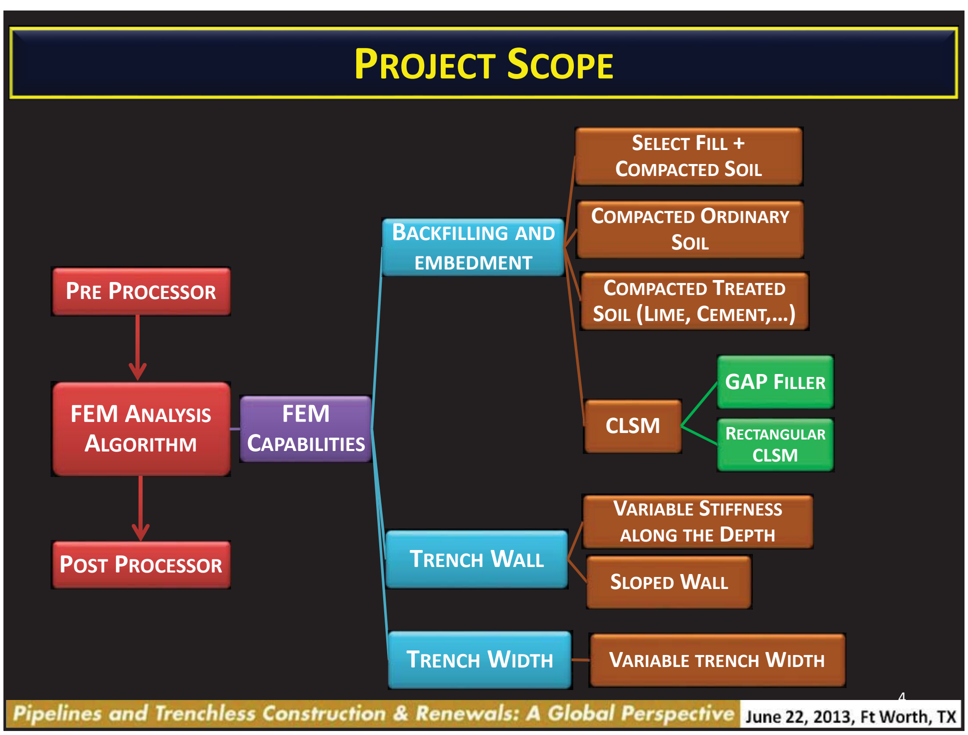
ACKNOWLEDGMENT



2

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

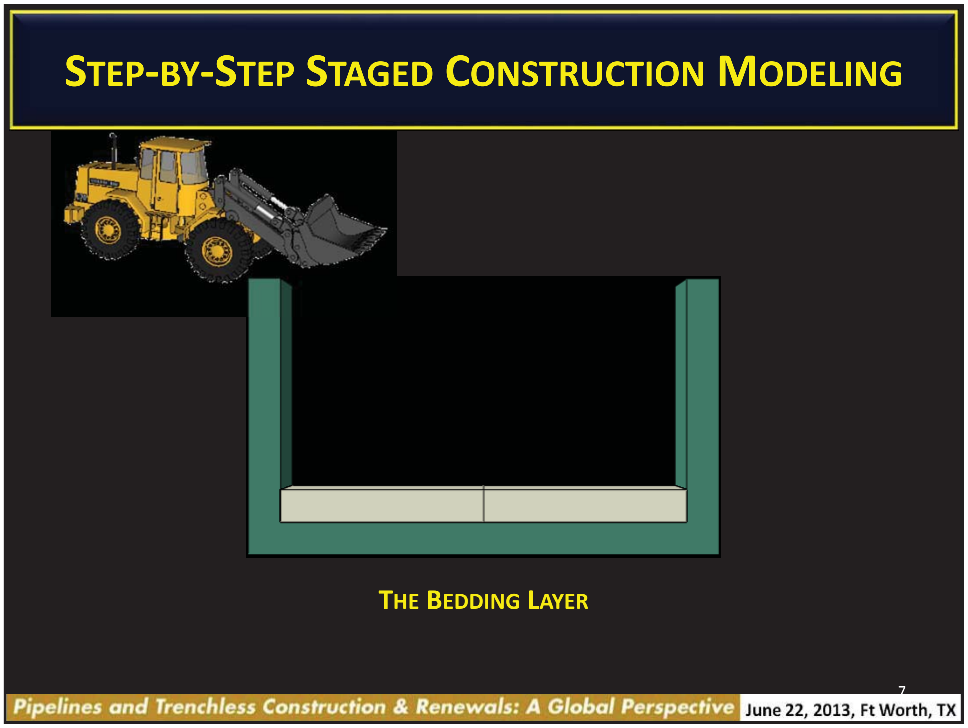

PROJECT SCOPE
STAGED CONSTRUCTION MODELING OF A LARGE DIAMETER STEEL PIPE USING NONLINEAR THREE DIMENSIONAL (3D) FINITE ELEMENT MODELING (FEM)
Experimental Tests
FEM Model
Soil Box Test (Rigid Trench Wall)
Field Test (Flexible Trench Wall)
Model Development
Model Verification with Soil Box and Field Tests
Developing Interface Program for Pre and Post Processing
Developing the Design Equations
3
Pipelines and Trenchless Construction & Renewals: A Global Perspective
June 22, 2013, Ft Worth, TX

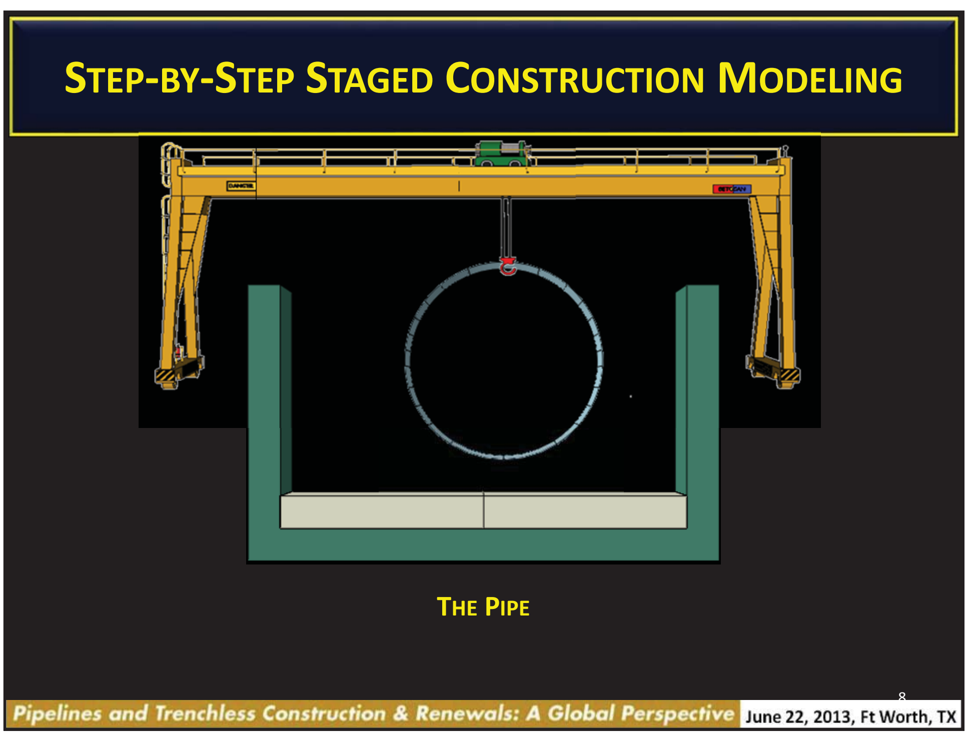

PROJECT SCOPE
PRE PROCESSOR
FEM ANALYSIS ALGORITHM
POST PROCESSOR
FEM CAPABILITIES
BACKFILLING AND EMBEDMENT
SELECT FILL + COMPACTED SOIL
COMPACTED ORDINARY SOIL
COMPACTED TREATED SOIL (LIME, CEMENT,...)
CLSM
GAP FILLER
RECTANGULAR CLSM
TRENCH WALL
VARIABLE STIFFNESS ALONG THE DEPTH
SLOPED WALL
TRENCH WIDTH
VARIABLE TRENCH WIDTH
4
Pipelines and Trenchless Construction & Renewals: A Global Perspective
June 22, 2013, Ft Worth, TX

FEM Model Development

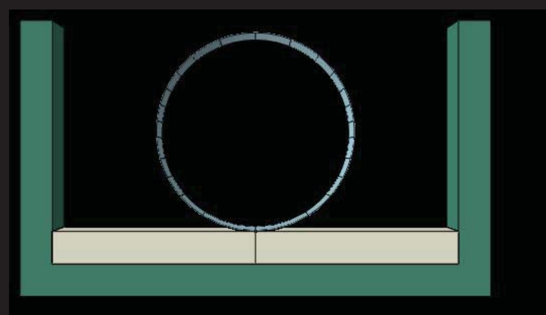
Step-by-Step Staged Construction Modeling

Concrete Box


STEP-BY-STEP STAGED CONSTRUCTION MODELING
THE BEDDING LAYER
7
Pipelines and Trenchless Construction & Renewals: A Global Perspective
June 22, 2013, Ft Worth, TX


STEP-BY-STEP STAGED CONSTRUCTION MODELING
THE PIPE
8
Pipelines and Trenchless Construction & Renewals: A Global Perspective
June 22, 2013, Ft Worth, TX

Step-by-Step Staged Construction Modeling

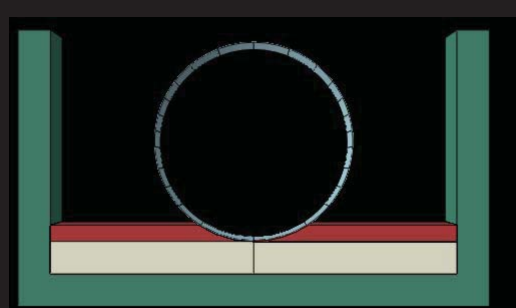


The Pipe

9

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

Step-by-Step Staged Construction Modeling

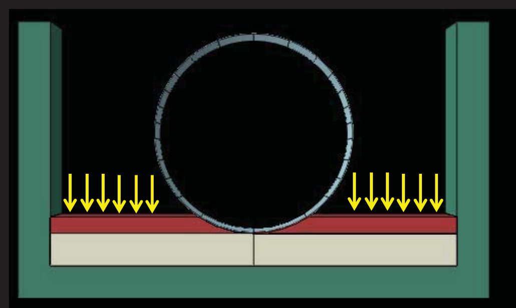


The First Layer

10

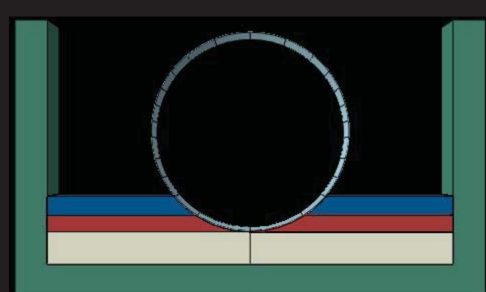
Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

STEP-BY-STEP STAGED CONSTRUCTION MODELING



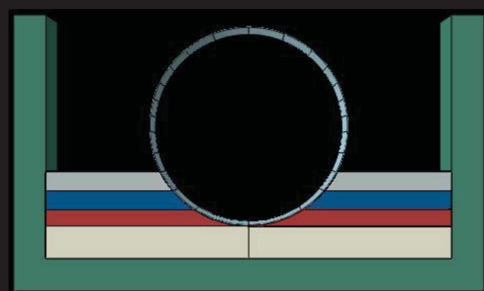
COMPACTION

STEP-BY-STEP STAGED CONSTRUCTION MODELING



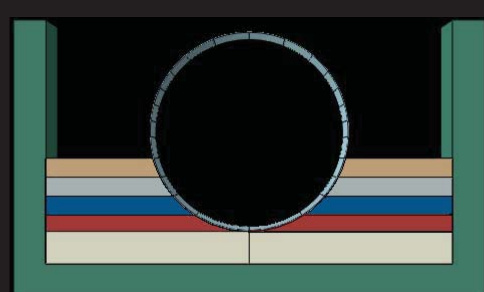
THE SECOND LAYER

Step-by-Step Staged Construction Modeling



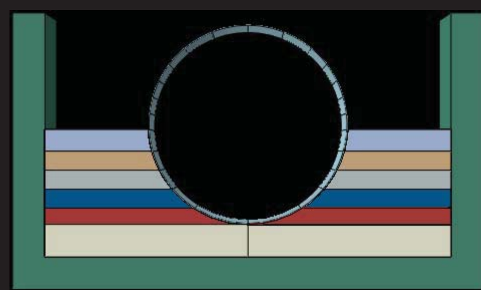
The Third Layer

Step-by-Step Staged Construction Modeling



The Forth Layer

STEP-BY-STEP STAGED CONSTRUCTION MODELING

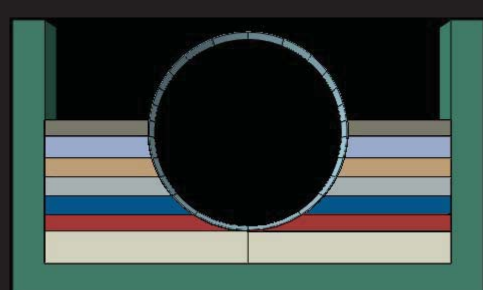


THE FIFTH LAYER

15

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

STEP-BY-STEP STAGED CONSTRUCTION MODELING

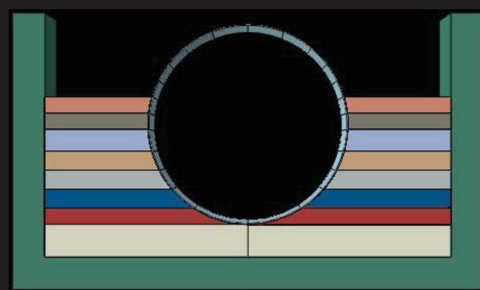


THE SIXTH LAYER

16

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

Step-by-Step Staged Construction Modeling

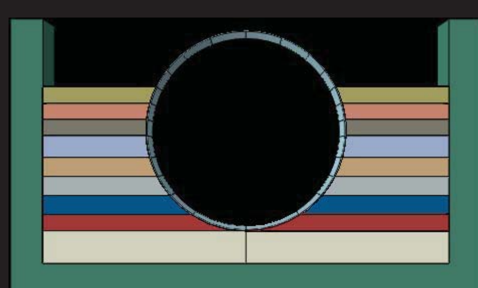


The Seventh Layer

17

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

Step-by-Step Staged Construction Modeling

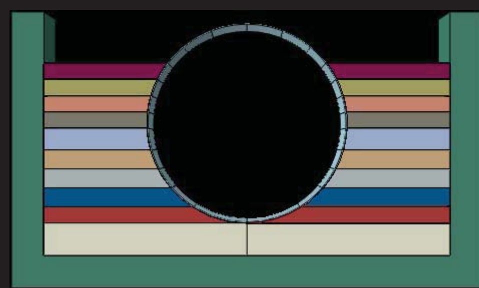


The Eighth Layer

18

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

Step-by-Step Staged Construction Modeling

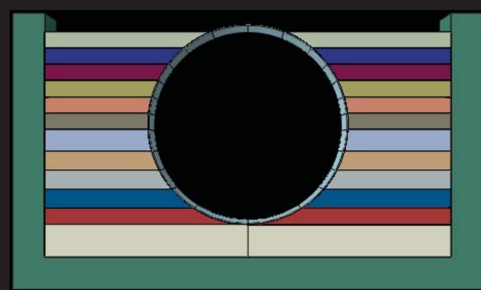


The Ninth Layer

Step-by-Step Staged Construction Modeling

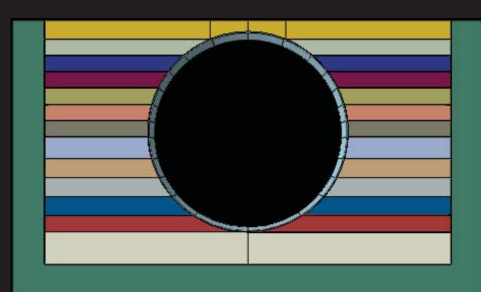
The Tenth Layer

STEP-BY-STEP STAGED CONSTRUCTION MODELING



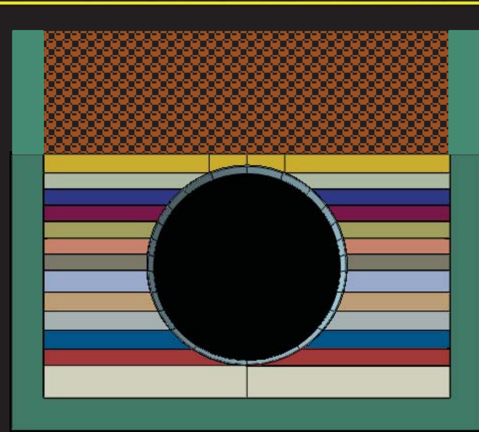
THE ELEVENTH LAYER

STEP-BY-STEP STAGED CONSTRUCTION MODELING



THE TWELFTH LAYER

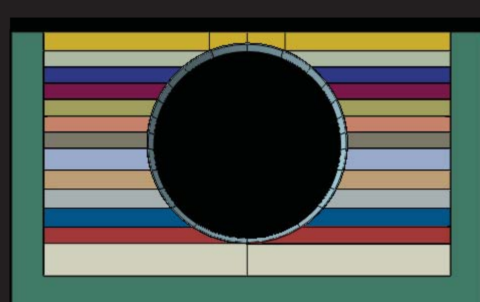
Step-by-Step Staged Construction Modeling



The Surcharge Layer

23

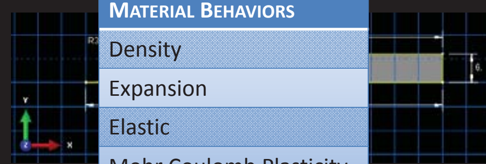
Step-by-Step Staged Construction Modeling



The FEM Model Parts

24

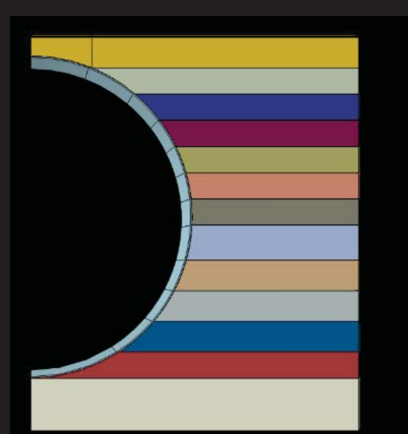
Step-by-Step Staged Construction Modeling



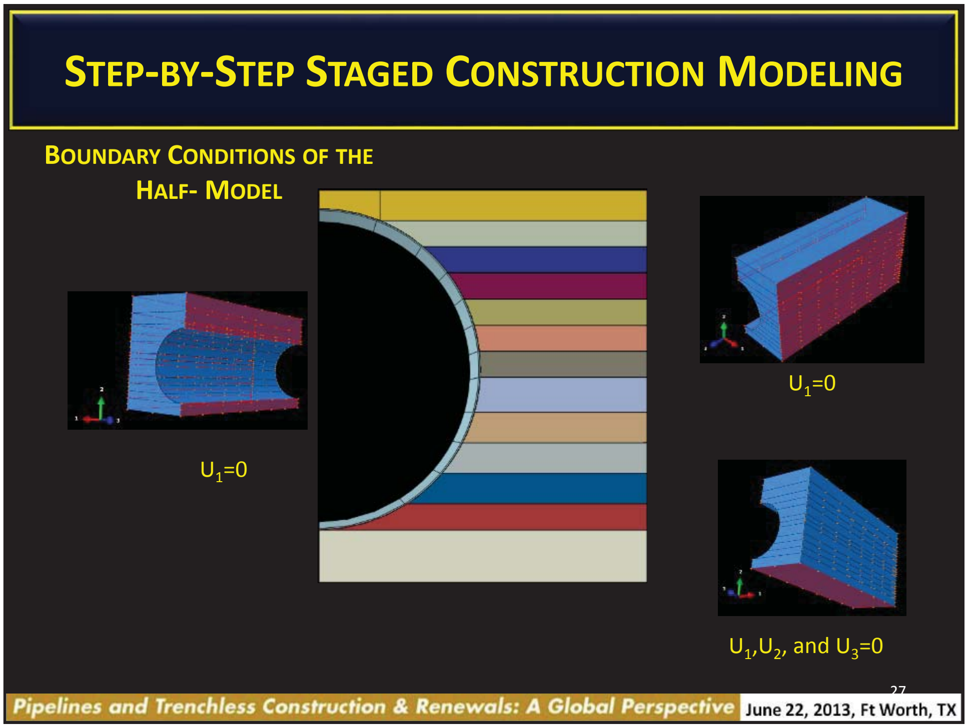
Material Behaviors
Density
Expansion
Elastic
Mohr Coulomb Plasticity

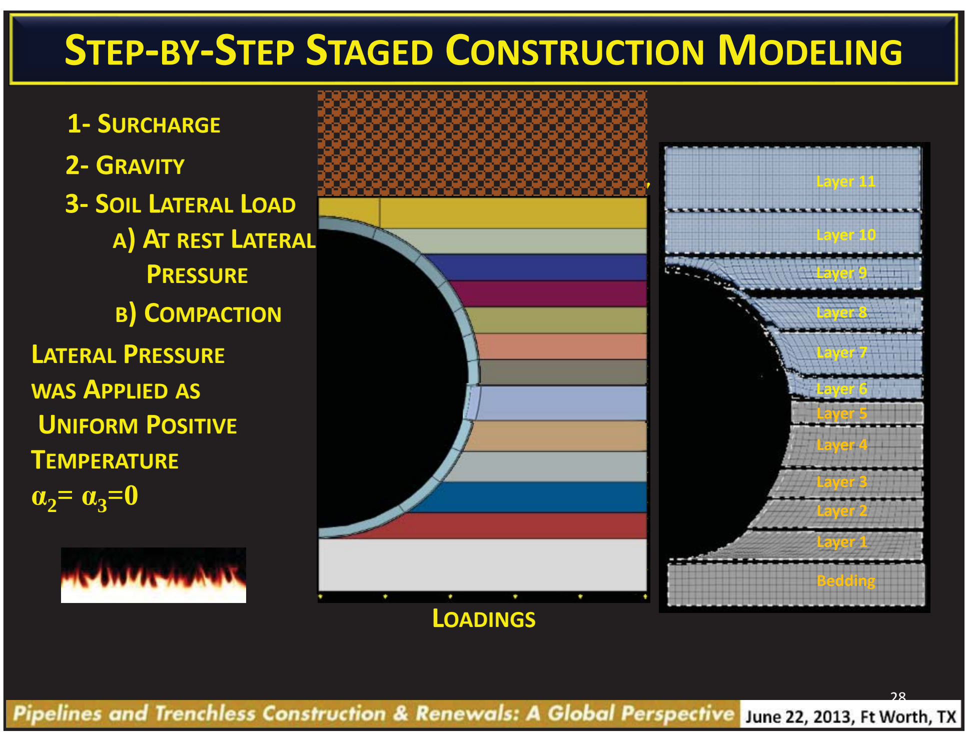
Defining Geometry and Material Properties for each Part

Step-by-Step Staged Construction Modeling

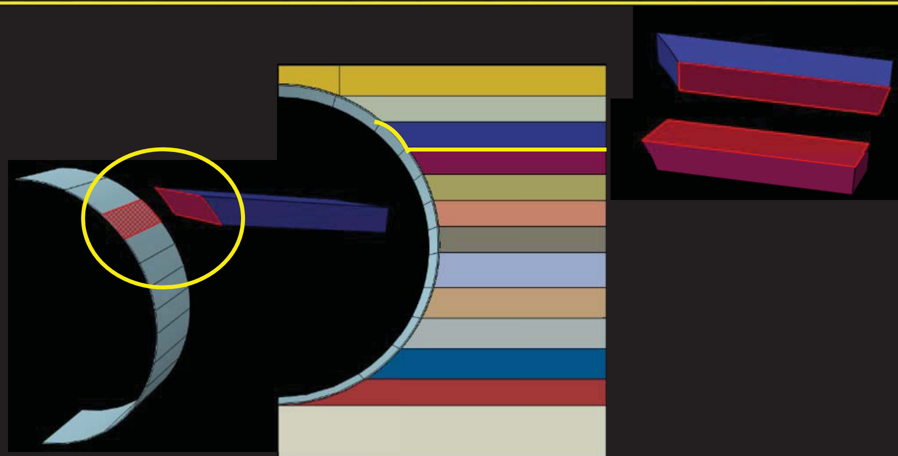


Assembling Half of the Model


STEP-BY-STEP STAGED CONSTRUCTION MODELING
BOUNDARY CONDITIONS OF THE HALF- MODEL
U_1=0
U_1=0
U_1,U_2, and U_3=0
27
Pipelines and Trenchless Construction & Renewals: A Global Perspective
June 22, 2013, Ft Worth, TX

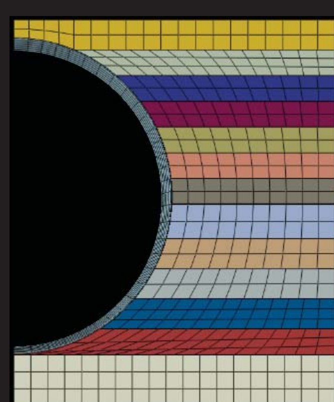

STEP-BY-STEP STAGED CONSTRUCTION MODELING
1- SURCHARGE
2- GRAVITY
3- SOIL LATERAL LOAD
A) AT REST LATERAL PRESSURE
B) COMPACTION
LATERAL PRESSURE WAS APPLIED AS UNIFORM POSITIVE TEMPERATURE
$\alpha_2 = \alpha_3 = 0$
Layer 11
Layer 10
Layer 9
Layer 8
Layer 7
Layer 6
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
Bedding
LOADINGS
28
Pipelines and Trenchless Construction & Renewals: A Global Perspective
June 22, 2013, Ft Worth, TX

Step-by-Step Staged Construction Modeling



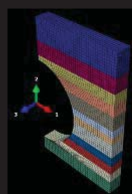
Contact Modeling

Step-by-Step Staged Construction Modeling

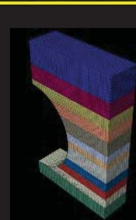


Initial Un-converged Mesh

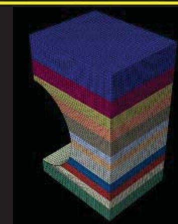
FEM Models



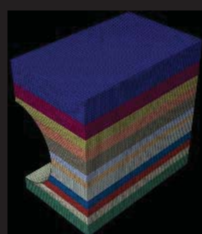
1 foot



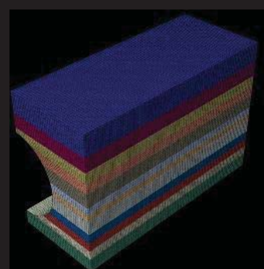
2 feet



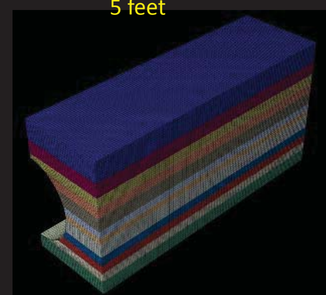
5 feet



10 feet



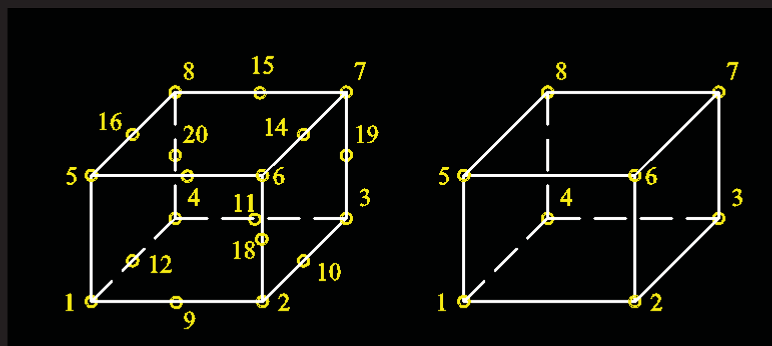
15 feet



20 feet

Theoretical Background

Type of Elements

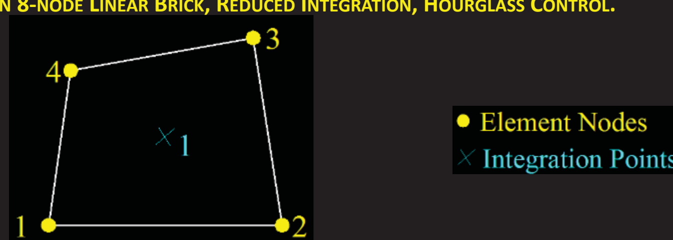


20-Node Brick Element

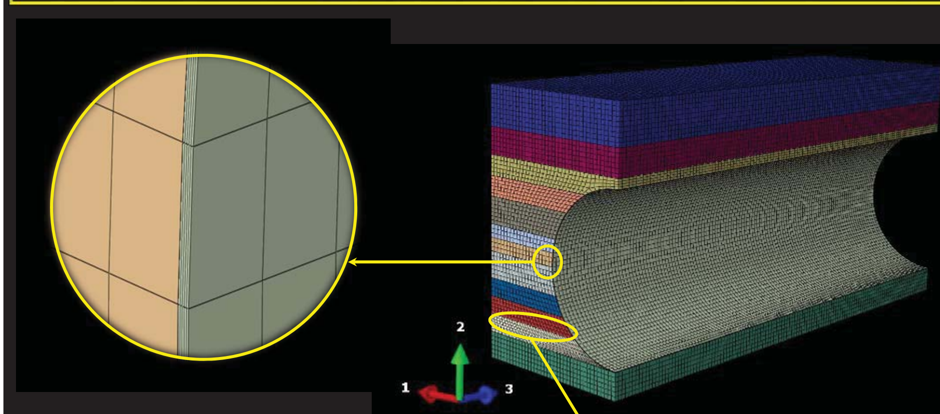
8-Node Brick Element

Type of Elements

C3D8R (For Pipe): An 8-node Linear Brick, Reduced Integration, Hourglass Control.



Contact Properties



Number of elements in pipe thickness: 5
Contact Soil-pipe:
Tangential: friction coefficient
Normal behavior: Hard contact

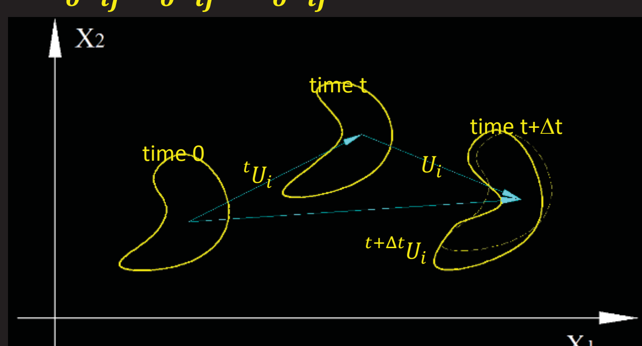
Contact Soil-Soil:
Tangential: friction coefficient
Normal behavior: Hard contact

Geometric, Material, and Contact Nonlinearities

$$\delta\ {}^{t+\Delta t}_{o}\varepsilon_{ij} = \delta\ {}_{o}\varepsilon_{ij}$$

$${}^{t+\Delta t}_{o}S_{ij} = {}^{t}_{o}S_{ij} + {}_{o}S_{ij}$$

$${}^{t+\Delta t}_{o}\varepsilon_{ij} = {}^{t}_{o}\varepsilon_{ij} + {}_{o}\varepsilon_{ij}$$



Geometric, Material, and Contact Nonlinearities

$${}^{t}_{o}\varepsilon_{ij} = \frac{1}{2}\left({}^{t}_{o}U_{i,j} + {}^{t}_{o}U_{j,i} + {}^{t}_{o}U_{k,i}\,{}^{t}_{o}U_{k,j}\right)$$

$${}^{t+\Delta t}_{o}\varepsilon_{ij} = \frac{1}{2}\left({}^{t+\Delta t}_{o}U_{i,j} + {}^{t+\Delta t}_{o}U_{j,i} + {}^{t+\Delta t}_{o}U_{k,i}\,{}^{t+\Delta t}_{o}U_{k,j}\right)$$

$${}_{o}\varepsilon_{ij} = \underbrace{\frac{1}{2}\left({}_{o}U_{i,j} + {}_{o}U_{j,i} + {}^{t}_{o}U_{k,i}\,{}_{o}U_{k,j} + {}_{o}U_{k,i}\,{}^{t}_{o}U_{k,j}\right)}_{\text{Linear in } U_i\ ({}_{o}e_{ij})} + \underbrace{\frac{1}{2}\,{}_{o}U_{k,i}\,{}_{o}U_{k,j}}_{\text{Non-Linear in } U_i\ ({}_{o}\eta_{ij})}$$

$${}_{o}\varepsilon_{ij} = {}_{o}e_{ij} + {}_{o}\eta_{ij}$$

$$\delta\,{}_{o}\varepsilon_{ij} = \delta\,{}_{o}e_{ij} + \delta\,{}_{o}\eta_{ij}$$

Geometric, Material, and Contact Nonlinearities

Geometric Nonlinearity

${}^{t}_{o}S_{ij}$: 2nd Piola Kirchhoff Stress Tensor
${}^{t}_{o}\tau_{ij}$: Cauchy Stress Tensor
${}^{t}_{o}\sigma_{ij}$: Physical Stress Tensor

$${}^{t}_{o}S_{ij} = \frac{{}^{o}\rho}{{}^{t}\rho}\,X_{i,m}\,\tau_{mn}\,X_{j,n}$$

For Isotropic Material:

$${}^{t}_{o}C_{ijrs} = \lambda\delta_{ij}\delta_{rs} + \mu(\delta_{ir}\delta_{js} + \delta_{is}\delta_{jr})$$

λ and μ are Lamé Constants:

$$\lambda = \frac{E}{(1+\nu)(1-2\nu)} \qquad \mu = \frac{E}{2(1+\nu)}$$

Geometric, Material, and Contact Nonlinearities

Large Deformation

For Total Lagrangian:

$$\int_{^oV} {}_oC_{ijrs}\ \ {}_oe_{rs}\, \delta_o e_{ij}\, d^oV + \int_{^oV} {}^t_oS_{ij}\ \delta_o\eta_{ij}\, d^oV = {}^{t+\Delta t}R - \int_{^oV} {}^t_oS_{ij}\ \delta_o e_{ij}\, d^oV$$

For Updated Lagrangian:

$$\int_{^tV} {}_tC_{ijrs}\ \ {}_te_{rs}\, \delta_t e_{ij}\, d^tV + \int_{^tV} {}^t_tS_{ij}\ \delta_t\eta_{ij}\, d^tV = {}^{t+\Delta t}R - \int_{^tV} {}^t\tau_{ij}\ \delta_t e_{ij}\, d^tV$$

Material Nonlinearity Only (M.N.O):

$$\int_V C_{ijrs}\ \Delta e_{rs}\, \delta e_{ij}\, dV = {}^{t+\Delta t}R - \int_V {}^{t+\Delta t}e_{ij}\ \delta e_{ij}\, dV$$

Geometric, Material, and Contact Nonlinearities

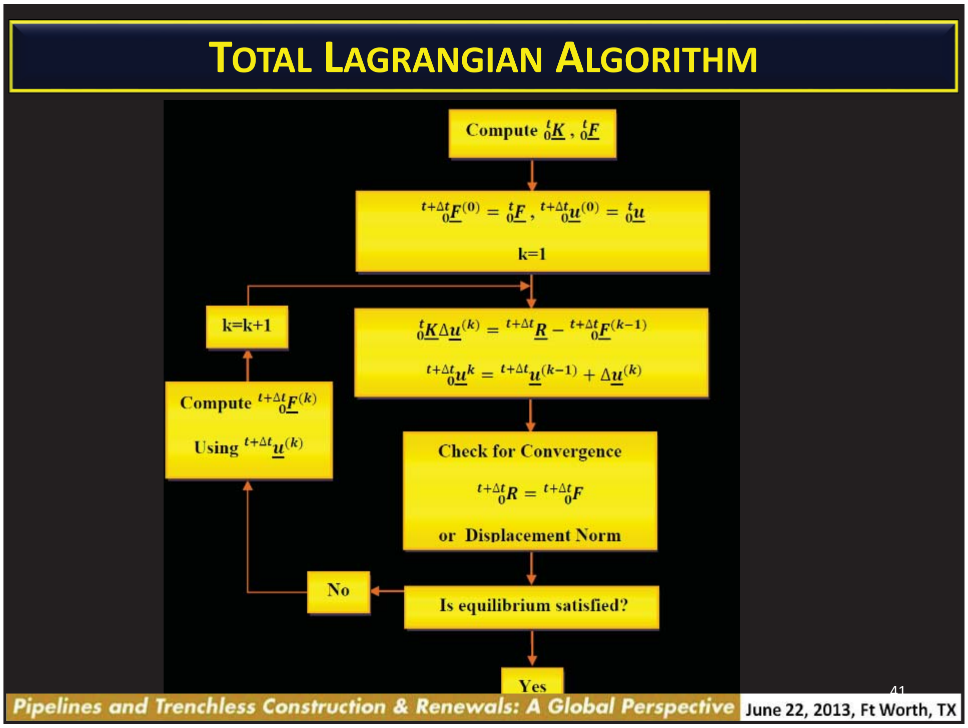
Large Deformation

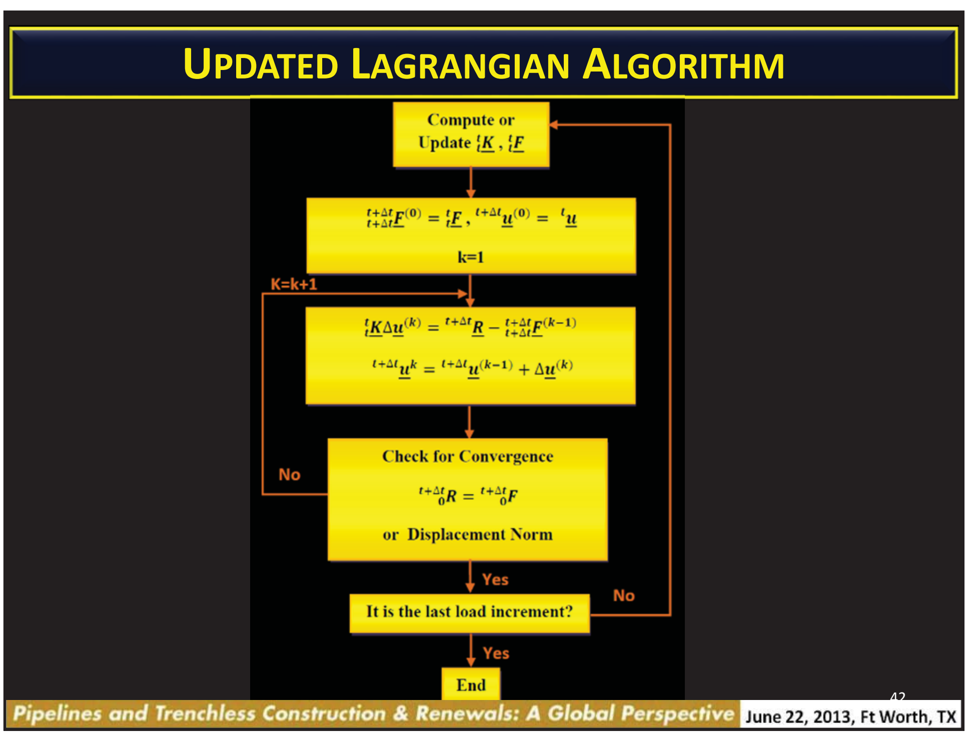
If explicit time integration is considered:

For TL: $${}^tR = \int_{^oV} {}^t_oS_{ij}\, \delta\, {}^t_o\varepsilon_{ij}\ d^oV$$

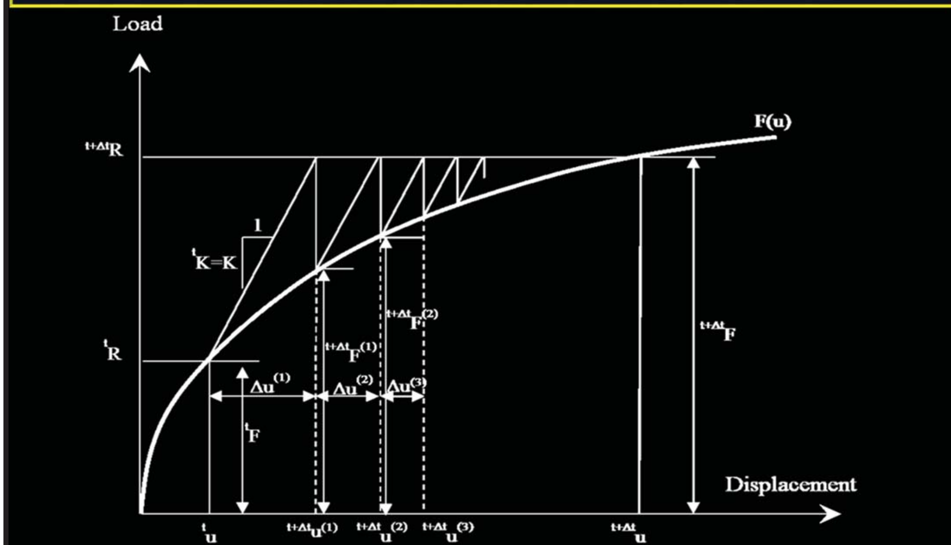
For UL: $${}^tR = \int_{^tV} {}^t\tau_{ij}\, \delta\ {}_t\varepsilon_{ij}\ d^tV$$

For M.N.O: $${}^tR = \int_V {}^t\sigma_{ij}\, \delta e_{ij}\ dV$$

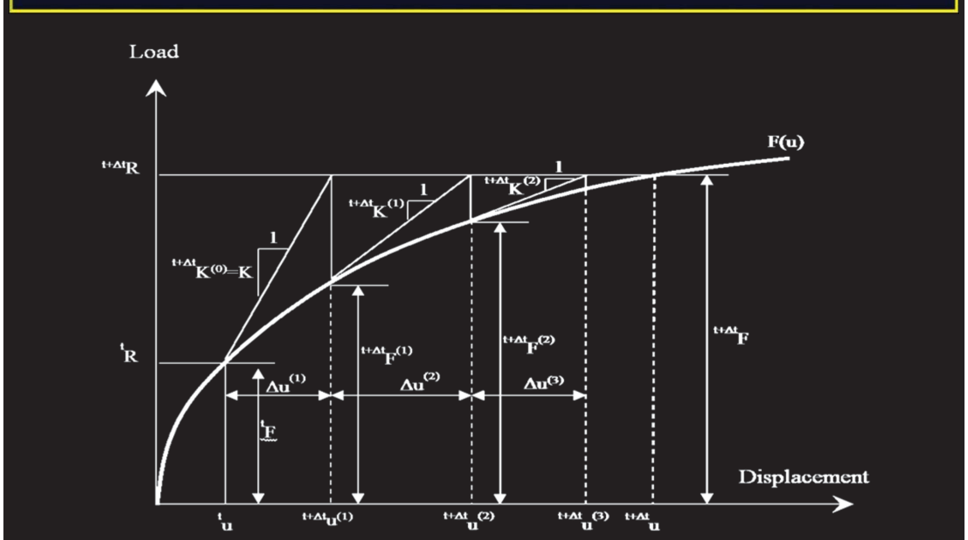

TOTAL LAGRANGIAN ALGORITHM
Compute ${}^{t}_{0}\underline{K}$, ${}^{t}_{0}\underline{F}$
${}^{t+\Delta t}_{0}\underline{F}^{(0)} = {}^{t}_{0}\underline{F}$, ${}^{t+\Delta t}_{0}\underline{u}^{(0)} = {}^{t}_{0}\underline{u}$
k=1
${}^{t}_{0}\underline{K}\Delta\underline{u}^{(k)} = {}^{t+\Delta t}\underline{R} - {}^{t+\Delta t}_{0}\underline{F}^{(k-1)}$
${}^{t+\Delta t}_{0}\underline{u}^{k} = {}^{t+\Delta t}\underline{u}^{(k-1)} + \Delta\underline{u}^{(k)}$
k=k+1
Compute ${}^{t+\Delta t}_{0}\underline{F}^{(k)}$
Using ${}^{t+\Delta t}\underline{u}^{(k)}$
Check for Convergence
${}^{t+\Delta t}_{0}R = {}^{t+\Delta t}_{0}F$
or Displacement Norm
Is equilibrium satisfied?
No
Yes
41
Pipelines and Trenchless Construction & Renewals: A Global Perspective
June 22, 2013, Ft Worth, TX


UPDATED LAGRANGIAN ALGORITHM
Compute or
Update ${}^{t}_{t}\underline{K}$, ${}^{t}_{t}\underline{F}$
${}^{t+\Delta t}_{t+\Delta t}\underline{F}^{(0)} = {}^{t}_{t}\underline{F}$, ${}^{t+\Delta t}\underline{u}^{(0)} = {}^{t}\underline{u}$
k=1
K=k+1
${}^{t}_{t}\underline{K}\Delta\underline{u}^{(k)} = {}^{t+\Delta t}\underline{R} - {}^{t+\Delta t}_{t+\Delta t}\underline{F}^{(k-1)}$
${}^{t+\Delta t}\underline{u}^{k} = {}^{t+\Delta t}\underline{u}^{(k-1)} + \Delta\underline{u}^{(k)}$
No
Check for Convergence
${}^{t+\Delta t}_{0}R = {}^{t+\Delta t}_{0}F$
or Displacement Norm
Yes
It is the last load increment?
No
Yes
End
42
Pipelines and Trenchless Construction & Renewals: A Global Perspective
June 22, 2013, Ft Worth, TX

MODIFIED NEWTON-RAPHSON SCHEME



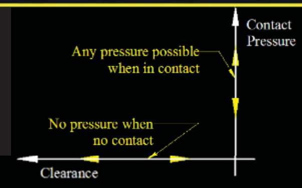
NEWTON-RAPHSON SCHEME



Contact Nonlinearity

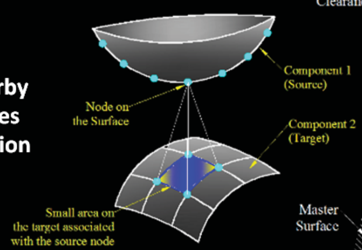
Contact Discretization

- Hard contact pressure-over closure relationship



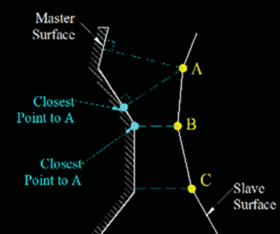
- Node-to-surface contact

Each contact involves a single slave node and a group of nearby master nodes from which values are interpolated to the projection point.



- Surface-to-surface contact

The surface-to-surface formulation enforces contact conditions in an average sense over regions nearby slave nodes rather than only at individual slave nodes



Material Nonlinearity for Steel

Yield Criteria:

$$^{t}F(\,^{t}\sigma_{ij} - \,^{t}k) = 0 \;\Rightarrow$$

Thus, $^{T}F=0$ through plastic deformation

$^{t}\sigma_{ij}$ = Current Stress State

^{t}k = Function of Plastic Strain

Flow Rule

$$de^{P} = \,^{t}\lambda \frac{\partial G}{\partial \sigma_{ij}}$$

G: Potential Function

If $G(\sigma_{ij}) = \,^{t}F$

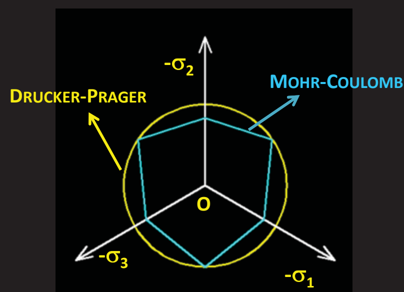
$$de^{P} = \,^{t}\lambda \frac{\partial \,^{t}F}{\partial \sigma_{ij}}$$

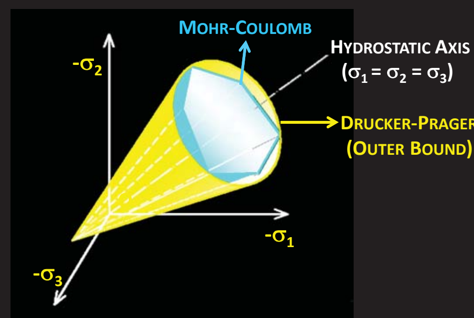
Hardening Rule

- ❑ Isotropic Hardening
- ❑ Kinematic Hardening
- ❑ Combined Hardening

Soil Plasticity Constitutive Models

- ❑ Drucker-Prager
- ❑ Mohr Coulomb





Literature Review for Effects of Compaction

- ❑ Katona, M.G., Meinhert, D.F., Orillac, R., Lee, C.H., 1979, "*Structural Evaluation of New Concepts for Long-Span Culverts and Culvert Installations,*" Federal Highway Administration Report No. FHWA-RD-79-115.
- ❑ Clayton, C. R. I., Symons, I. F., 1992, "*The Pressure of Compacted fill on Retaining walls,*" Geotechnique 42, No. 1, pp. 127-130.
- ❑ Seed, R. B., Duncan, J. M., 1984, "*SSCOMP: A Finite Element Analysis Program for Evaluation of Soil-Structure Interaction and Compaction Effects,*" Geotechnical Engineering Research Report No. UCB/GT/84-02, University of California, Berkeley.
- ❑ Seed, R. B., Duncan, J. M., 1983, "*Soil-Structure Interaction Effects of Compaction-Induced Stresses and Deflections,*" Geotechnical Engineering Research Report No. UCB/GT/83-06, University of California, Berkeley.
- ❑ Duncan, James M., Seed, Raymond B., 1986, "*Compaction-Induced Earth Pressures under K_0-Conditions,*" Journal of Geotechnical Engineering, Vol. 112, No. 1, pp. 1-22.
- ❑ Seed, Raymond B., Duncan, James M., 1986, "*FE Analysis: Compaction-Induced Stresses and Deformations,*" Journal of Geotechnical Engineering, Vol. 112, No. 1, pp. 23-43.

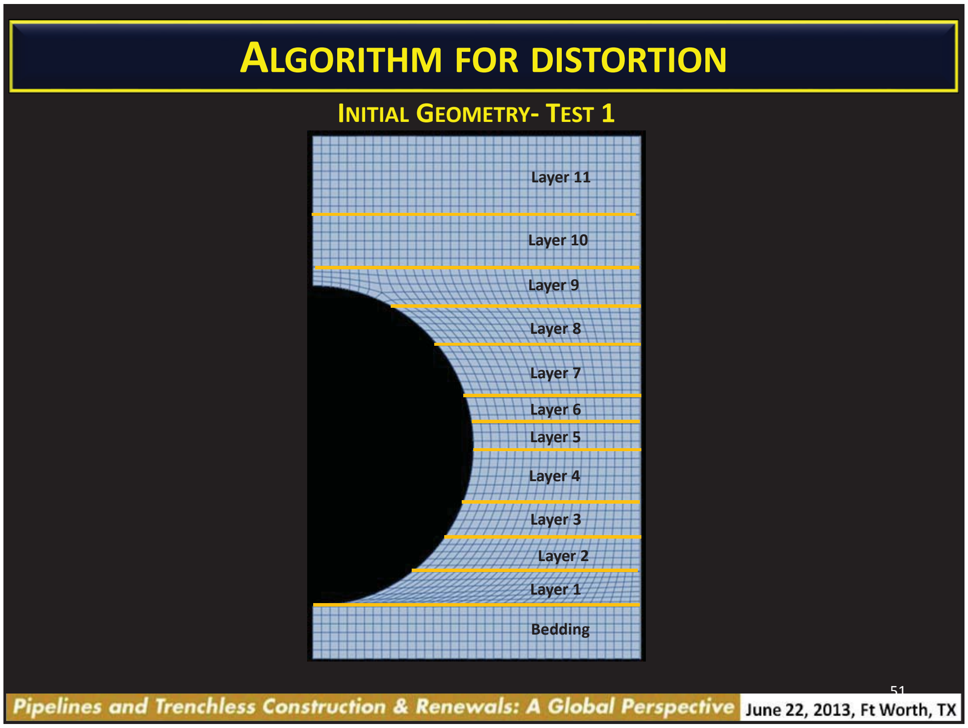
Induced Horizontal Load on the Pipes due to Compaction

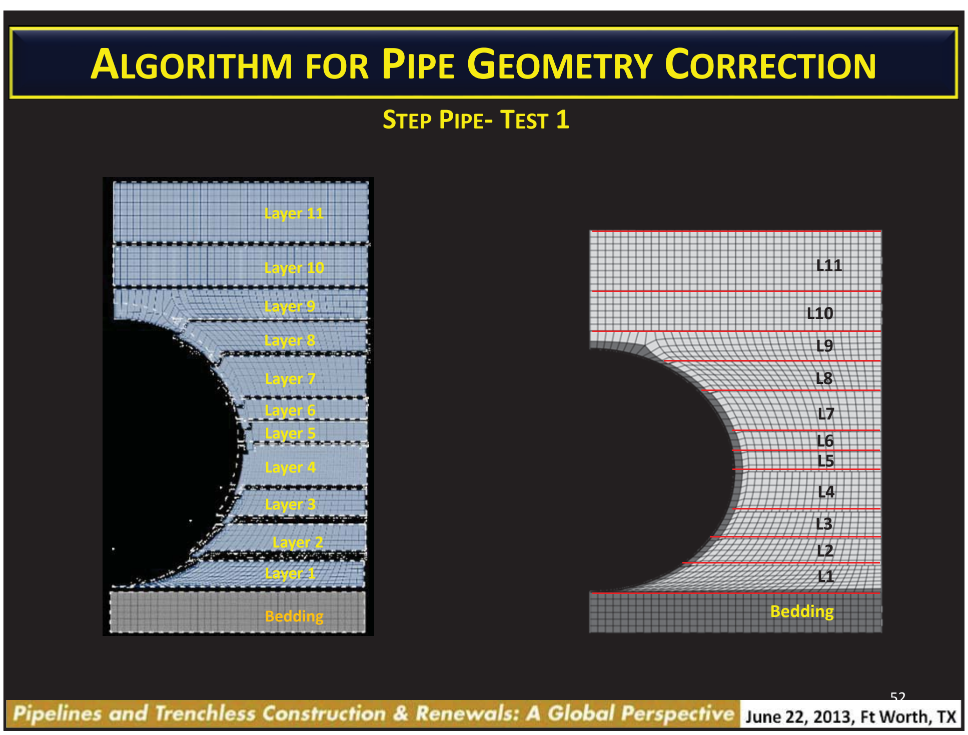
- Although Sophisticated, Well-Proven Theories Do Not Yet Exist for the Accurate Prediction of the Pressure Distribution from Compacted Soil
- Lateral Stress is Proportional to the Compacted Undrained Shear Strength of the Clay and is a Function of its Plastic Index
- For Higher and Lower Soil Plastic Indices , $0.8C_U$ and $0.2\ C_U$ is Recommended for Simulation of Lateral Pressure, Respectively.
- Lateral Pressure due to Compaction is Higher than Earth Pressure at-rest (or Active) and it's Uniform
- Compaction and At-Rest Lateral Soil Pressure is Applied in Term of Uniform Temperature Distribution

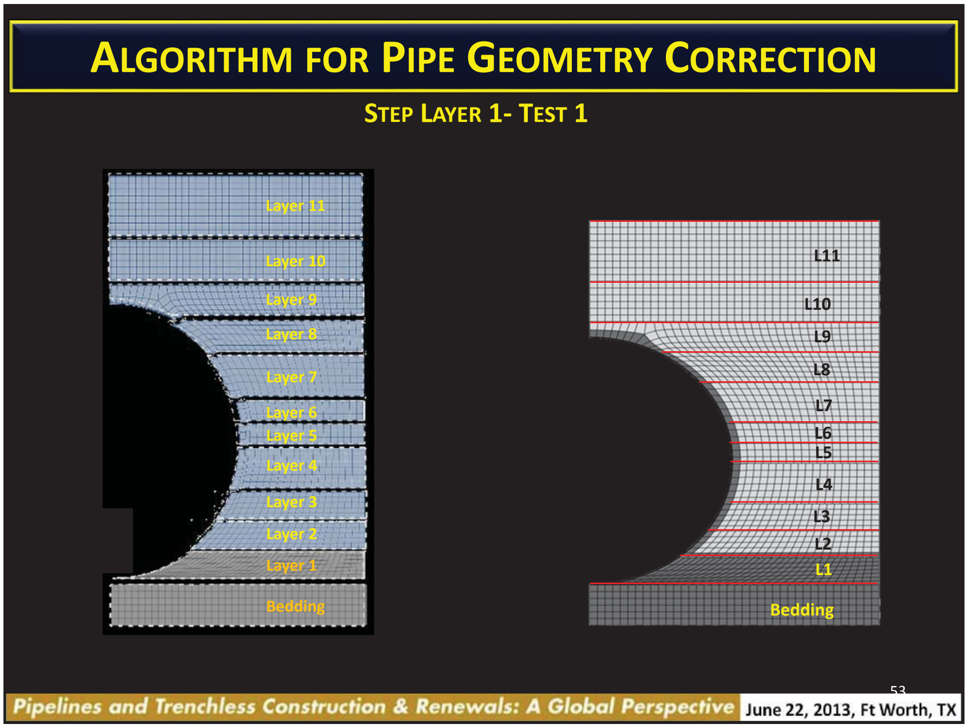
Induced Horizontal Load on the Pipes due to Compaction

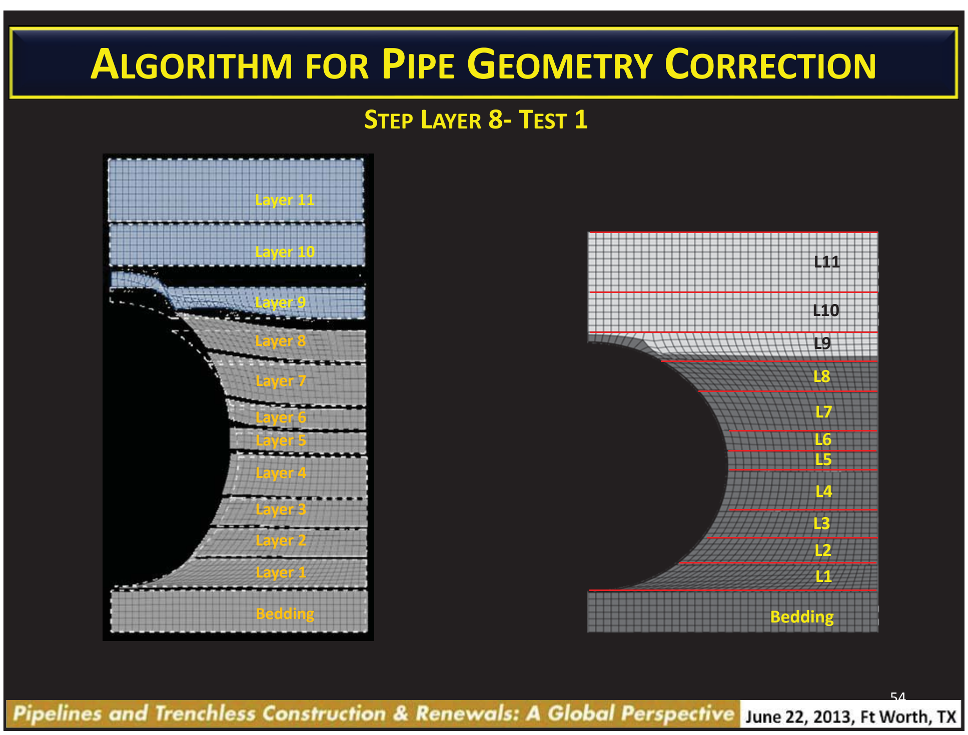
- Lateral Soil Pressure due to Compaction is Verified Using Soil Box Test Results
- An Equation is Developed For Lateral Soil Pressure Due to Compaction Using Mechanics of Material Formulation for Series Springs and the Results from Soil Box Test

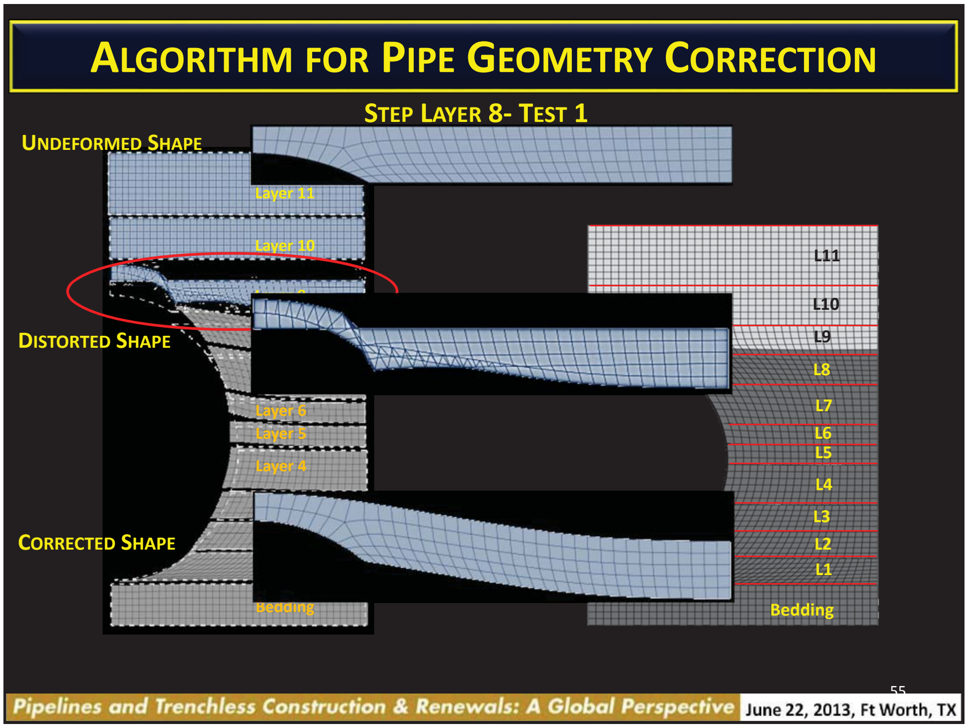
$$\alpha \Delta T = \sigma_S\left(-\frac{A}{l.K_{Pipe}} - \frac{A}{l.K_{Wall}} - \frac{1}{E_{Soil}}\right)$$

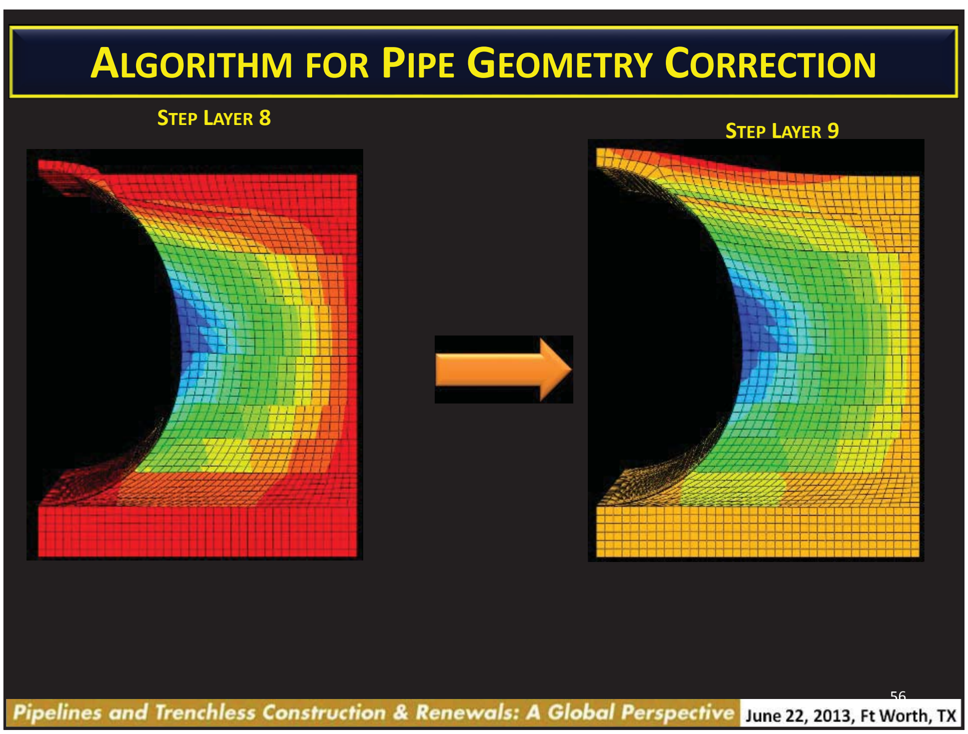

ALGORITHM FOR DISTORTION
INITIAL GEOMETRY- TEST 1
Layer 11
Layer 10
Layer 9
Layer 8
Layer 7
Layer 6
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
Bedding
51
Pipelines and Trenchless Construction & Renewals: A Global Perspective
June 22, 2013, Ft Worth, TX


ALGORITHM FOR PIPE GEOMETRY CORRECTION
STEP PIPE- TEST 1
Layer 11
Layer 10
Layer 9
Layer 8
Layer 7
Layer 6
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
Bedding
L11
L10
L9
L8
L7
L6
L5
L4
L3
L2
L1
Bedding
52
Pipelines and Trenchless Construction & Renewals: A Global Perspective
June 22, 2013, Ft Worth, TX


ALGORITHM FOR PIPE GEOMETRY CORRECTION
STEP LAYER 1- TEST 1
Layer 11
Layer 10
Layer 9
Layer 8
Layer 7
Layer 6
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
Bedding
L11
L10
L9
L8
L7
L6
L5
L4
L3
L2
L1
Bedding
53
Pipelines and Trenchless Construction & Renewals: A Global Perspective
June 22, 2013, Ft Worth, TX


ALGORITHM FOR PIPE GEOMETRY CORRECTION
STEP LAYER 8- TEST 1
Layer 11
Layer 10
Layer 9
Layer 8
Layer 7
Layer 6
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
Bedding
L11
L10
L9
L8
L7
L6
L5
L4
L3
L2
L1
Bedding
54
Pipelines and Trenchless Construction & Renewals: A Global Perspective
June 22, 2013, Ft Worth, TX

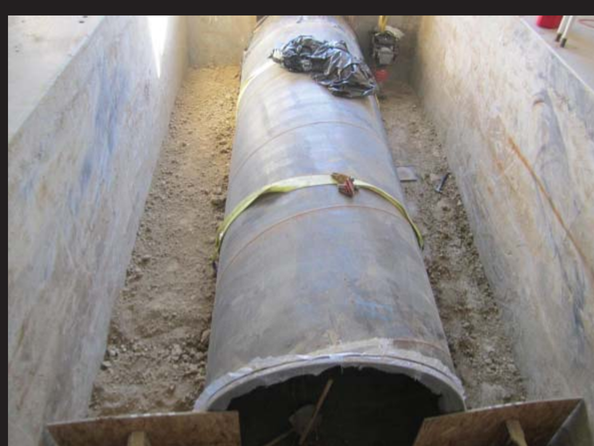

ALGORITHM FOR PIPE GEOMETRY CORRECTION
STEP LAYER 8- TEST 1
UNDEFORMED SHAPE
DISTORTED SHAPE
CORRECTED SHAPE
Layer 11
Layer 10
Layer 6
Layer 5
Layer 4
L11
L10
L9
L8
L7
L6
L5
L4
L3
L2
L1
Bedding
55
Pipelines and Trenchless Construction & Renewals: A Global Perspective
June 22, 2013, Ft Worth, TX


ALGORITHM FOR PIPE GEOMETRY CORRECTION
STEP LAYER 8
STEP LAYER 9
56
Pipelines and Trenchless Construction & Renewals: A Global Perspective
June 22, 2013, Ft Worth, TX

Soil Box Test (Rigid Trench Wall)

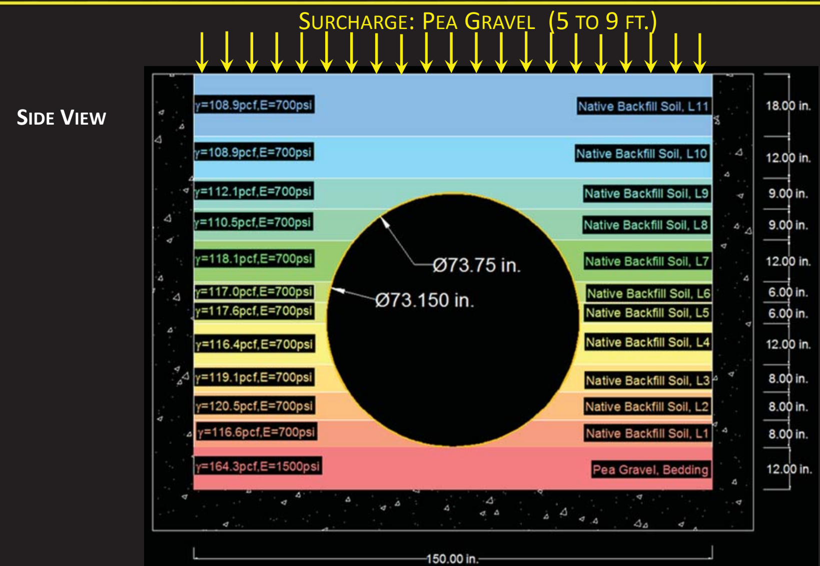
57

Soil Box Test-Test 1- Ordinary Backfill



58

Soil Box Test-Test 1- Ordinary Backfill



59

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

Soil Box Tests Specifications

- Test 1
  - Bedding: Pea Gravel
  - Layers 1 to 14: Ordinary Backfill Soil
  - Surcharge: Pea Gravel

SUMMARY OF TEST RESULTS for B6 soil					
Sample location ID			B6	B6	B6
% Lime added			Control (0% lime)	6% lime treated	3% cement+10 % fly ash treated
ENGINEERING TESTS	Standard Proctor	MDD*, pcf	108.1	98.6	105.6
		OMC** (%)	16.2	19.0	17.0
	UU Triaxial	Undrained Cohesion, C_u, kPa	98.0 (14.5)	160 (23.2)	220 (31.9)
		Angle of internal friction, φ	8.1°	25.8°	36.9°
	UCS	Unconfined compression strength, kPa	156.6 (22.7)	425.0 (61.7)	725.0 (105)
ELASTIC MODULUS, kPa	Confining pressure = 50 kPa		3900 (565.6)	24492.3 (3552.4)	150,000.4 (21755.6)
	Confining pressure = 100 kPa		4350 (630.9)	53963.9 (7826.9)	175,000.0 (25381.6)
	Confining pressure = 150 kPa		4530 (657.03)	53101.3 (7701.8)	229,166.7 (33237.8)

Notes:
All values in paranthesis are in psi units
* MDD is Maximum dry density
** OMC is Optimum moisture content

* Soil Specifications from Geotechnical Report

60

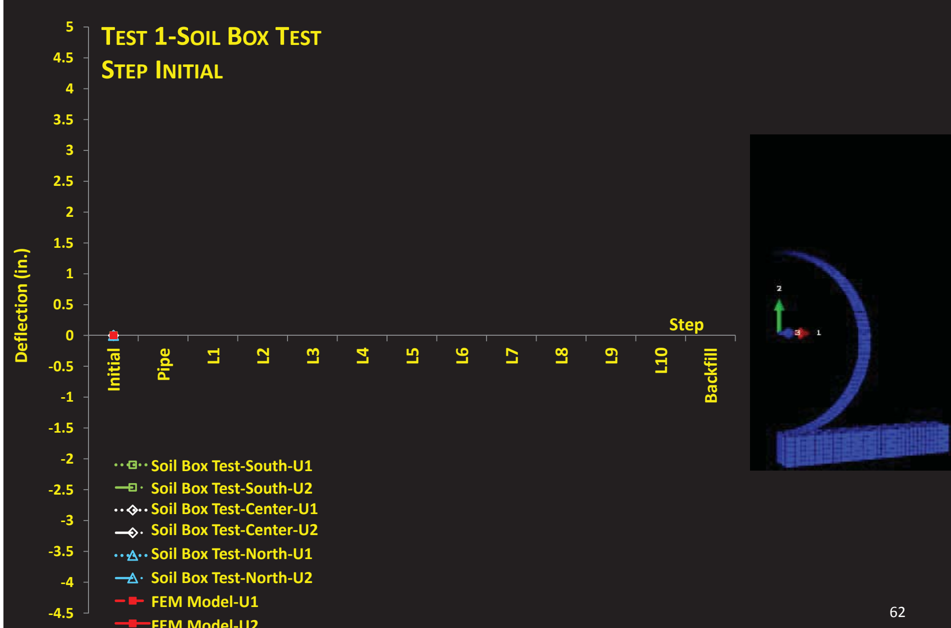
Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

FEM Results of Soil Box Test

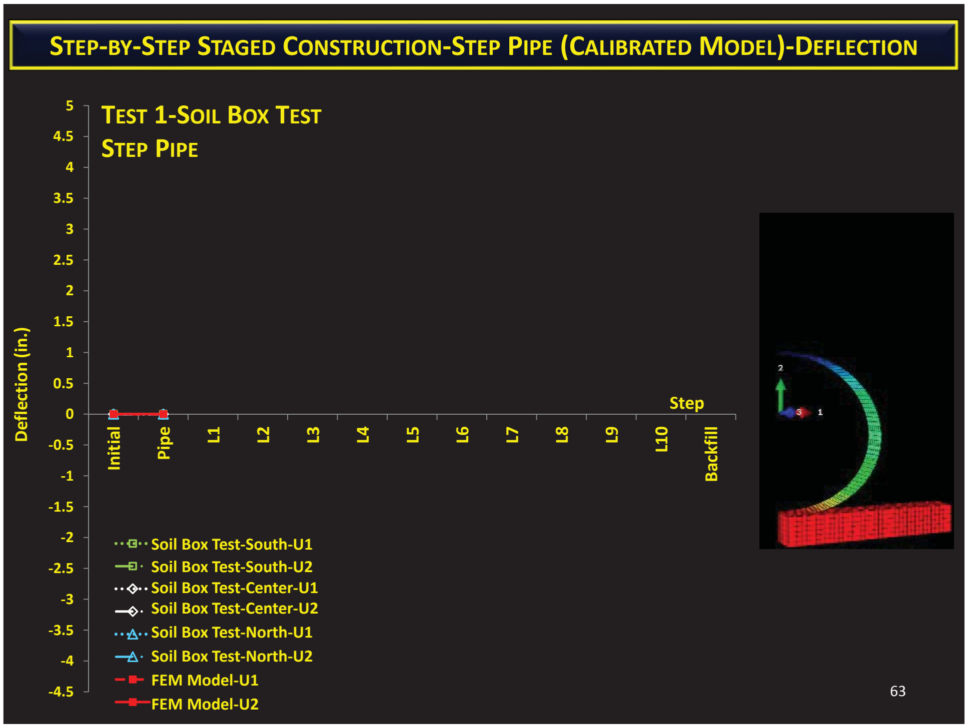
61

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

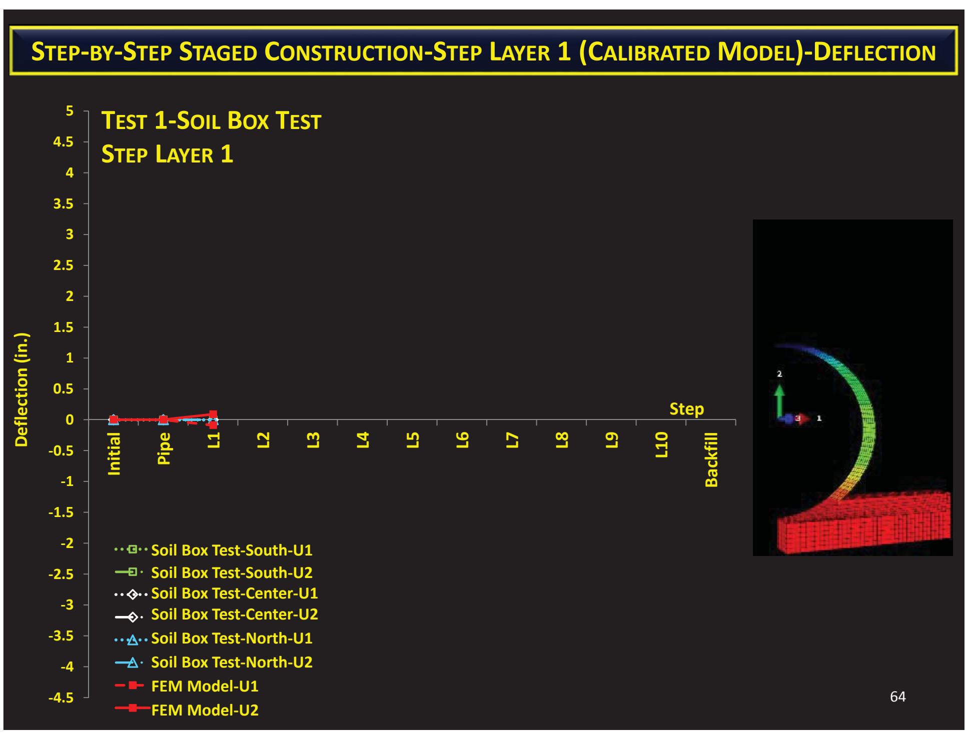
Step-by-Step Staged Construction-Step Initial (Calibrated Model)-Deflection



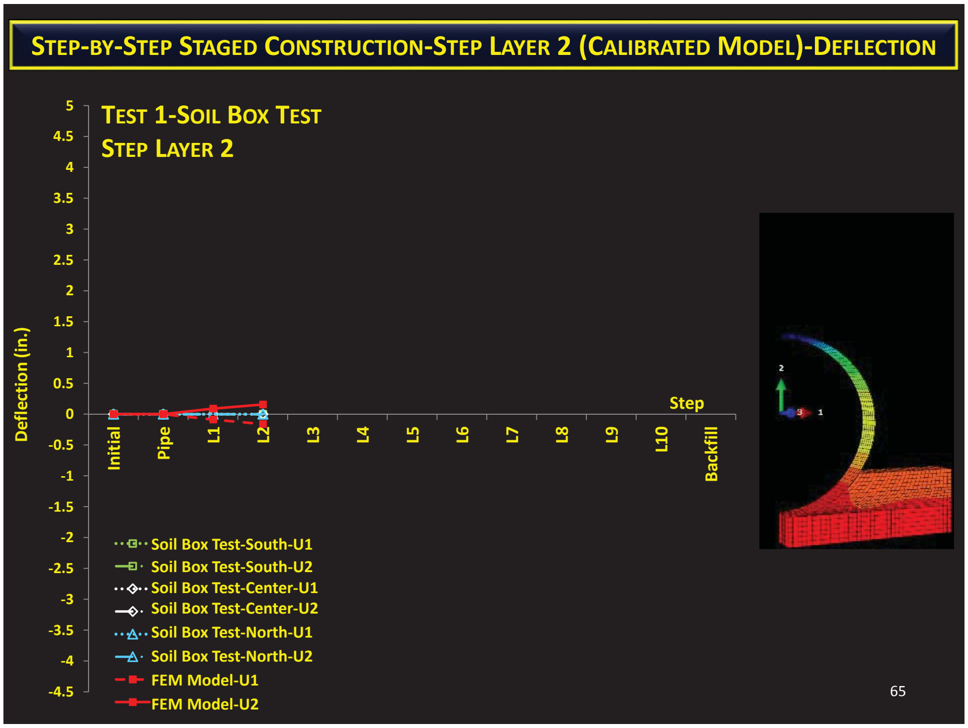
62

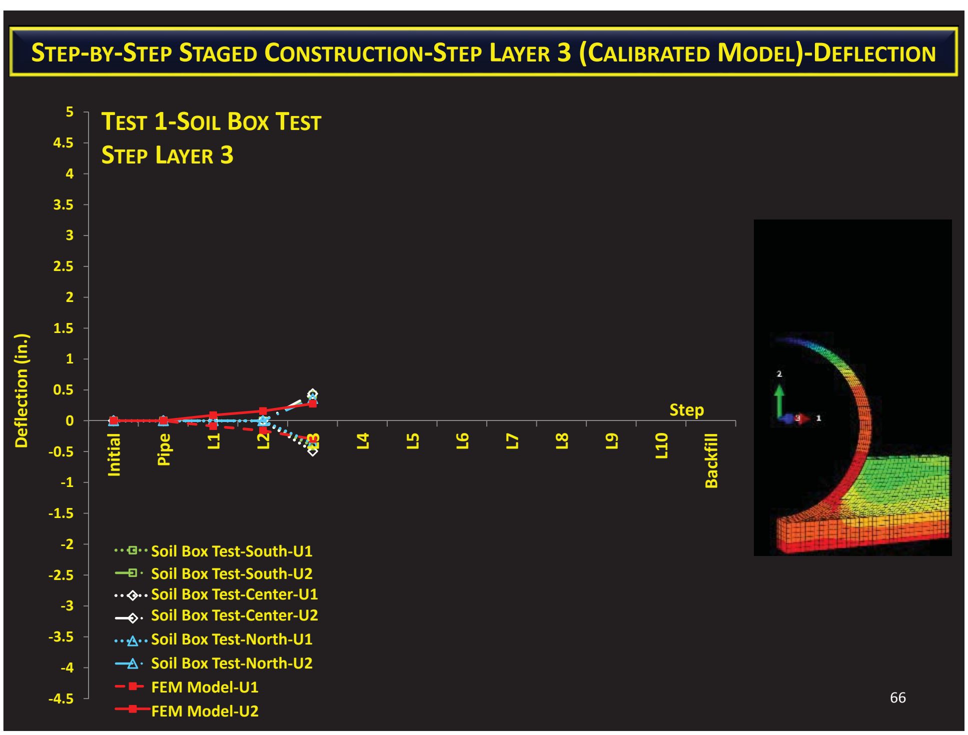


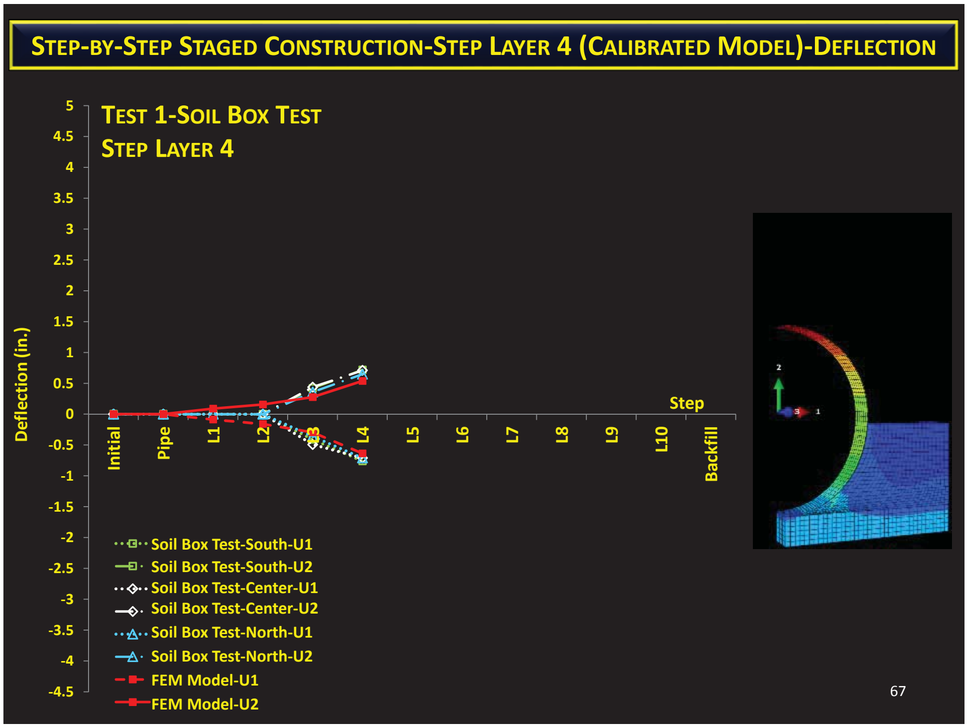
Step-by-Step Staged Construction-Step Pipe (Calibrated Model)-Deflection
Test 1-Soil Box Test
Step Pipe
Deflection (in.)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
Step
Initial
Pipe
L1
L2
L3
L4
L5
L6
L7
L8
L9
L10
Backfill
Soil Box Test-South-U1
Soil Box Test-South-U2
Soil Box Test-Center-U1
Soil Box Test-Center-U2
Soil Box Test-North-U1
Soil Box Test-North-U2
FEM Model-U1
FEM Model-U2
63



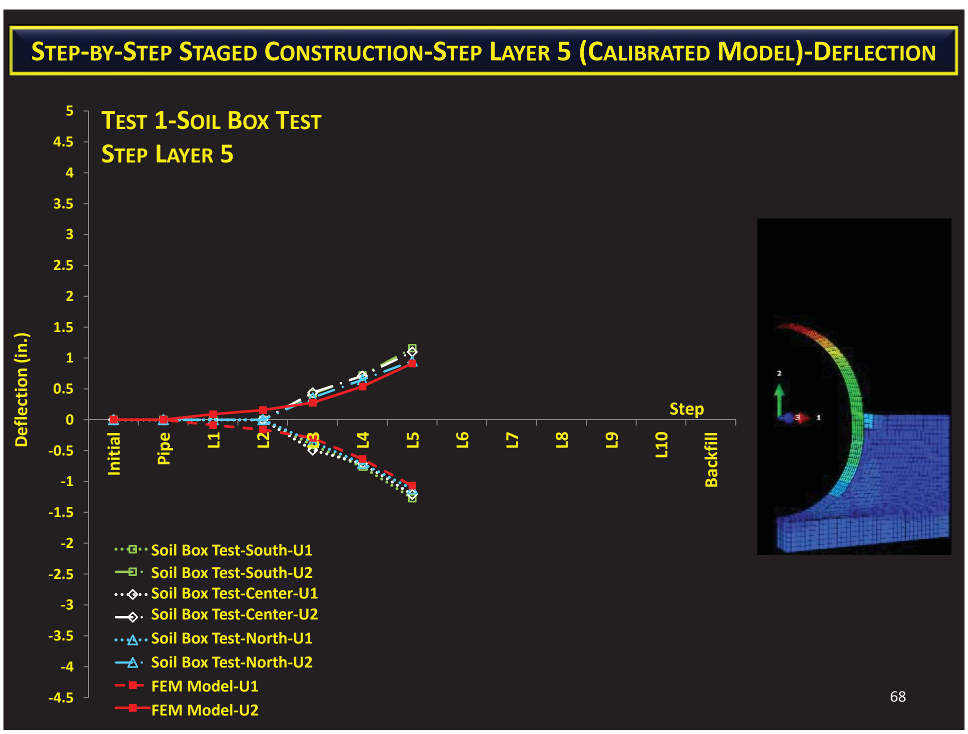
Step-by-Step Staged Construction-Step Layer 1 (Calibrated Model)-Deflection
Test 1-Soil Box Test
Step Layer 1
Deflection (in.)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
Step
Initial
Pipe
L1
L2
L3
L4
L5
L6
L7
L8
L9
L10
Backfill
Soil Box Test-South-U1
Soil Box Test-South-U2
Soil Box Test-Center-U1
Soil Box Test-Center-U2
Soil Box Test-North-U1
Soil Box Test-North-U2
FEM Model-U1
FEM Model-U2
64


STEP-BY-STEP STAGED CONSTRUCTION-STEP LAYER 2 (CALIBRATED MODEL)-DEFLECTION
TEST 1-SOIL BOX TEST
STEP LAYER 2
Deflection (in.)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
Step
Initial
Pipe
L1
L2
L3
L4
L5
L6
L7
L8
L9
L10
Backfill
Soil Box Test-South-U1
Soil Box Test-South-U2
Soil Box Test-Center-U1
Soil Box Test-Center-U2
Soil Box Test-North-U1
Soil Box Test-North-U2
FEM Model-U1
FEM Model-U2
65

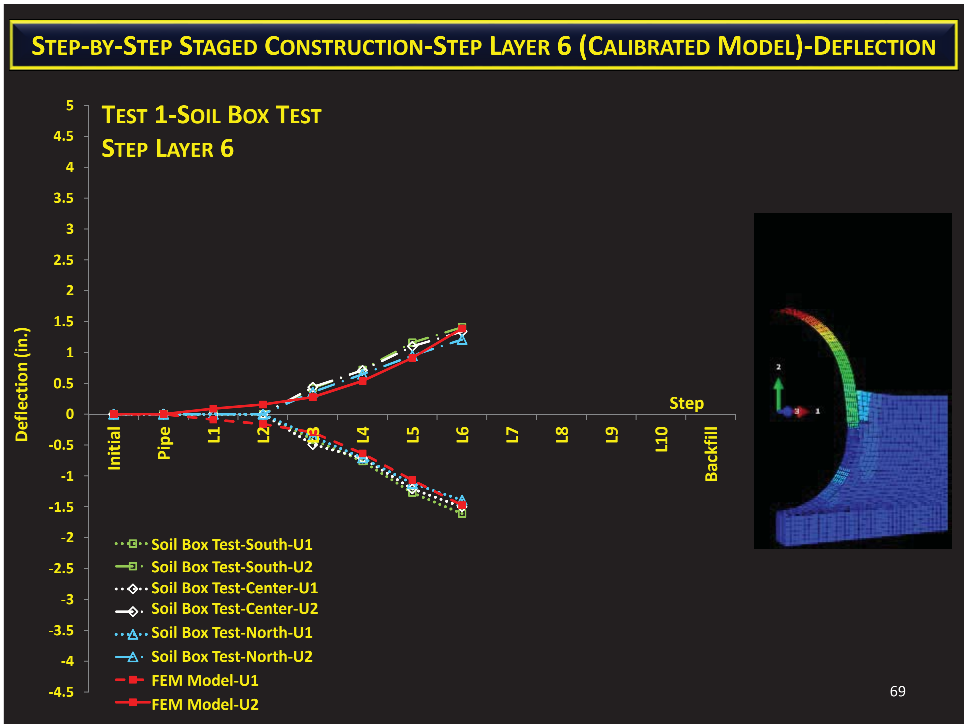

STEP-BY-STEP STAGED CONSTRUCTION-STEP LAYER 3 (CALIBRATED MODEL)-DEFLECTION
TEST 1-SOIL BOX TEST
STEP LAYER 3
Deflection (in.)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
Step
Initial
Pipe
L1
L2
L3
L4
L5
L6
L7
L8
L9
L10
Backfill
Soil Box Test-South-U1
Soil Box Test-South-U2
Soil Box Test-Center-U1
Soil Box Test-Center-U2
Soil Box Test-North-U1
Soil Box Test-North-U2
FEM Model-U1
FEM Model-U2
66



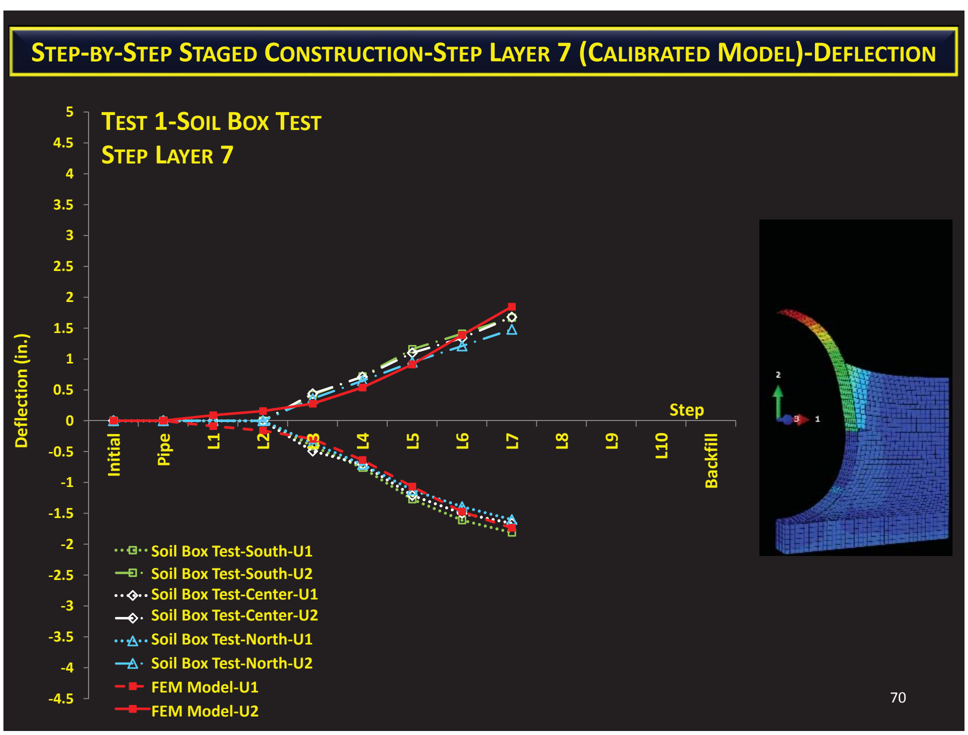
STEP-BY-STEP STAGED CONSTRUCTION-STEP LAYER 4 (CALIBRATED MODEL)-DEFLECTION
TEST 1-SOIL BOX TEST
STEP LAYER 4
Deflection (in.)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
Step
Initial
Pipe
L1
L2
L3
L4
L5
L6
L7
L8
L9
L10
Backfill
Soil Box Test-South-U1
Soil Box Test-South-U2
Soil Box Test-Center-U1
Soil Box Test-Center-U2
Soil Box Test-North-U1
Soil Box Test-North-U2
FEM Model-U1
FEM Model-U2
67



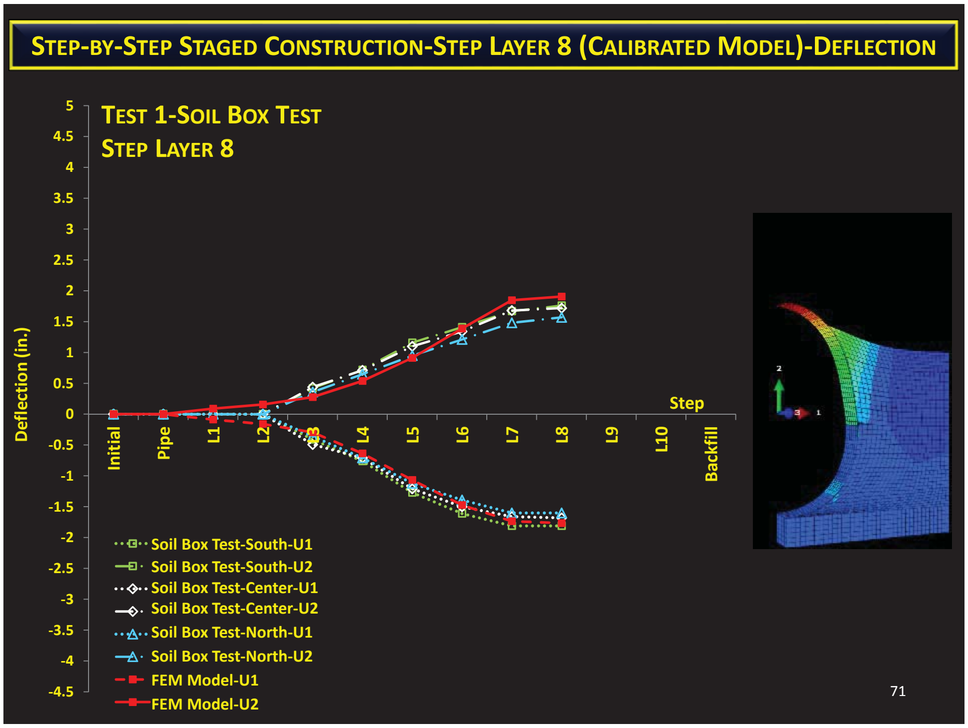
STEP-BY-STEP STAGED CONSTRUCTION-STEP LAYER 5 (CALIBRATED MODEL)-DEFLECTION
TEST 1-SOIL BOX TEST
STEP LAYER 5
Deflection (in.)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
Step
Initial
Pipe
L1
L2
L3
L4
L5
L6
L7
L8
L9
L10
Backfill
Soil Box Test-South-U1
Soil Box Test-South-U2
Soil Box Test-Center-U1
Soil Box Test-Center-U2
Soil Box Test-North-U1
Soil Box Test-North-U2
FEM Model-U1
FEM Model-U2
68



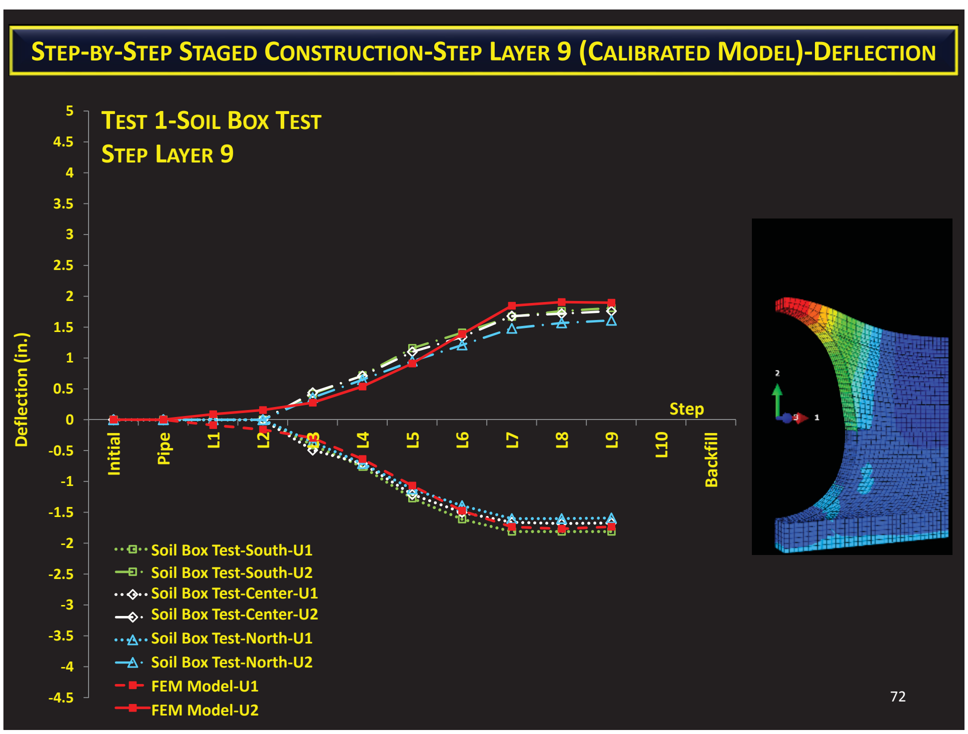
STEP-BY-STEP STAGED CONSTRUCTION-STEP LAYER 6 (CALIBRATED MODEL)-DEFLECTION
TEST 1-SOIL BOX TEST
STEP LAYER 6
Deflection (in.)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
Step
Initial
Pipe
L1
L2
L3
L4
L5
L6
L7
L8
L9
L10
Backfill
Soil Box Test-South-U1
Soil Box Test-South-U2
Soil Box Test-Center-U1
Soil Box Test-Center-U2
Soil Box Test-North-U1
Soil Box Test-North-U2
FEM Model-U1
FEM Model-U2
69



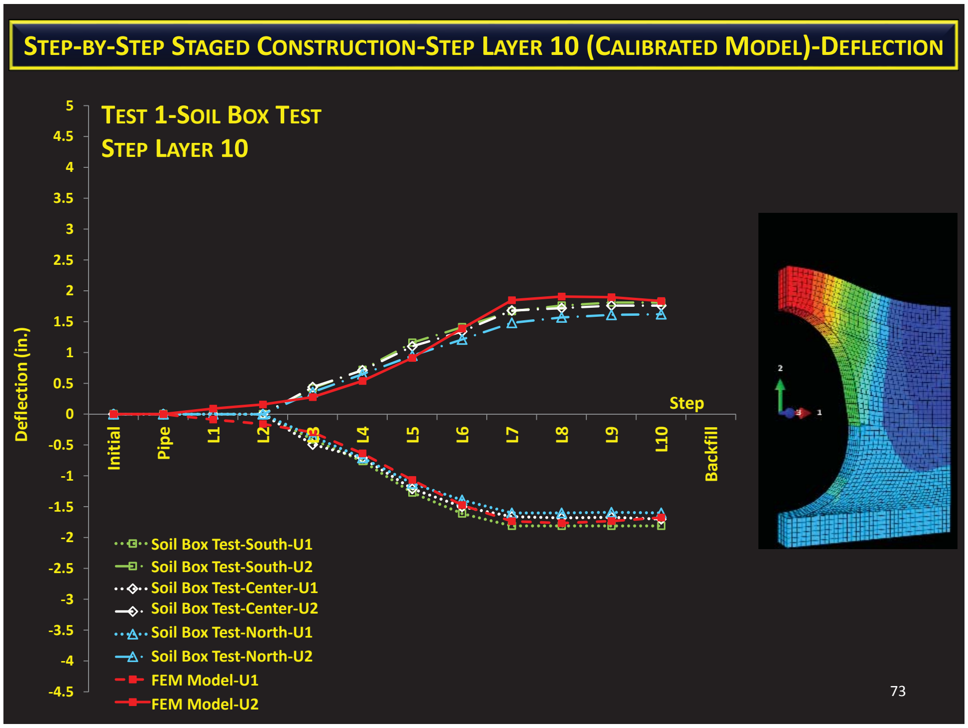
STEP-BY-STEP STAGED CONSTRUCTION-STEP LAYER 7 (CALIBRATED MODEL)-DEFLECTION
TEST 1-SOIL BOX TEST
STEP LAYER 7
Deflection (in.)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
Step
Initial
Pipe
L1
L2
L3
L4
L5
L6
L7
L8
L9
L10
Backfill
Soil Box Test-South-U1
Soil Box Test-South-U2
Soil Box Test-Center-U1
Soil Box Test-Center-U2
Soil Box Test-North-U1
Soil Box Test-North-U2
FEM Model-U1
FEM Model-U2
70

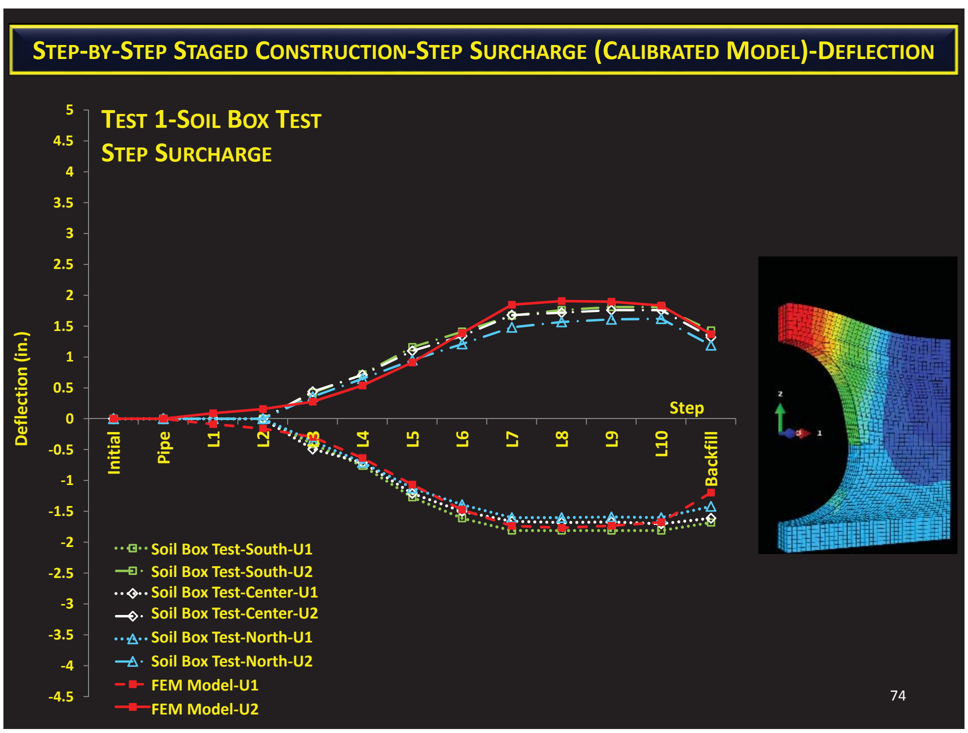


Step-by-Step Staged Construction-Step Layer 8 (Calibrated Model)-Deflection
Test 1-Soil Box Test
Step Layer 8
Deflection (in.)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
Step
Initial
Pipe
L1
L2
L3
L4
L5
L6
L7
L8
L9
L10
Backfill
Soil Box Test-South-U1
Soil Box Test-South-U2
Soil Box Test-Center-U1
Soil Box Test-Center-U2
Soil Box Test-North-U1
Soil Box Test-North-U2
FEM Model-U1
FEM Model-U2
71



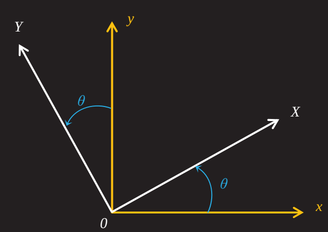
Step-by-Step Staged Construction-Step Layer 9 (Calibrated Model)-Deflection
Test 1-Soil Box Test
Step Layer 9
Deflection (in.)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
Step
Initial
Pipe
L1
L2
L3
L4
L5
L6
L7
L8
L9
L10
Backfill
Soil Box Test-South-U1
Soil Box Test-South-U2
Soil Box Test-Center-U1
Soil Box Test-Center-U2
Soil Box Test-North-U1
Soil Box Test-North-U2
FEM Model-U1
FEM Model-U2
72

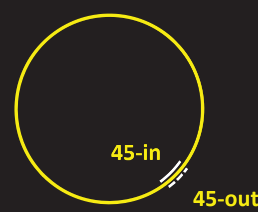

STEP-BY-STEP STAGED CONSTRUCTION-STEP LAYER 10 (CALIBRATED MODEL)-DEFLECTION
TEST 1-SOIL BOX TEST
STEP LAYER 10
Deflection (in.)
Step
Initial
Pipe
L1
L2
L3
L4
L5
L6
L7
L8
L9
L10
Backfill
Soil Box Test-South-U1
Soil Box Test-South-U2
Soil Box Test-Center-U1
Soil Box Test-Center-U2
Soil Box Test-North-U1
Soil Box Test-North-U2
FEM Model-U1
FEM Model-U2
73


STEP-BY-STEP STAGED CONSTRUCTION-STEP SURCHARGE (CALIBRATED MODEL)-DEFLECTION
TEST 1-SOIL BOX TEST
STEP SURCHARGE
Deflection (in.)
Step
Initial
Pipe
L1
L2
L3
L4
L5
L6
L7
L8
L9
L10
Backfill
Soil Box Test-South-U1
Soil Box Test-South-U2
Soil Box Test-Center-U1
Soil Box Test-Center-U2
Soil Box Test-North-U1
Soil Box Test-North-U2
FEM Model-U1
FEM Model-U2
74

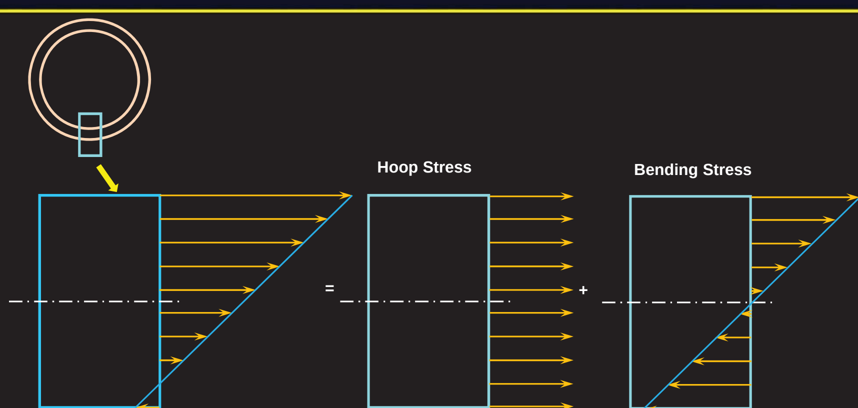
Stress Transformation for 45° Stresses

$$\begin{bmatrix}\sigma_{XX}\\ \sigma_{YY}\\ \sigma_{XY}\end{bmatrix} = \begin{bmatrix}\cos^2\theta & \sin^2\theta & 2\sin\theta\cos\theta\\ \sin^2\theta & \cos^2\theta & -2\sin\theta\cos\theta\\ -\sin\theta\cos\theta & \sin\theta\cos\theta & (\cos^2\theta-\sin^2\theta)\end{bmatrix}\begin{bmatrix}\sigma_{xx}\\ \sigma_{yy}\\ \sigma_{xy}\end{bmatrix}$$

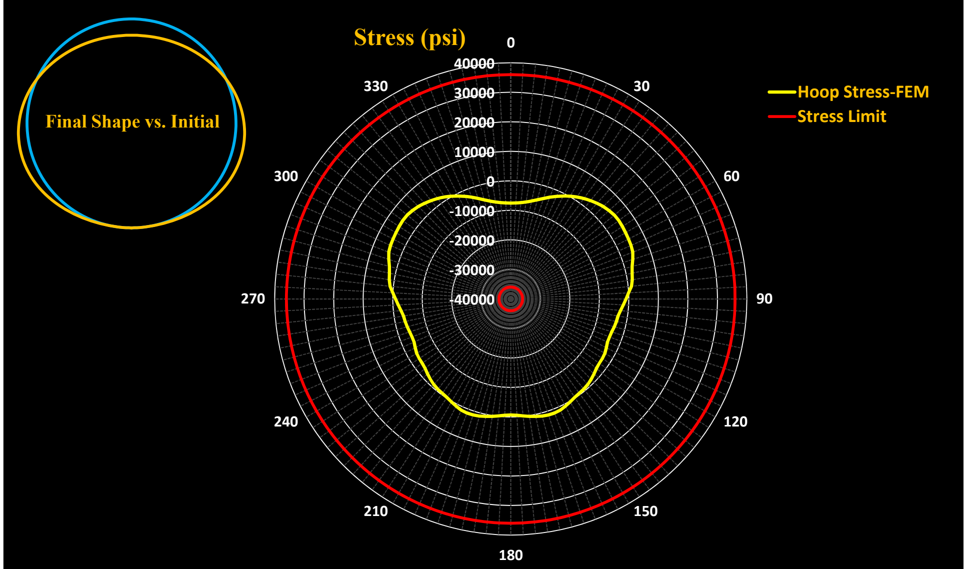




Hoop Stress



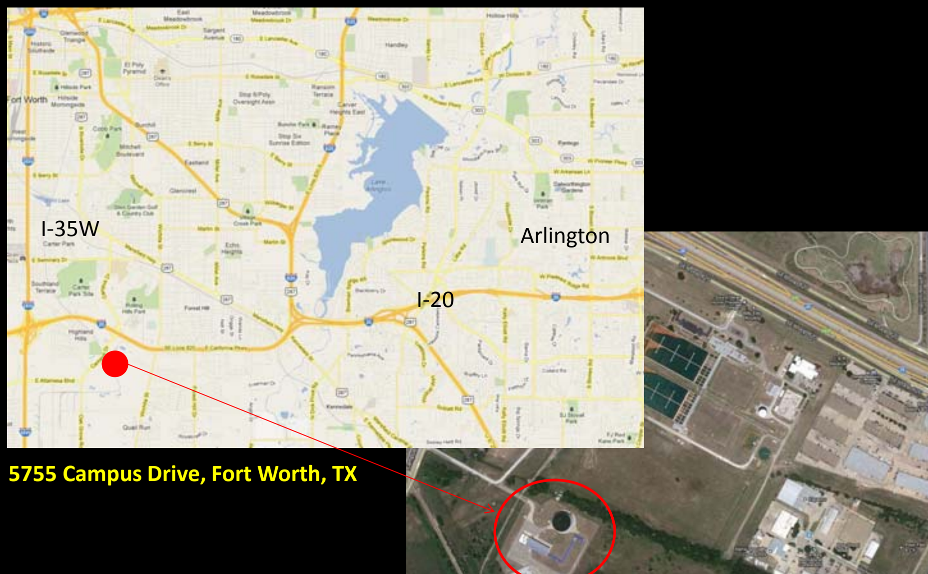
Hoop Stress- Soil Box Test



Field Test (Flexible Trench Wall)

Proposed Site for TRWD-IPL Field Test

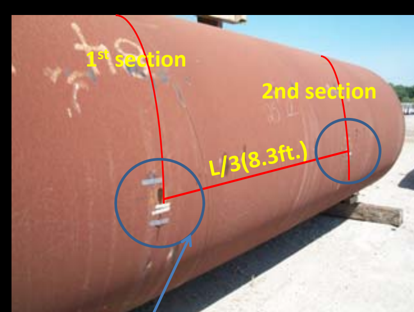
- Rolling Hills Booster Pump Station (RHBPS)

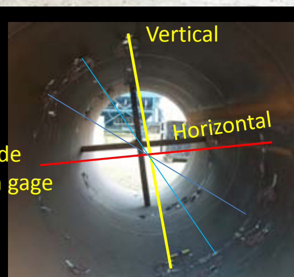


5755 Campus Drive, Fort Worth, TX

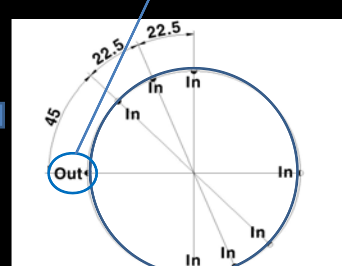
Inspection & Instrumentation

- Location of gages : L/3 each (Longitudinal)



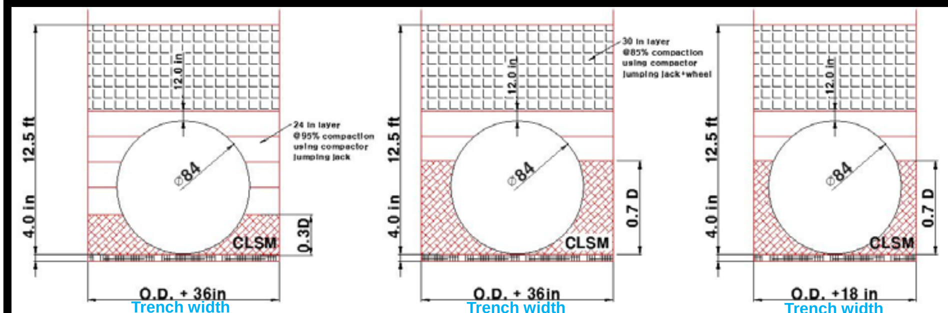


Outside Strain gage



Specification of Experimental Sections

Three-84 in. Steel Pipes



CASE-1

$$\frac{D}{t} = \frac{84in}{0.358in} \approx 235$$

Measured Length : 25 .0 ft
Trench : O.D. + 36in
Measured trench width : 19.5 in/side

CASE-2

$$\frac{D}{t} = \frac{84in}{\frac{3}{8}in} \approx 224$$

Measured Length : 25 .0 ft
Trench : O.D. + 36in
Measured trench width : 20 in/side

CASE-3

$$\frac{D}{t} = \frac{84in}{\frac{3}{8}in} \approx 224$$

Measured Length : 25 .0 ft
Trench : O.D. + 18in
Measured trench width : 10in/side

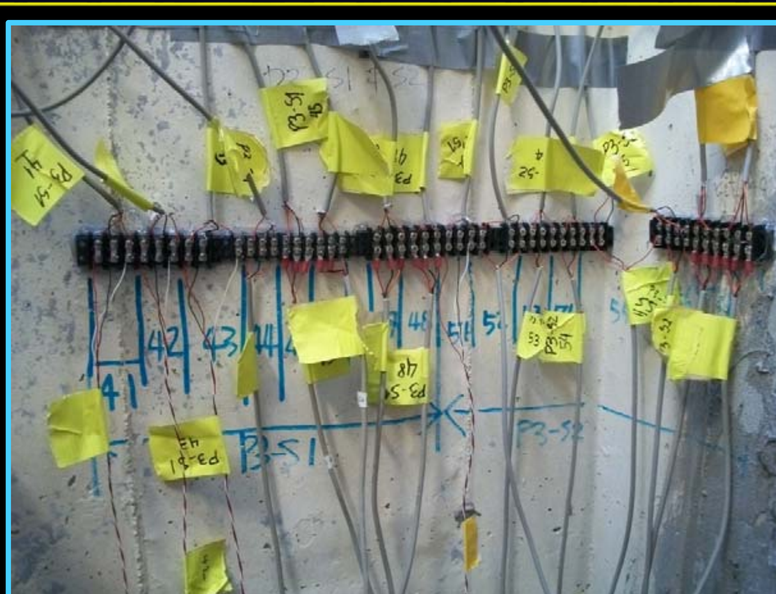
Test Setup : Oct-24-2012 to Oct-26-2012

Installed Pipes and the Manholes

INSTRUMENTATION : OCT-29-2012 TO NOV-4-2012

Gages and Transducers

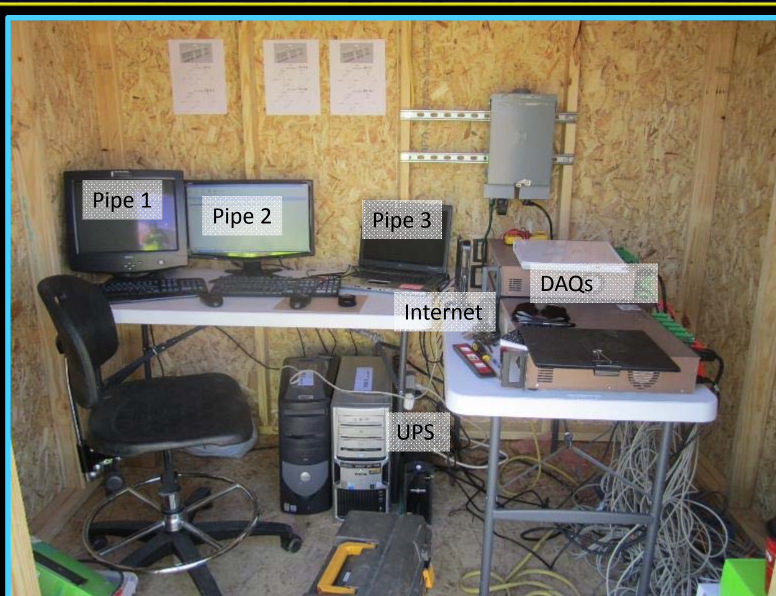
INSTRUMENTATION : OCT-29-2012 TO NOV-4-2012



Terminals for the Connection

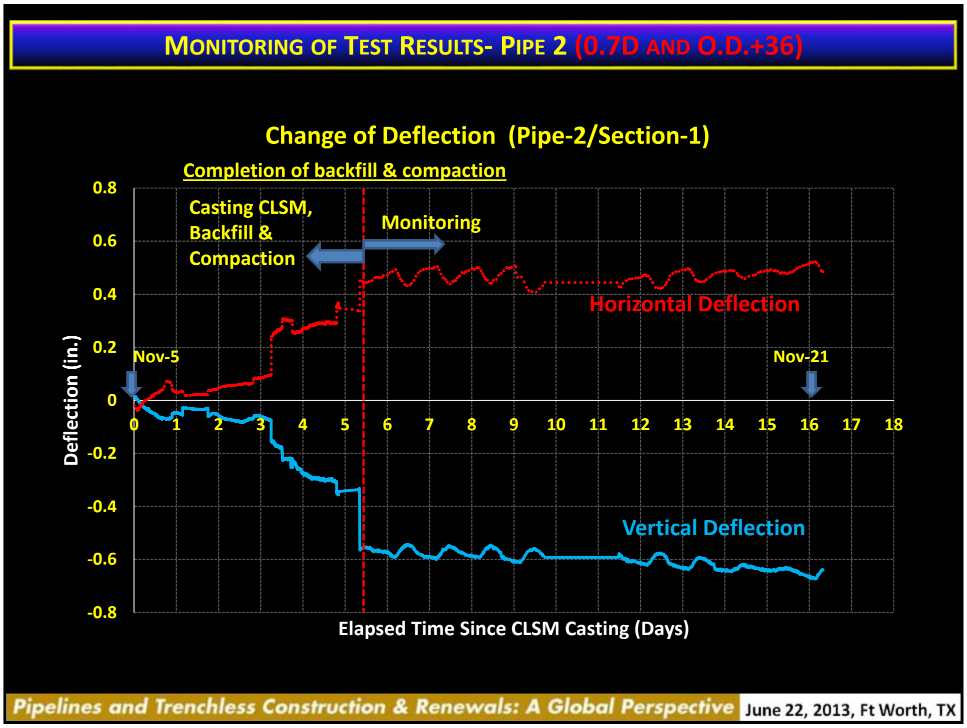
Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

INSTRUMENTATION : OCT-29-2012 TO NOV-4-2012

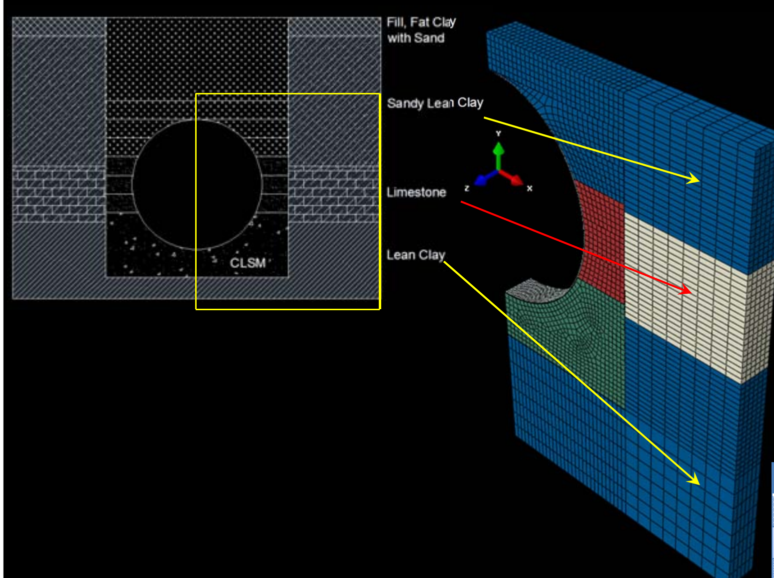


DAQ Headquarter

RESULTS OF FIELD TEST (CHANGE OF DISPLACEMENT)



Pipe – CLSM 0.3OD – Trench Wall

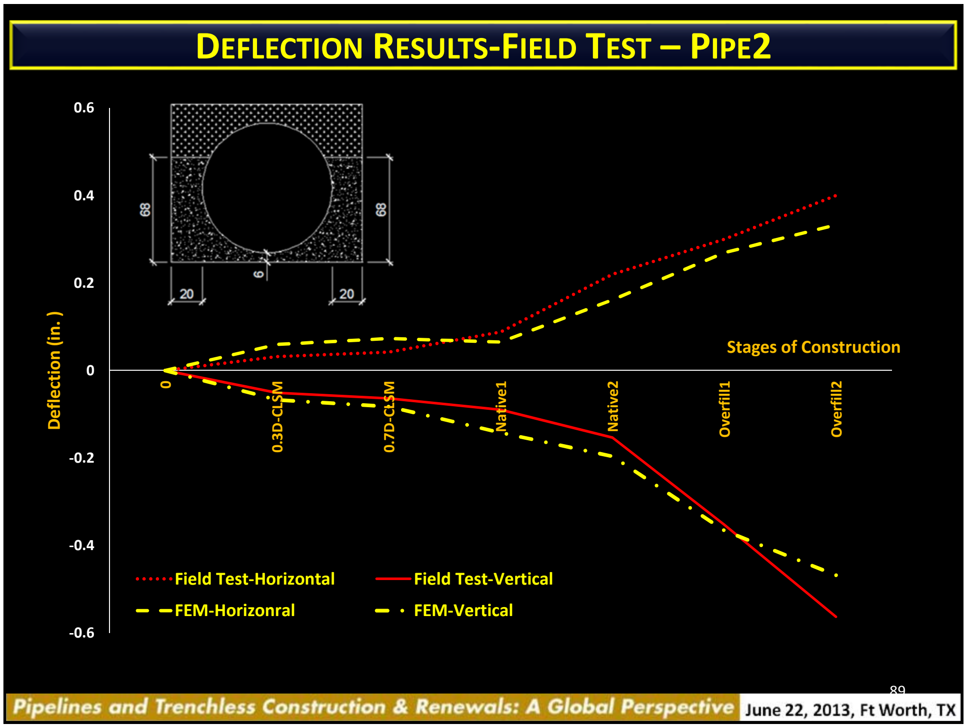


Parameter	Value
E (psi)	700
Poisson R.	0.3
γ (pcf)	120

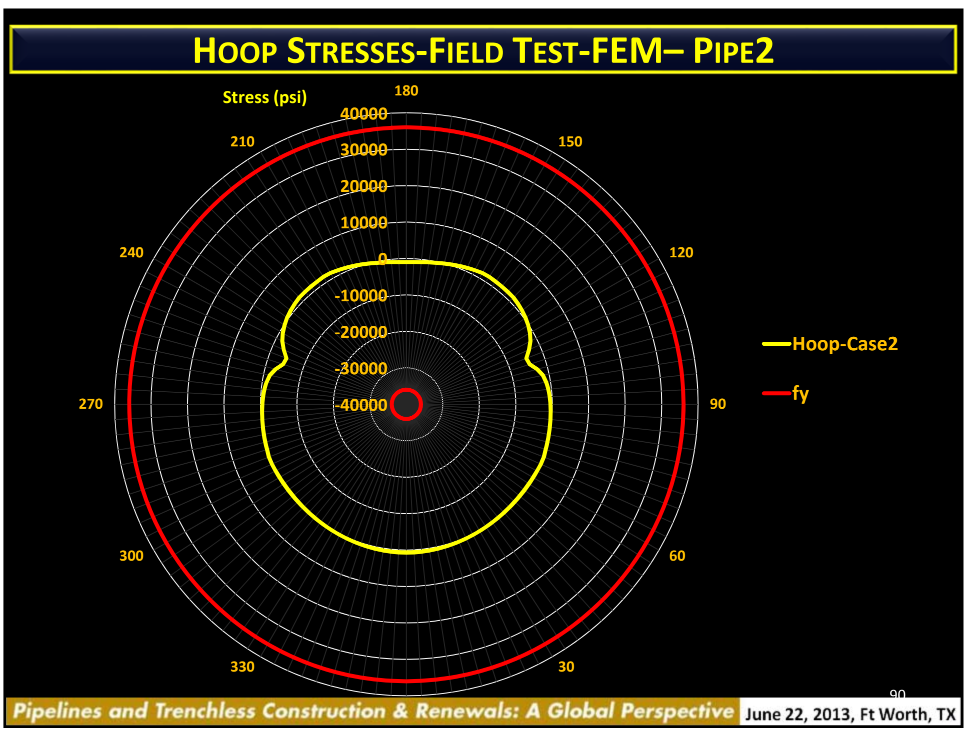
Parameter	Value
E (Psi)	20,000
Poisson R.	0.35
γ (pcf)	100

Parameter	Value
E (psi)	1,450
Poisson R.	0.3
γ (pcf)	100

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX



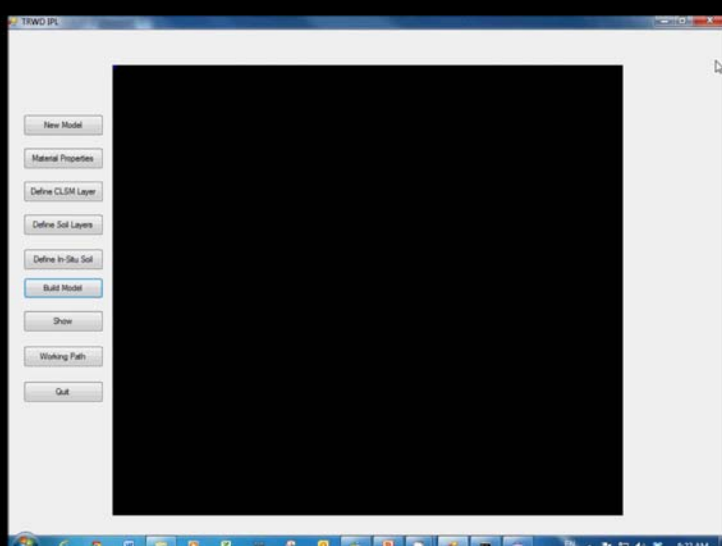
DEFLECTION RESULTS-FIELD TEST – PIPE2
Deflection (in.)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
68
68
20
20
9
Stages of Construction
0
0.3D-CLSM
0.7D-CLSM
Native1
Native2
Overfill1
Overfill2
Field Test-Horizontal
Field Test-Vertical
FEM-Horizonral
FEM-Vertical
89
Pipelines and Trenchless Construction & Renewals: A Global Perspective
June 22, 2013, Ft Worth, TX



HOOP STRESSES-FIELD TEST-FEM– PIPE2
Stress (psi)
180
150
120
90
60
30
330
300
270
240
210
40000
30000
20000
10000
0
-10000
-20000
-30000
-40000
Hoop-Case2
fy
90
Pipelines and Trenchless Construction & Renewals: A Global Perspective
June 22, 2013, Ft Worth, TX

INTERFACE PROGRAM (PRE AND POST PROCESSOR)

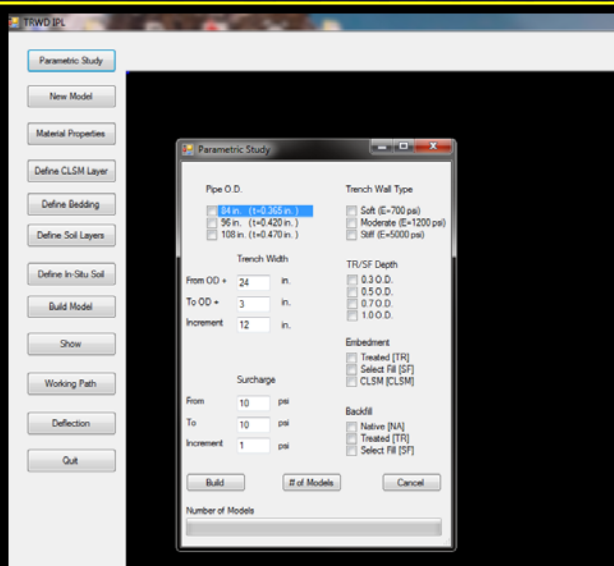
91



92

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

Example of How to Create Parametric Study Models

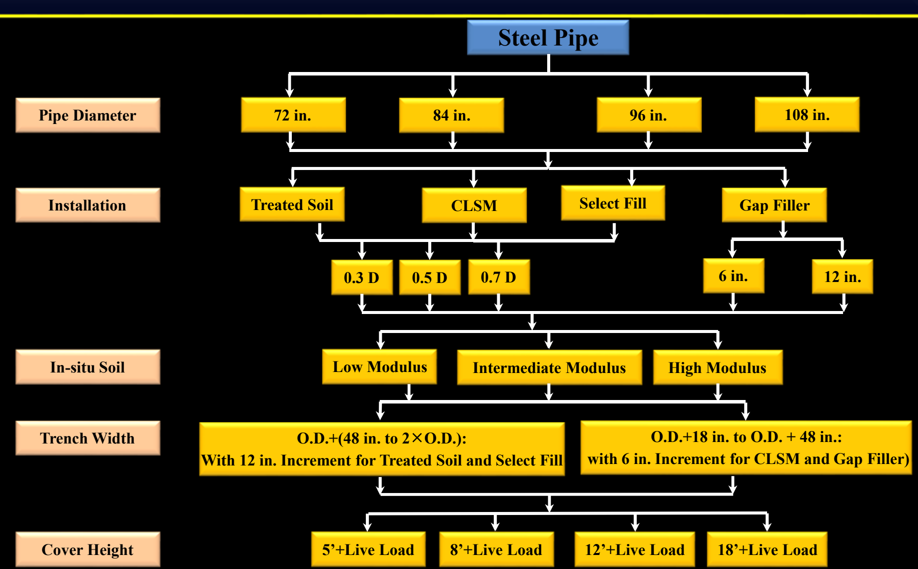


Pre Processor and Post Processor

- ❑ A python Code Has Been Created to Produce Queue of the Models to Run Without Opening the FEM Software
- ❑ A Code Has Been Prepared in Python to Extract the Results from Output
- ❑ Using the Post Processor a Unique Graph for Hoop Stresses is Generated

PARAMETRIC STUDY

PROPOSED SENSITIVITY STUDY- IPL DESIGN



Summary and Conclusion

- FEM is Developed Based on Soil Box Test (Rigid Trench Wall) Results
- Compaction and At-Rest Lateral Soil Pressure is Applied in Term of Uniform Temperature Distribution
- Lateral Pressure Due to Compaction is Calculated Based on Soil Properties, Soil Compaction, and Soil Box Test Deflection Result
- The FEM Model is Used to Create An Interface Program to Analyze Different Trench Conditions
- Three Field Tests (Flexible Trench Wall) are Conducted
- The FEM Model is Used to Model the Field Tests
- The FEM Model is Successfully Predicted the Field Test Results
- A Python Code Prepared to Draw a Unique Graph for Hoop Stresses

97

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE PIPELINE RESEARCH NEEDS SYMPOSIUM

QUESTIONS

☺

98

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

WERF
Water Environment Research Foundation
Collaboration. Innovation. Results.

LIFT
Leaders Innovation Forum for Technology

Water Environment Federation
the water quality people

Future Conveyance System and Asset Management Research Needs Through the LIFT Program - Overview

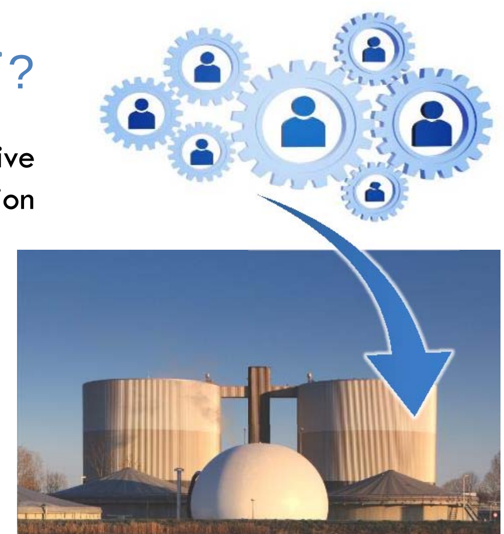
Walter Graf
Program Director - Infrastructure Management
Water Environment Research Foundation
Alexandria, VA

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

What Is LIFT?

A WEF/WERF Initiative
Accelerating Innovation
Into Practice



Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

Why LIFT for Research Needs?

- The WERF Strategic Asset Management Challenge will end in 2013
- The Aging Water Infrastructure Cooperative Agreement with EPA is in its final year
- Any future pipeline and asset management research will come through the WERF Unsolicited Program and LIFT

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

How will LIFT work?

- WERF subscriber and WEF member input and
- Survey results
- Other industry requests

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Technology Survey

Purpose:

- Identify new technologies currently being evaluated at facilities
- Identify technology topics of interest
- Provide a networking and collaboration tool for facility owners

Pipelines and Trenchless Construction & Renewals: A Global Persp

x

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Technology Survey

Who: LIFT-TEP Working Group (reps from WERF subscriber municipal and industrial facility owners; reps are research or tech lead at those organizations)

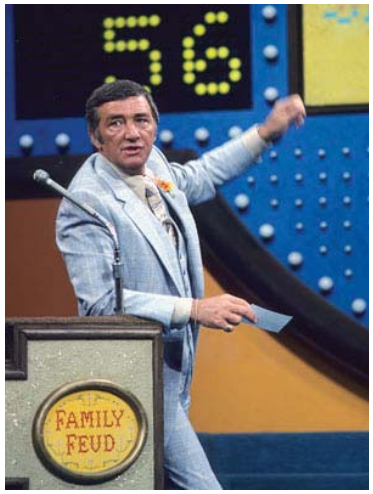
For purposes of this survey, a new "technology" can be a process, invention, method, or the like.

- What is being done at facilities
- Peer to peer networking
- First step of 6 step LIFT technology process is to identify technology needs, then screen technologies to match needs, then select technologies to evaluate

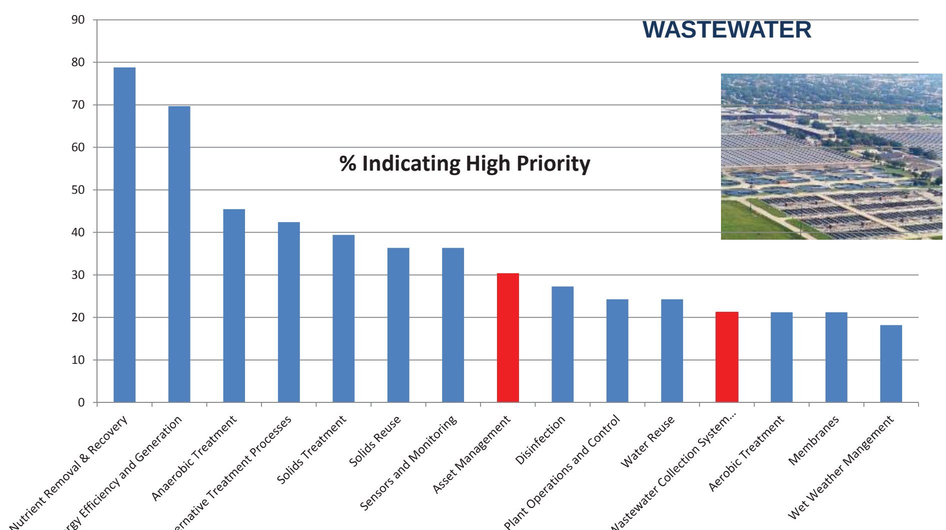
Pipelines and Trenchless Construction & Renewals: A Global Persp

x

Survey Results



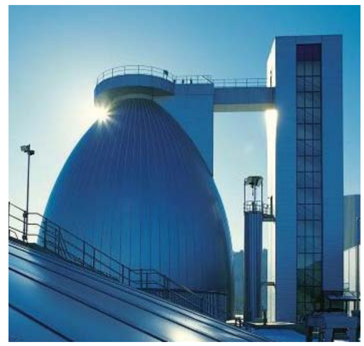
Wastewater Technology Topics of Interest



ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Technology Evaluation Program (TEP)

1. Identify
2. Screen
3. Evaluate
4. Share Risk & Cost
5. Integrate Technology



Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Where's the Next Big Idea?

TX

Technology Evaluation Program (TEP) Screening

STAFF SCREENING CRITERIA

- Financial
- Maturity Level
  - US
  - International
- Applications
  - US
  - International
  - Innovative adaptations of existing technology
  - Cross sector applications
    - Adaptations from other industries
- Intellectual Property Status
  - Legal issues and rights
- Data availability
  - How much data is available? Quality?
  - Regulatory Issues, Compliance
  - Barriers
- Level of interest

EXPERT SCREENING CRITERIA

- Technical Viability
  - Does it work?
  - Retrofit capability
- Game Changer
  - How disruptive
  - Potential for positive, significant change
- Number of Technology Providers
  - Uniqueness
  - How many vendors?
- Risk
  - Probability of success
    - High/low
  - Potential impact on industry
    - Big/small
    - Benefits from success

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

People and Policy

- Address Local, State, and Federal Barriers to Innovation
- Benchmark Facility Owner R&D Programs

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

Communication

- Training
- Education
- Outreach

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Informal Forum for R&D Managers

- For individuals responsible for technology identification and deployment

- Share experiences, activities, and interests

Pipelines and Trenchless Construction & Renewals: 13, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Technology Evaluation Program Benefits

- Credible, well-documented vetting system to screen new technologies and processes
- Ability to more rapidly deploy new technologies and remove existing impediments
- Mitigation of risk and cost of innovative technology deployment through partnerships
- Facilitation of collaboration among facilities for the evaluation and testing of new technologies
- Peer-reviewed information about emerging technologies

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

LIFT-TEP Participants

Working Group:

- Initially about 25 facility owner members, currently about 100+ members

VEP (Volunteer Experts Pool):

- Established for non-facility owners including consultants, academics, equipment manufacturers, etc.

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE PIPELINE RESEARCH NEEDS SYMPOSIUM

Current LIFT-TEP Technology Focus Areas

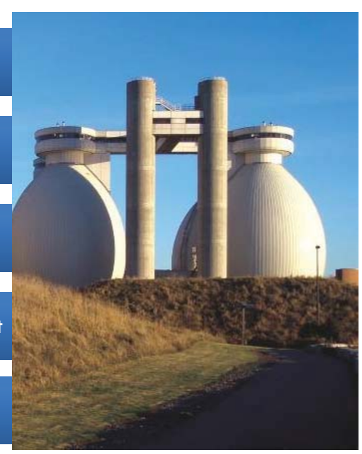
1. Shortcut Nitrogen Removal
2. P-Recovery
3. Digestion Enhancements
4. Biosolids to Energy
5. Energy from Wastewater

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE PIPELINE RESEARCH NEEDS SYMPOSIUM

Top-Down Approach

- Driven by Opportunity
- Problem Specific
- Scans Marketplace for Innovation
- Robust Pre-Screening Saves Time & Effort
- Leverages Innovation Across Sectors



Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

Summary

Using the survey data, the LIFT Working Group selected five Tier 1 technology focus areas. Tier 2 areas are good candidates for future consideration: Collection Systems and Asset Management may be the next selected. Estimated to start by the end of 2013.

Tier 1:

Shortcut N Removal, P-recovery, Digestion Enhancements, Biosolids to Energy, Energy from Wastewater

Tier 2:

Disinfection, Collection Systems, Odor Control, Wet Weather, Sensors, Asset Management, Solids Treatment

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Questions?

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

LIFT Contacts at WEF and WERF

WERF

Jeff Moeller – jmoeller@werf.org 571-384-2104
Ravi George – rgeorge@werf.org 571-384-2105

- Technology Evaluation Program (TEP)
- Volunteer Expert Pool (VEP)
- LIFT-TEP Working Group
- Technology Focus Groups

WEF

Matt Ries – mries@wef.org 703-684-2406

- People and Policy
- Communication and Education

LIFT Contacts at WEF and WERF

Walter Graf
Program Director Infrastructure Management

wgraf@werf.org 571-384-2102

Water Conveyance Infrastructure Research Needs: An EPA/ORD Perspective

Michael D. Royer, Physical Scientist,
Urban Watershed Management Branch,
Water Supply & Water Resources Division
National Risk Management Research Laboratory
U.S. Environmental Protection Agency
Edison, NJ 08837

Overview

- **Introduction**
  - Water conveyance infrastructure
  - Sources of pipe/pipeline research needs
- **Water conveyance infrastructure research needs**
  - Safe & Sustainable Water Resources (SSWR)
  - Rehabilitation
  - Condition assessment
  - Drinking water quality/DSRICP
- **Summary**

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Water Conveyance Infrastructure

- **Wastewater Collection Systems**
  - Combined Sewers
  - Sanitary Sewers
  - Storm Sewers
  - Gravity & Force Mains
  - Laterals-Mains-Interceptors-Trunk Mains-Storage
  - In-building plumbing#
- **Drinking Water Conveyance Systems**
  - Raw & Treated Water Transmission
  - Distribution
  - Storage
  - Service lines
  - In-building plumbing#
- **Water Reuse**
- **Manholes, Hydrants, Pumps, Valves, etc.**
  - # Not addressed

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Sources of Pipe/Pipeline Research Needs

- Sustainable Water Infrastructure Program
- Safe & Sustainable Water Resources Research Program ($; 2012 -)
- Aging Water Infrastructure Research Program ($; 2007-2011)
- Distribution Systems Research & Information Collection Partnership (DSRICP)
- Some related topics not addressed

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Water Conveyance Infrastructure Research Needs: from SSWR Research Plan

- **Rehabilitation**
  - National database structure for retrospective life-cycle performance assessment of water & wastewater rehabilitation technologies
  - Decision support tools for utilities for selection of rehabilitation technologies and methods
- **Leak detection**
  - New pipe leak detection platform based on networking of economic acoustic & pressure sensors coupled with robust signal processing & data mining technologies
- **Green infrastructure**
  - Pilot and full-scale demonstrations
  - Green vs. gray infrastructure assessments
- **Investigation of contaminant intrusion through pipe cracks**
- **Investigation of sediment re-mobilization in storage tanks**
- **Small Systems Research Center (RFA: Open 5/13 – Close 8/13)**

5

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Water Conveyance Infrastructure Research Needs: Rehabilitation for Both Wastewater Collection & Water Distribution (1 of 2)

- **Rehabilitation selection guidance (SSWR)**
- **Systematic approach to rehabilitation design & QA/QC**
- **Integration of condition assessment & rehab design**
- **Integration of sustainable & green technology concepts**
  - Especially for I/I control issues; Consider carbon footprint
- **Better inspection/assessment/repair methods for rehabilitated pipe**
- **Faster field installation rates**
- **More cost-effective cleaning of tuberculated pipe**

6

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

Water Conveyance Infrastructure Research Needs:
Rehabilitation
for Both Wastewater Collection & Water Distribution (2 of 2)

- **Rehabilitation Demonstrations, recent examples:**
  - Spray-on & CIPP for water mains
  - Flood grouting for laterals
  - Asbestos cement rehabilitation – ongoing (EPA-WERF-WaterRF)
  - No-dig manhole rehabilitation – ongoing (EPA-WERF-WaterRF)
  - Integrated assess & fix approach for water mains – ongoing (EPA-WERF-WaterRF)
- **CFRP for PCCP rehab –** data for design standard (EPA-WERF-WaterRF)
- **Databases –** populate & analyze, e.g.:
  - Laterals CA & Rehab database (EPA-WERF)
  - Water & sewer main rehab & CA database (EPA-WERF)
  - Main break database (WaterRF)

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Water Conveyance Infrastructure Research Needs:
Rehabilitation
for Wastewater Collection Systems

- **Rehab of in-service sewers with large diameter, non-circular shape, angles & bends**
- **Rapid & cost-effective sealing of annular gap between the liner & the host pipe**
- **Rehab of manholes, cleanouts, pump stations**
- **Document & reduce cost of bypass pumping, temporary piping**
- **Investigate $Mg(OH)_2$ crown spray systems**

ASCE | **PIPELINE RESEARCH NEEDS SYMPOSIUM**

Water Conveyance Infrastructure Research Needs:
Rehabilitation
for Drinking Water Distribution Systems

- **Evaluation of lead service lining & coating technologies (NCER-STAR)**
- **Improve service line connections re-instatement after re-lining**
- **Increased use of standardized coding to document installed condition**
- **Evaluate cost-effectiveness of cathodic protection for push-on pipe**
- **Document & reduce ancillary costs of water main rehabilitation**
- **For SIPP, study the effects of ambient conditions, cleaning requirements, & installation practices on resin curing, polymeric formulations, & adhesion**

ASCE | **PIPELINE RESEARCH NEEDS SYMPOSIUM**

Water Conveyance Infrastructure Research Needs:
Condition Assessment
for Wastewater Collection Systems (1 of 3)

- **Demonstration of emerging acoustical inspection technologies for rapidly determining pipe condition & cleaning requirements (EPA)**
- **Innovative technology performance, benefit, & cost data**
  - Example technologies with strong “cross-over” potential , e.g.:

gamma-gamma logging	infrared thermography
micro-deflection	ground penetrating radar

- **Factors that Influence the Formation of FOG deposits in Sewer Collection Systems (EPA)**
- **Rapid Detection of Sewer Pipe Problems using Background DNA Marker & QPCR Technology (EPA)**

Water Conveyance Infrastructure Research Needs:

Condition Assessment

for Wastewater Collection Systems (2 of 3)

- **Document costs & benefits of pipe inspection & rehab**
- **Inspection technology improvements for:**
  - Reducing confined-space entry for sewer inspections
  - Affordable multi-sensor devices on small transportable packages
  - Pipes below the waterline
  - Laterals
  - Force main wall thickness data over a long distance from a single point
  - Live insertion & retrieval of existing inspection tools (i.e. avoid shutdown, dewatering, cleaning) into force mains

ASCE PIPELINE RESEARCH NEEDS SYMPOSIUM

Water Conveyance Infrastructure Research Needs:

Condition Assessment

for Wastewater Collection Systems (3 of 3)

- **Better capability to track asset condition over time**
  - Geospatial information (with a high degree of accuracy) needs to be linked with pipe history & condition data
- **Information transfer to practitioners, topics include:**
  - Infrastructure failure mechanisms
  - Using historical inspection data for condition assessment applications
  - Applying the PACP coding system to characterize pipe defects
  - Developing a condition assessment program
  - Preparing accurate record drawings for new & rehabilitated pipe
  - Simple condition assessment tools (i.e. scattergraphs) for analyzing flow data, decision trees, & rules of thumb

Water Conveyance Infrastructure Research Needs:

Condition Assessment

for Drinking Water Distribution Systems (1 of 3)

- ***Evaluate & improve pipe location capability***
  - Polymer & asbestos cement pipes
- ***Evaluate & improve leakage characterization capability***
  - Leak detection, location, rate, change in rate
  - Speed & cost; low intrusion
  - Operation in "noisy" environments (EPA-EPRI)
    - e.g., flow, traffic, air pockets
  - Polymer pipes & asbestos cement pipes
  - Effects of pressure management on leakage rates & main breaks (DSRICP & WaterRF)
  - Innovative indirect methods

Water Conveyance Infrastructure Research Needs:

Condition Assessment

for Drinking Water Distribution Systems (2 of 3)

- **Evaluate & improve pipe structural condition assessment capability**
  - Cost-effective usage of data on pipe location, characteristics, installation, & O&M
  - Web-accessible databases on pipe failure (WaterRF) & technology performance & cost (EPA/WERF)
  - Retrospective - CA effects on failures, catastrophic events, & associated direct & indirect costs
  - Retrospective – CA effects on premature replacement & life-cycle cost
  - Innovative approaches for linking soil characteristics and pipe corrosion (e.g., LPR)

Water Conveyance Infrastructure Research Needs: Condition Assessment for Drinking Water Distribution Systems (3 of 3)

- **Evaluate & improve pipe structural condition assessment capability (cont'd)**
  - Low-cost NDE for small diameter CI & DI pipes (WaterRF)
  - In-line NDE for detecting cracks & joint rotation in large CI & DI pipes
  - NDE technologies for unbroken, corroded wires in PCCP
  - Advanced AE analysis for rapid assessment of PCCP (EPA-WERF-WaterRF)
  - NDE for AC, PVC, & PE pipe

Water Conveyance Infrastructure Research Needs: Top 10 from Distribution Systems RICP# (1 of 2)

Estimation of Contaminated Water Volumes & Contaminant Concentrations Introduced Into WDS Due to Backflow Events from Unprotected Cross-Connections Based on Model Predictions and Field and Pilot-Scale Experiments
Survey of WDS Pressure Management Practices
Characterize Propagation of Pressure Events through WDS to Improve Pressure Management Approaches
Epidemiological Studies of Health Effects Associated with Low or Negative Pressure Events
 # Distribution Systems Research & Information Collection Partnership; Members = EPA & WaterRF

Water Conveyance Infrastructure Research Needs:
Top 10 from Distribution Systems RICP#
(2 of 2)

Best Practices to Minimize Risks Associated with Cross Connections and Backflow
Contaminant Entry from Breaches in Storage Facilities
Best Practices for Minimizing Risks Associated with Storage Facilities
Survey of Large Drinking Water Utility Distribution Systems
Targeted Surveys to Obtain Information on State & Local Regulations, Policies, Manufacturing Practices & Guidelines for Distribution Systems
Quantitative Microbial Risk Assessment (QMRA) to Evaluate Exposure to Pathogens through Distribution Systems

Summary

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Water Conveyance Infrastructure Research Needs (1 of 3)

- **Coordination & Collaboration**
  - Topics, Priorities, Funding, & Implementation
  - Packaging & Dissemination of Results
- **Sustainable Water (Conveyance) Infrastructure**
  - Asset Management
  - Water & Energy Efficiency
  - Expand & Accelerate Use of Best Information, Technologies & Approaches
- **Public Health & Water (Conveyance) Infrastructure**
  - Transport, exposure, & effects of contaminants
  - Prevention &/or control of contaminant adverse effects

19

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Water Conveyance Infrastructure Research Needs (2 of 3)

- **Assess & Re-assess User Community & Their Needs & Priorities**
  - Problem scenario characteristics – intensive & extensive
  - Drinking water, wastewater, stormwater, & water reuse
  - Past, present, & future water infrastructure
  - Strategic, tactical, and O&M level
  - National, regional, & local
  - Information needs: Decision support & Task implementation
    - Benefit, cost, value, & affordability

20

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE PIPELINE RESEARCH NEEDS SYMPOSIUM

Water Conveyance Infrastructure Research Needs (3 of 3)

- **Technology Development & Assessment**
  - Match problems & innovative solutions in these areas:
    - Renewal, water loss control
    - Pipe location, monitoring &/or condition assessment
    - Advanced design concepts & new materials
    - Decision support tools &/or databases
  - Do research, development, testing, demo, &/or evaluation
    - Produce performance, cost, & value data for decision-makers
    - Retrospective assessments for long-term performance data
    - Triple bottom line & life-cycle assessments where applicable
- **Measure Improvements in Sustainability & Public Health**
  - Single applications – Utility-wide – Utility Cluster – National

ASCE PIPELINE RESEARCH NEEDS SYMPOSIUM

Thank you!
Questions?

Notice

The U.S. Environmental Protection Agency, through its Office of Research and Development, funded and managed, or partially funded and collaborated in, the research described herein. It has been subjected to the Agency's administrative review and has been approved for external publication. Any opinions expressed in this paper are those of the author (s) and do not necessarily reflect the views of the Agency, therefore, no official endorsement should be inferred. Any mention of trade names or commercial products does not constitute endorsement or recommendation for use.

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Energy Pipeline Challenges & Related Research

Robert Smith

Pipeline & Hazardous Materials Safety Administration

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Thank You!

- ASCE for the opportunity to share!
- There is much to discuss!
- Many common challenges!
- We hope to expand our research enterprise

"We face many changing pipeline challenges together leaving no room for duplication or wasted time. A research enterprise targeting these challenges will be paramount in overcoming them."

Remarks by Vice Admiral Thomas J. Barrett, (USCG Ret.) Administrator, DOT/PHMSA during the 2007 Government/Industry Pipeline R&D Forum

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

PHMSA's Charge

We develop and enforce regulations for the safe, reliable and environmentally sound operation of:

Approximately

- **2.6 M pipeline miles (4 M KM)**
- **2,600 pipeline operators**
- **1M daily hazmat shipments**
  - By land, sea and air

http://www.phmsa.dot.gov/pipeline

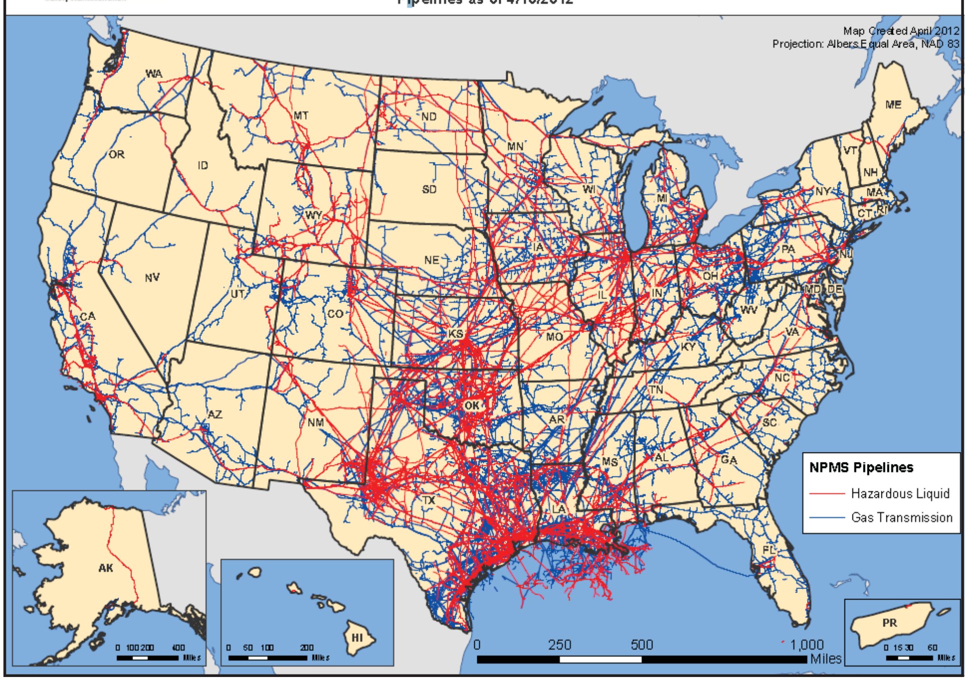
- 3 -

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

U.S. Department of Transportation
Pipeline and Hazardous Materials Safety Administration

Gas Transmission And Hazardous Liquid Pipelines

Pipelines as of 4/10/2012

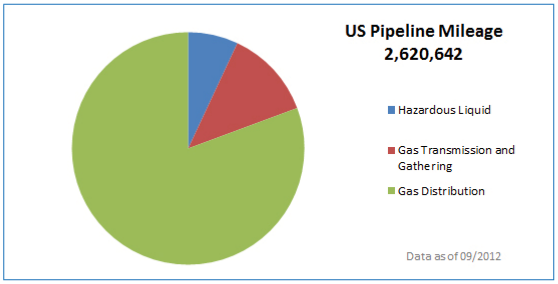


PIPELINE RESEARCH
NEEDS SYMPOSIUM

Energy Pipeline Systems

National Pipeline System Components

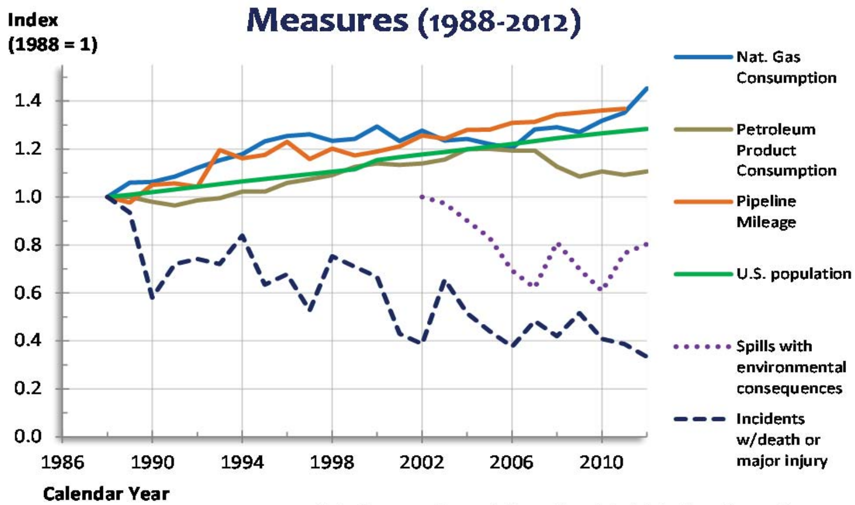
Pipeline	Mileage	% Total	Operators	% Total
Hazardous Liquid	182,166	7	350	13
Gas Transmission and Gathering	324,832	12	1,034	39
Gas Distribution	2,113,643	81	1,285	48
Main line	*1,232,266*	*47*		
Service line	*881,378*	*34*		
Total	**2,620,642**	**100**	**2,669**	**100**



Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

PIPELINE RESEARCH
NEEDS SYMPOSIUM

Pipeline Safety with Context Measures (1988-2012)

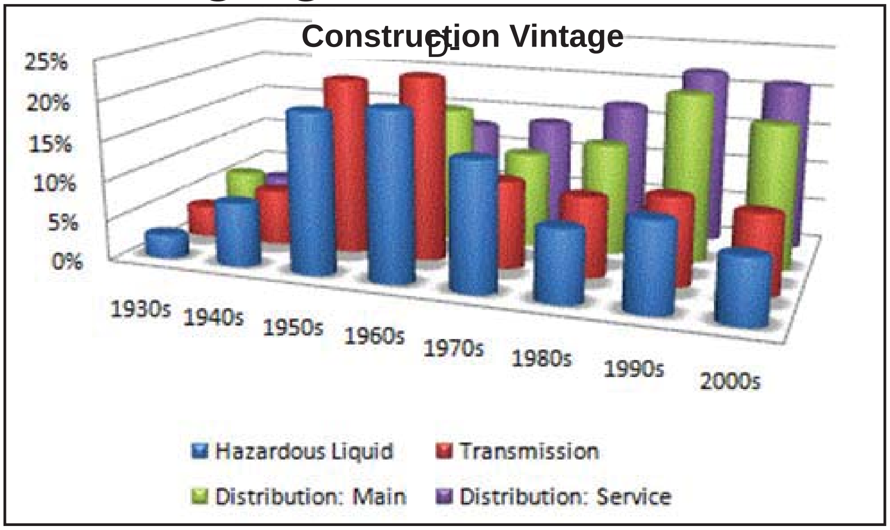


Data Sources: Energy Information Administration, Census Bureau, PHMSA Annual Report Data, PHMSA Incident Data - as of April 1, 2013

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

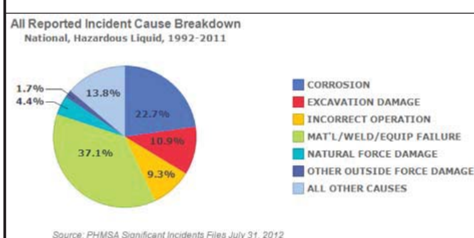
ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

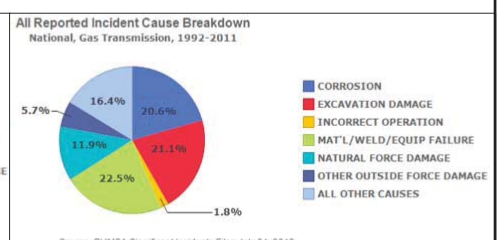
Aging Infrastructure?

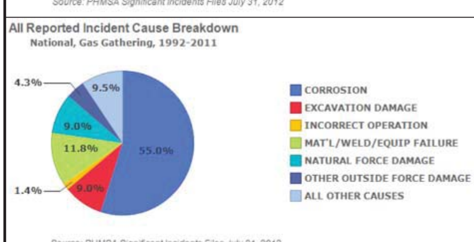


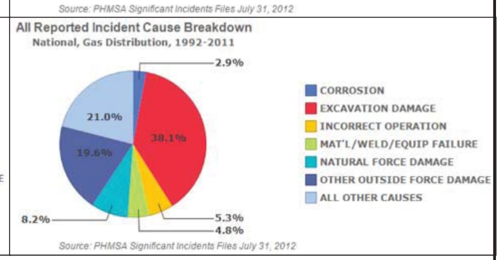
ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Threat/Frequency - Pipeline Type









Corrosion: Consequence

All Pipeline Systems: Corrosion Incident Details: 1992-2011

Reported Cause of Incident	Number	%	Fatalities	Injuries	Property Damage	% of Property Damage
EXTERNAL CORROSION	797	7.7%	10	69	$329,645,057	5.9%
INTERNAL CORROSION	753	7.3%	13	6	$222,118,708	3.9%
UNSPECIFIED CORROSION	291	2.8%	1	11	$8,340,845	0.1%
Total:	**1,841**	**17.9%**	**24**	**86**	**$560,104,610**	**10.0%**

Recent Pipeline Incidents

Dec 11, 2012: A 20" gas transmission pipeline
(1967 vintage)
Sissonville, WV

March 29, 2013: A 20" crude oil pipeline
(1947-48 vintage)
Mayflower, AR

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Challenge: Construction Quality

- **Pipeline construction boom over past few years!**
- **Large increase of pipeline construction inspections**
  - Many examples seen of failure to maintain quality and strength of materials
    - *Pipeline operators*
    - *Pipe mills*
    - *Construction contractors*
- **2009 Public workshop convened beginning of grass roots effort for improving quality**

- 11 -

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Areas of Deficiency

- **Application of exterior pipe coatings**
- **Mechanized and manual welding**
- **Installing pipe in excavations and pipe cover**
- **Nondestructive testing**
- **Bending of pipe**
- **Line pipe low and variable yield strength**
- **Backfill and lowering of pipe in the ditch**
- **New Pipe – HF ERW**
- **Miscellaneous**

- 12 -

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

Challenge: Pipe Seams

SAW Failure in San Bruno, CA

Hydrotest Failure

ERW Seam Failure in Carmichael, MS

Pipeline Safety RD&T

Pipeline Safety RD&T Program Mission:

To sponsor research and development projects focused on providing near-term solutions that will improve the safety, reduce environmental impact, and enhance the reliability of the Nation's pipeline transportation system.

Key Points

- We employ a collaborative approach to address mutual challenges
- We help remove technical barriers on a given challenge
- We measure our research results/impacts
- We are transparent - http://primis.phmsa.dot.gov/rd/

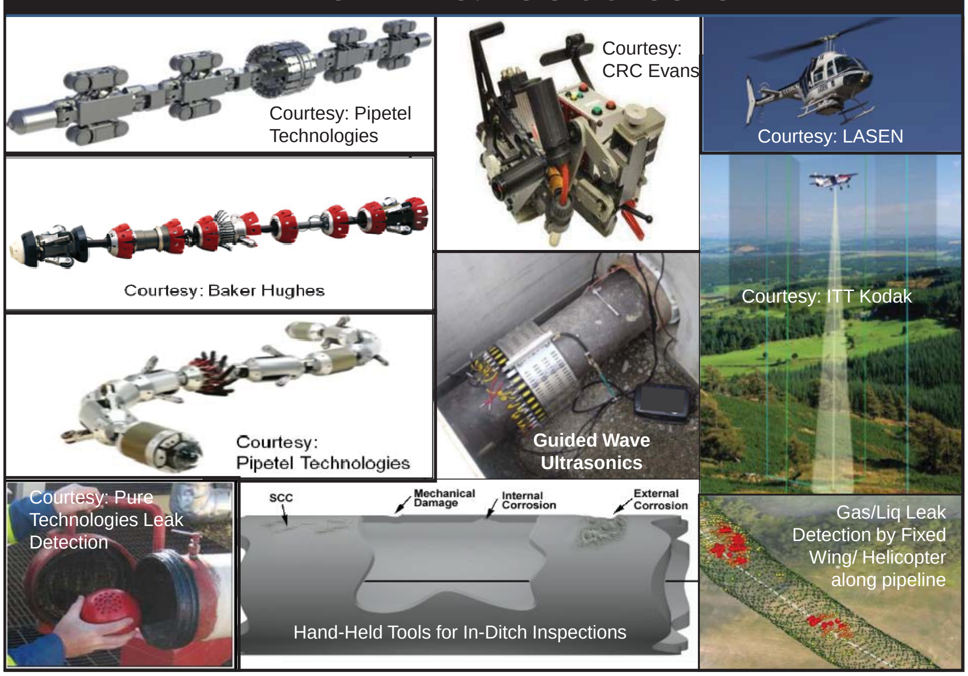
Pipeline Safety Improvement Act of 2002 established our modern program

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Program Objectives

Developing Technology	Strengthening Consensus Standards	Promoting Knowledge
Fostering the development of new technologies so that pipeline operators can improve safety performance and more effectively address regulatory requirements.	Targeting and feeding new knowledge into the process of keeping standards relevant to their purpose.	Generating and promoting general knowledge to decision makers.

PHMSA RD&T SUCCESSES



ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Performance Record (since 2002)

Event Type	Events Held	Stakeholders Reached
Blue Ribbon Panel	2	39
Gov/Industry R&D Forums	5	995
Interagency Coordination Meetings	13	101
R&D Workshops/Conferences	14	2135
Safety Advisory Committees	1	30
Grand Totals:	**35**	**3300**

Website Usage Metric	Measure
Total Number of Hits	17,535,705
Average Number of Hits/Month	147,358
Files Downloaded (since 1/01/2008)	996,975

Fostering Development of New Technologies

Number of projects developing new technology: 70
Number of tech developments now in the commercial market: 20
Number of projects demonstrating new technologies: 38
Number of U.S./Foreign Patent applications resulting from projects: 19

Strengthening Regulatory Requirements and Consensus Standards

Number of projects strengthening new/revised Industry Standards: 63
Number of project results used to revise Consensus Standards: 4
Number of Consensus Standards revised by project results: 3
Number of projects addressing NTSB Recommendations: 8

Promoting Knowledge for Decision Makers

Number of projects promoting knowledge to decision makers: 128
Number of final reports publicly available: 142
Number of conference/journal papers presented: 80

Logic modeling used to determine best attainable & sustainable metrics

Performance metrics all publically available at:

https://primis.phmsa.dot.gov/rd/performance.htm

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Research Knowledge Is Shared!

	Researcher Name	Project Title
1.	Stress Engineering Services	Deepwater GOM Pipeline Damage Characteristics & Repair Options
2.	Edison Welding Institute, Inc.	Advanced Welding Repair and Remediation Methods for In-Service Pipelines
3.	Battelle Memorial Institute	A New Approach to Control Running Fracture in Pipelines
4.	Pipeline Research Council International	Pipeline Integrity Management for Ground Movement Hazards
5.	Battelle Memorial Institute	Integrity Management for Wrinklebends and Buckles
6.	Battelle Memorial Institute	Model Modules to Assist Assessing and Controlling Stress Corrosion Cracking

Wow! Final reports for these projects were collectively downloaded over 15,000 times from the PHMSA website. We've been tracking this information since January 2008 with over 996,000 downloads via all facets of our program website - https://primis.phmsa.dot.gov/rd/

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=390

Research & Development Program
Time: 04/26/2013 07:06 PM

Comprehensive Study to Understand Longitudinal ERW Seam Failures

Project Categories

Click on any category to see other projects in this category.

- Onshore Transmission Pipeline
- Weld/Fabrication Defects
- Integrity Management

Main Objective

Three primary objectives –

1. Integrate industry and PHMSA data to quantify vintage seam failure statistics with focus on LFERW seams
2. Understand longitudinal ERW seam failures and on that basis quantify the effectiveness of inspection and hydrotesting to manage integrity and ensure safety to avoid/eliminate catastrophic failures
3. Combine outcomes of the first two objectives to help favorably close National Transportation Safety Board (NTSB) Recommendation P-09-1

Public Abstract

The objective of the proposed project is to assist PHMSA in favorably closing NTSB Recommendation P-09-1 arising from the Carmichael MS pipeline rupture involving an ERW seam, which directed that PHMSA conduct a comprehensive study of ERW pipe properties and the means to assure that they do not fail in service. The proposed work is anticipated to validate that periodic use of the current ERW seam integrity assessment methods (hydrostatic testing and in-line inspection using a crack-detection tool) are the best means to prevent ERW seam ruptures.

The work will address the characteristics of ERW seams that make them susceptible to failure, and it will identify the factors the pipeline operators must consider in order to assure that their ERW pipelines are safe.

Fast Facts	
Research Award Recipient	Battelle Memorial Institute Headquarter Address: 505 King Avenue, Columbus, OH 43201 Seattle address: Suite 400 1100 Dexter Avenue North Seattle, WA 98109-3598 Columbus, OH 43201-2696
AOTR	Steve Nanney, steve.nanney@dot.gov, (713)272-2855
Contract #	DTPH56-11-T-000003
Project #	390
Researcher Contact Info	Brian Leis (614) 424-4421; (614) 458-4421 (fax); leis@battelle.org
Peer Review	More than Effective (PHP-7-2012, Apr 11-24, 2012)
Technology and Commercialization	
Technology Demonstrated?	TBD
Commercialized (in whole/part)?	TBD
Financial and Status Data	
Project Status	Active
Start Fiscal Year	2011 (05/26/2011)
End Fiscal Year	2014 (05/31/2014)
PHMSA $$ Budgeted	$4,154,488.84

OTHER FILES

Effectiveness of Hydrostatic Testing for Assessing the Integrity of ERW and Flash-weld Pipe Seams
TASK1 2-EFFECTIVENESS OF HYDROSTATIC TESTING-KOLOVICH.PDF (250,287 bytes) [VIEW] [DOWNLOAD/SAVE...]

Track Record of In-Line Inspection as a Means of ERW Seam Integrity Assessment
TASK1 3-TRACK RECORD OF IN-LINE INSPECTION-KIEFNER.PDF (1,316,507 bytes) [VIEW] [DOWNLOAD/SAVE...]

Battelle's Experience with ERW and Flash Weld Seam Failures: Causes and Implications
TASK1 4-BATTELLE EXPERIENCE W ERW AND FW SEAM FAILURES-LEIS.PDF (4,273,451 bytes) [VIEW] [DOWNLOAD/SAVE...]

Models for Predicting Failure Stress Levels for Defects Affecting ERW and Flash-Welded Seams / Addendum on PAFFC
TASK2 4-MODELS FOR PREDICTING FAILURE STRESS LEVELS-KIEFNER.PDF (2,258,637 bytes) [VIEW] [DOWNLOAD/SAVE...]

Selective Seam Weld Corrosion Literature Review
TASK3 1-SELECTIVE SEAM WELD CORROSION LITERATURE REVIEW BROSSIA.PDF (624,604 bytes) [VIEW] [DOWNLOAD/SAVE...]

Predicting Times to Failure for ERW Seam Defects that Grow by Pressure-Cycle-Induced Fatigue
TASK 2.5 - FATIGUE MODELS REPORT - KIEFNER.PDF (471,680 bytes) [VIEW] [DOWNLOAD/SAVE...]

Report Analyzing 280 ERW (high-frequency-welded, low-frequency-welded, and DC-welded) and Flash Weld Seam Failures in Natural Gas and Hazardous Liquid Pipelines
TASK1 4-ERW AND FLASH WELD SEAM FAILURES-KIEFNER-SEPT2012.PDF (11,900,061 bytes) [VIEW] [DOWNLOAD/SAVE...]

- 19 -

Pipelines and Trenchless Construction & Renewals: A Global Perspective | June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Charpy Type Test for HSS

PHMSA/NIST embarking on new program to characterize crack arresting capacity modern high toughness/strength steels

- A medium scale test to assess resistance to unstable ductile tearing in a long ligament specimen at velocities relevant to pipeline performance
- A dynamic fracture model to facilitate correlation of the test outputs with each other, and with full scale testing
- Progress towards a small scale test for evaluating and validating HS & HT steel alloys for use in newer structural design philosophies such as strain-based design
- Communicate with ASTM Committee to revise existing impact testing protocols with the ASTM E23 Standard

- 20 -

Pipelines and Trenchless Construction & Renewals: A Global Perspective | June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Ethanol Research Completed!

11 Projects Now Complete

- PHMSA $2.8M + Co-Funding $3.2M
- Final reporting publically available for standards committees possible use NACE & API interests (eSCC)

	Project Title	Researcher
1.	Determine the Requirements for Existing Pipeline, Tank and Terminal Systems to Transport Ethanol without Cracking	Pipeline Research Council International
2.	Effect of Concentration and Temperature of Ethanol in Fuel Blends on Microbial and Stress Corrosion Cracking of Pipeline Steels	Colorado School of Mines
3.	Monitoring Conditions Leading to SCC/Corrosion of Carbon Steel	Det Norske Veritas (U.S.A.), Inc.
4.	Effect of Ethanol Source on Stress Corrosion Cracking of Carbon Steel	Det Norske Veritas (U.S.A.), Inc.
5.	Effect of Ethanol Blends and Batching Operations on Stress Corrosion Cracking of Carbon Steel	Det Norske Veritas (U.S.A.), Inc.
6.	Feasibility of Using Plastic Pipe for Ethanol Low Stress Lines	Gas Technology Institute
7.	New Design and Construction Techniques for Transportation of Ethanol and Ethanol/Gasoline Blends in New Pipelines	Electricore, Inc.
8.	Stress Corrosion Cracking of Pipeline Steels in Fuel Grade Ethanol and Blends	Georgia Tech Research Corporation
9.	Technical and Economic Feasibility of Preventing SCC through Control of Oxygen	Det Norske Veritas (U.S.A.), Inc.
10.	Feasibility of Chemical Inhibition of Ethanol SCC	Det Norske Veritas (U.S.A.), Inc.
11.	Compatibility of Non-Ferrous Metals with Ethanol	Det Norske Veritas (U.S.A.), Inc

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

New Research Strategy/Plan

July 2012 Gap Analysis/Roadmapping R&D Forum

https://primis.phmsa.dot.gov/rd/mtg_071812.htm

215 regulators/operators/standards orgs/trade orgs/ vendors/researchers/general public

1. Threat Prevention
2. Leak Detection/Mitigation & Storage
3. Anomaly Detection/Characterization
4. Anomaly Repair & Remediation
5. Design/Materials/Welding-Joining/Valves



New Research Strategy/Plan

- **Solicited for 20 topics based on Forum consensus**
- **89 White Papers down to 38 Proposals**
- **June 2013 – Recommending 21 awards & $15M PHMSA investment in the below areas:**
    1. Threat Prevention
    2. Leak Detection/Mitigation & Storage
    3. Anomaly Detection/Characterization
    4. Anomaly Repair & Remediation
    5. Design/Materials/Welding-Joining/Valves

Competitive Academic Agreement Program (CAAP): Objectives

- Program to spur pipeline safety innovation through academic research
- Intended to deliver "hand-off" solutions for further investigations in PHMSA's core research program
- Expose "graduate students" to pipeline safety challenges and how technical discipline is needed
- PHMSA to spend up to $500K each year with this new program
    - Supports 5 project awards to any non-profit institute of higher learning in the US

More Technology is Coming!

1. Handheld tool to quantify residual stress measurements in mechanical damage
2. Buried ROW Encroachment Monitoring Sensors
3. Portable, hand-held instrument for detection of petroleum product leaks from buried pipelines at stand-off distances
4. Portable, handheld, low-cost instrument to measure hydrogen sulfites and mercaptans
5. Dual magnetic field MFL technology to detect mechanical damage to discriminate between critical and benign anomalies

Pipeline Safety RD&T Contacts

Jim Merritt
Department of Transportation
Pipeline & Hazardous Materials Safety Administration
Office of Pipeline Safety
P(303) 638-4758
Email james.merritt@dot.gov

Robert Smith
Department of Transportation
Pipeline & Hazardous Materials Safety Administration
Office of Pipeline Safety
P(919) 238-4759
Email robert.w.smith@dot.gov

PHMSA RD&T
Providing/Supporting:

Program Page - https://primis.phmsa.dot.gov/rd/
Project Matrix - https://primis.phmsa.dot.gov/matrix/

PIPELINE CORROSION PREVENTION WHAT IS NEEDED?

Presented by:
James A. Hart, NACE International
Oil & Gas Industry, Program Manager

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

NACE QUICK FACTS

- NACE is the World's Largest Corrosion Technical Society
- Founded by 11 Pipeline Engineers in 1943
- Today 31,000 Members in 130 countries
- 337 Technical Committees Serving Every Major Industry
- 153 Standards – 55 Coatings and 40 Pipeline Related
- The World's Largest Corrosion Conference
- 500 Training Classes Held Annually
- Over 32,000 NACE Certified Professionals Worldwide
- Offices in U.S., Malaysia, China and Saudi Arabia

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

OVERVIEW

- State of the Industry
- Key Challenges?
- Impact of Corrosion on U.S Pipelines
  - Summary of Corrosion related incidents
  - Cost of Corrosion
- What needs to be done?
- What Can You Do?

ASCE PIPELINE RESEARCH NEEDS SYMPOSIUM

STATE OF THE INDUSTRY

- Aging Infrastructure and zero tolerance for error
- New infrastructure demands
- Push for transfer of technology based on research partially funded by government grants to standards
- Industry under intense scrutiny by the public and lawmakers
- More inspections, Increased penalties and fines

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

RECORD ENFORCEMENT NUMBERS AND PENALTIES IN 2012

- PHMSA issued 116 enforcement orders to pipeline operators, its second highest year, for problems with integrity management programs, qualified personnel, corrosion control, and other violations
- The also issued its largest penalty ever in the amount of $3,699,200 stemming from a July 2010 corrosion-related rupture that spilled more than 20,000 barrels of crude oil

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

KEY CHALLENGES

- Disengagement of senior level management on corrosion related issues and costs
- Increasing demand for qualified workforce converging with loss of knowledge base due to mergers, downsizing and retirements
- Funding for research and development for new technology
- Inconsistent message from trade groups, research and standards organizations

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINES 2013 CONFERENCE

Pipelines and Trenchless Construction & Renewals: A Global Perspective

Pipeline Research Needs for Future Practice Improvements – A Designer's Perspective

By:
Sri Rajah, Ph.D., P.E., P.Eng., M.ASCE
HDR Engineering, Inc.
Chair, Pipeline Location & Installation Technical Committee

ASCE | Pipeline Location and Installation Technical Committee | Pipeline Division

HDR

ASCE | PIPELINES 2013 CONFERENCE

Pipelines and Trenchless Construction & Renewals: A Global Perspective

Agenda

- Role of Research for Practice Improvements
- Influence of Historical Research
  - Example: Outcome of Uncoordinated Research
  - Example: Outcome of Undocumented Research
- AWWA Standards Development
- Process Improvement Needs
- Conclusions

ASCE | PIPELINES 2013 CONFERENCE
Pipelines and Trenchless Construction & Renewals: A Global Perspective

Role of Pipeline Research for Practice Improvements

- Monitor
  - ✓ Evaluate Existing Practice
  - ✓ Study Case Histories (Successes & Failures)
  - ✓ Identify Practice Improvement Needs
- Research
  - ✓ Identify Research Needs
  - ✓ Collaborate with Stakeholders
  - ✓ Conduct Research
  - ✓ Document Findings!!
- Develop Practice Improvements for
  - ✓ Design
  - ✓ Construction
  - ✓ Operation and Maintenance
- Develop/Update Practice Requirements
  - ✓ Best Practices
  - ✓ Guidelines
  - ✓ Standards
  - ✓ Codes

Research with No or Inadequate Documentation will have Very Limited Use.

Identified and Fully Developed Practice Improvements Should be Documented for Use in Actual Practice.

ASCE PIPELINES 2013 CONFERENCE Prepared for Teaching & Educational Purposes Only; No Other Use Permitted 3

ASCE | PIPELINES 2013 CONFERENCE
Pipelines and Trenchless Construction & Renewals: A Global Perspective

Historical Research in Water/Wastewater Industry

- Initiatives are Primarily Led by Manufacturers
  - Competitive Product Development
    - Proprietary
    - Pipe Material Specific
    - Uncoordinated & Inconsistent
- Initiatives Supported by Joint Efforts Between Manufacturers, Public Agencies and Organizations
  - Refine Design Practices
    - e.g., Flange Design for Water Pipelines
  - Address Widespread Issues of Concern
    - e.g., Research on PCCP
- Initiatives by Public Agencies
- Initiatives by Academic/Research Institutions

ASCE PIPELINES 2013 CONFERENCE Prepared for Teaching & Educational Purposes Only; No Other Use Permitted 4

ASCE | PIPELINES 2013 CONFERENCE
Pipelines and Trenchless Construction & Renewals: A Global Perspective

Influence of Historical Research on Current Practice

Uncoordinated Research	• Inconsistent and material specific design approaches, standards, and guidelines. • Results in Unnecessary Confusion for Practicing Engineers • Extremely Difficult to Develop, Maintain and Update Design, Construction and O&M Standards and Guidelines.

Undocumented Research	• Lack of Research Funds for Adequate Documentation
	  • Inadequate or No Documentation
	• Failure to Disseminate
	  • Lost Data and Documentation
	• Intentional Withholding of Information
	  • To Gain Competitive Advantage

Reluctance to Improve Design Practices	• Until a Widespread Issue is Recognized
Passive Approach to Codes/Standards Development	• Lack of Proactive Practice Improvements

ASCE | PIPELINES 2013 CONFERENCE
Pipelines and Trenchless Construction & Renewals: A Global Perspective

Outcome of Uncoordinated Research

- Inconsistent and material specific design approaches, standards, and guidelines.
  - Results in Unnecessary Confusion for Practicing Engineers
  - Extremely Difficult to Develop, Maintain and Update Design, Construction and O&M Standards and Guidelines.
  - e.g., Thrust Restraint Design Practice in AWWA Design Manuals

	M-9 Concrete	M-11 Steel	M-23 PVC	M-41 DIP	M-45 Fiberglass	M-55 HDPE
Magnitude of Unbalanced Force (per leg)	PAsin(Δ/2)	PA(1-cosΔ)	PAsin(Δ/2)	PAsin(Δ/2)	PAsin(Δ/2)	N/A
Direction of Unbalanced Force in each leg	Along unbalanced force resultant	Along the leg	Along unbalanced force resultant	Along unbalanced force resultant	Along unbalanced force resultant	N/A

Inconsistent Backfill Specification Systems for Pipe Installation

		SOIL DESCRIPTION					
		Crushed Stone or Rock	Coarse Grained Soil (Little or No Fines)	Coarse Grained Soil with Fines	Fine Grained Soil (Low Plasticity)	Fine Grained Soil (High Plasticity)	Organic Silt, Clay, Peat
STD. SOIL CLASSIFICATION SYSTEMS	USCS [1]	GW, GP	GW, GP, SW, SP	GM, GC, SM, SC	ML, CL	MH, CH	OL,OH, PT
	AASHTO [2]		A1, A3	A2, A4, A6	A2, A4, A6	A5, A7	A5, A7
ASTM STANDARDS	D2321	Class I	Class II	Class III	Class IV	Class V	Class V
	C1479		Category I	Category II	Category II/III	Category IV	Category IV
	D2774		Gravels & Sands	Sands & Gravels			
ASCE DESIGN MANUALS	ASCE 15-98 [3]		Gravelly Sand	Sandy Silt, Silty Clay	Sandy Silt, Silty Clay	Silty Clay	
AWWA DESIGN MANUALS [4]	M9 (Concrete)		Category I	Category II	Category III	Category III	
	M11 (Steel)		GW, GP, SW, SP	GM, GC, SM, SC	ML, CL	MH, CH	OL,OH, PT
	M23 (PVC)	SC1	SC2	SC3	SC4	SC5	SC5
	M41 (DIP)		Clean Sand, Clean Gravel	Coh-Gran, Sand Silt	Clay 2, Silt 2	Clay1, Silt 1	
	M45 (Fiberglass)	SC1	SC2	SC3	SC4	SC5	SC5
	M55 (HDPE)	Crushed rock	GW,GP, SW,SP	GM,GC, SM,SC	CL,ML, ML-CL	CH, MH, CH-MH	

NOTES:
1. Unified Soil Classification System, as described in ASTM D 2487
2. AASHTO Soil Classification System, as described in AASHTO M145.
3. As described in ASCE 15-98.
4. Manuals of water supply practices published by AWWA.

Thrust Blocks: Allowable Lateral Soil Bearing Pressure (psf)

Soil Type	M-9[1] Concrete	M-11[2] Steel	M-23[3] PVC	M-41[3] DIP	M-45[3] Fiberglass	M-55[4] HDPE
Muck, Peat	(1)	(2)	0	0	0	(4)
Soft Clay	(1)	(2)	500	1,000	1,000	(4)
Silt	(1)	(2)	-	1,500	1,500	(4)
Sandy Silt	(1)	(2)	-	3,000	3,000	(4)
Sand	(1)	(2)	1,000	4,000	4,000	(4)
Sand and Gravel	(1)	(2)	1,500	-	-	(4)
Sandy Clay	(1)	(2)	-	6,000	6,000	(4)
Sand and Gravel with Clay	(1)	(2)	2,000	-	-	(4)
Sand and Gravel Cemented with Clay	(1)	(2)	4,000	-	-	(4)
Hard Pan (clay)	(1)	(2)	5,000	9,000	9,000	(4)

Notes:
1. Based on knowledge of local soil conditions. Factor of Safety of 1.0.
2. To be determined from field tests by qualified geotechnical engineers. Factor of Safety of 1.0.
3. Factor of Safety of 1.5.
4. Thrust blocks do not resist pullout and are not a substitute for external mechanical restraint.

Inconsistent and Questionable Soil Parameters for Design

Gravel and Sands - 95% Compaction

		SOIL DESCRIPTION			
		Friction Angle Phi (degrees)	Cohesion c (psf)	Unit Weight (pcf)	Modulus Soil Reaction [1] (psi)
STD. SOIL CLASSIFICATION SYSTEMS	USCS [(1)]	GW, GP, SW, SP			
AWWA DESIGN MANUALS	M9 (Concrete)	48	0	140	N/A
	M11 (Steel)	?	?	?	1600 – 2500 (Depends on Cover)
	M23 (PVC)	31 - 35	0	110	3000
	M41 (DIP)	36	0	100	500 (Reflects installation conditions)
	M45 (Fiberglass)	?	?	?	1415- 5000 [1] (Depends on Cover)
	M55 (HDPE)	?	?	118-150	1600 – 2500 (Depends on Cover)

NOTES: [1]. Constrained soil Modulus for M45;

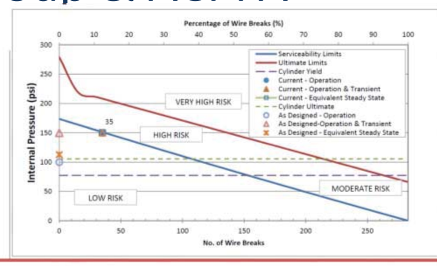
ASCE PIPELINES 2013 CONFERENCE
Pipelines and Trenchless Construction & Renewals: A Global Perspective

Outcome of Research with Incomplete Documentation

- Reasons for Incomplete Documentation Could be
  - Lack of Research Funds for Adequate Documentation
  - Failure to Disseminate
    - Lost Data and Documentation
  - Intentional Withholding of Information
    - To Gain Competitive Advantage
- Examples are:
  - PCCP Research Supported by PCCP Users Group and American Concrete Pressure Pipe Association (ACPPA)
  - Thrust Restraint Design Approach Presented in AWWA M9.

PCCP Research Supported by PCCP User's Group & ACPPA

- Design Practice of PCCP Evolved
  - Increased Experience of Successful Use
  - Desire to Maintain Competitive Advantage
  - Increased Occurrence of Failure on Pipes Manufactured Between 1971 and 1979.
  - Prestressing Wire Breaks Impact the Structural Capacity of Pipes
- Research on PCCP performance with broken wires
  - Completed with Support from
    - PCCP User's Group
    - American Concrete Pressure Pipe Association (ACPPA)
  - Limited (Incomplete) Documentation via Conference Papers
  - No Publicly Known Final Report!!

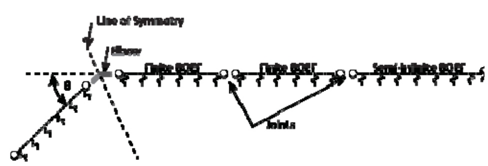


Lack of Complete, Identifiable, Unique Final Documentation of this Funded Research Effort

- ✓ Makes Independent Verification Difficult
- ✓ Discourages Research Efforts on the Subject by Others
- ✓ Limits the Full Use of Research Findings to People Conducted the Research
- ✓ Slow or Difficult Process to Eventual Widespread Use of Research Findings

Thrust Restraint Design Approach Design Manual M9 (AWWA 2008)

- Recognizes the Need to Consider Pipe Soil Interaction
  - Thrust induced Stresses on the Pipe Design
- Incomplete Guidance
  - Approach is Not Fully Described
  - Difficult to use
  - Needs Improvement!!



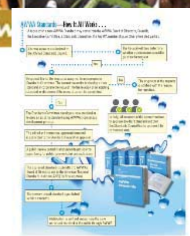
Lack of Clear, Concise, and Complete Documentation in an AWWA Design Manual

- ✓ Makes it Difficult to Use Guidance
- ✓ Decreases Trust in AWWA Manuals
- ✓ Limited Use.

AWWA Design Manuals are Not ANSI Certified – and Require Lower Care!!

AWWA Standard Development Process

Formal Request for New AWWA Standard
↓
Standard Council Assigns to Standards Committee
↓
Standards Committee Develops and Approves the New Standard
↓
Standards Council Approves by Consensus Vote
↓
Council Approved Standard is Presented for Public Review
↓
Approved Standard is Presented to AWWA Board of Directors & ANSI for Final Approval



Standards Committee may Create a Subcommittee to Develop the New Standard
- ✓ Subcommittee procedures may not be regulated strictly
- ✓ All subcommittee work is forwarded to the Standards Committee for final approval
- ✓ Key Ballots and Approvals may be made by People with Limited Technical Information or Details

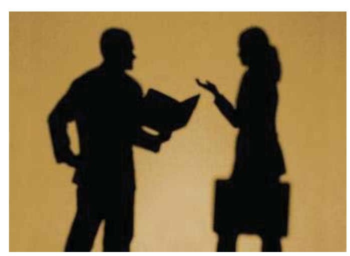
Details of Standard Development Progress is not Available for Non-Member Stakeholders, except during Public Comment Period
- ✓ Narrow Public Comment Period Does not Address this Lack of Transparency.

ASCE PIPELINES 2013 CONFERENCE — Prepared for Teaching & Educational Purposes Only; No Other Use Permitted — 13

Process Improvement Needs

ASCE PIPELINES 2013 CONFERENCE — Pipelines and Trenchless Construction & Renewals: A Global Perspective

- Collaborate with Stakeholders
  - Owners, Manufacturers, Contractors, Designers, and Researchers
- Document Research Findings
  - Clear, Concise, Complete
- Develop & Document Practice Improvements
  - Best Practices, Manuals, Guidelines, Standards, and Codes
- Improve Standard/Code Development Process



ASCE PIPELINES 2013 CONFERENCE — Prepared for Teaching & Educational Purposes Only; No Other Use Permitted — 14

ASCE | PIPELINES 2013 CONFERENCE
Pipelines and Trenchless Construction & Renewals: A Global Perspective

Conclusion - Ideal Process for Practice Improvements

- Monitor
  - ✓ Evaluate Existing Practice
  - ✓ Study Case Histories (Successes & Failures)
  - ✓ Identify Practice Improvement Needs
- Research
  - ✓ Identify Research Needs
  - ✓ Collaborate with Stakeholders
  - ✓ Conduct Research
  - ✓ Document Findings!!
- Develop Practice Improvements for
  - ✓ Design
  - ✓ Construction
  - ✓ Operation and Maintenance
- Develop/Update Practice Requirements
  - ✓ Best Practices
  - ✓ Guidelines
  - ✓ Standards
  - ✓ Codes

- Collaborative Effort to Conduct Research
- Fully Document All Research Findings
- Implement Practice Improvements
  - Effectively
  - Expeditiously
  - Maximizing Positive Contribution and Impact
- Collaborative Effort to Develop/Establish Practice Requirements

A Fundamental Shift in Approach to the Maintenance of Existing and the Development of New Guidance Documents is Essential.

New Research Efforts Should Recognize the Need for a Radically Different Approach towards Standards /Codes Development to Significantly Influence Future Practice Improvements.

ASCE | PIPELINES 2013 CONFERENCE
Pipelines and Trenchless Construction & Renewals: A Global Perspective

Questions?

- Contacts:
  - Pipeline Location and Installation Technical Committee
    - Chair: Sri Rajah (sri.rajah@hdrinc.com)

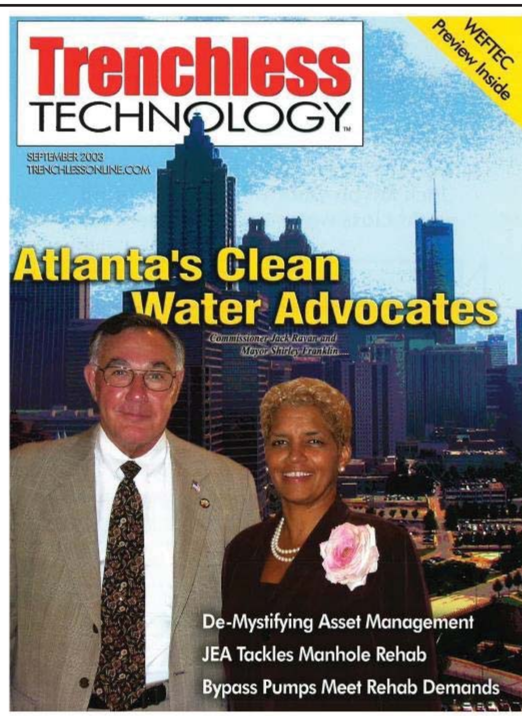
ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Development of Asset Management Certification and a Living Lab

Tom Iseley, Ph.D., P.E.
Professor, Purdue School of Engineering & Technology, IUPUI
Chair, Buried Asset Management Institute-International

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE



June 22, 2013, Ft Worth, TX

Water & Sewer Champion

- **Mayor Shirley Franklin – Atlanta's Sewer Mayor**
  - Atlanta Journal-Constitution – July 15, 2002

    Atlanta eager to develop world-class sewer system

    - People worldwide dream of living in a community with clean water, plentiful jobs and affordable housing. Over the Next 12 years, Atlanta will make its largest investment ever in such a dream. To assure high water quality and long-term economic stability for ourselves, our children and grandchildren, we are embarking on a $3B sewer improvement program.
    - Most of this investment is required under a federal court order --- **it is our opportunity to develop a world-class sewer system**

ASCE PIPELINE RESEARCH NEEDS SYMPOSIUM

World-Class Utility: What does it take?

- Innovation
- Validation
- Education

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

Technology – Essential for meeting the needs of our water utilities' infrastructure.

Technology – Results from research. $ invested in research is wasted if technical solutions are not commercialized.

LL – Important for TRIP (Transferring Research into Practice)

IUPUI SCHOOL OF ENGINEERING AND TECHNOLOGY
A PURDUE UNIVERSITY SCHOOL
Indianapolis

BAMI-I
Buried Asset Management Institute - International

RCL
the Community Anchor since 1948
P. O. Box 22156
Indianapolis, IN 46222

RWELLS
Riverside Watershed Environmental Living Lab For Sustainability

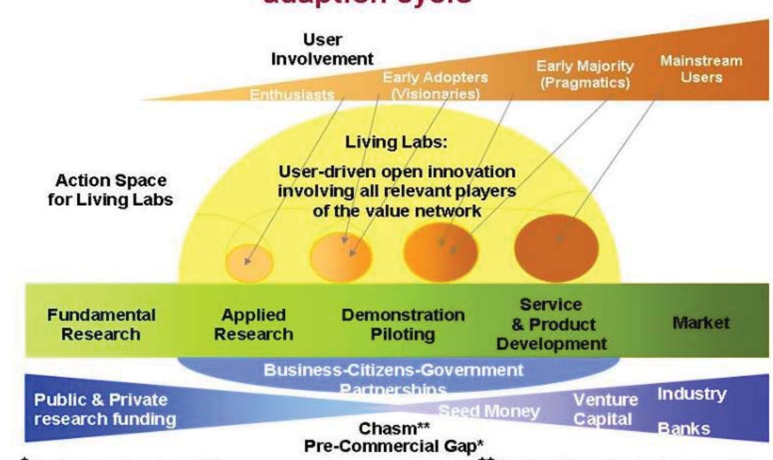
Riverside
Watershed
Environmental
Living
Lab for
Sustainability

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

LIVING LAB

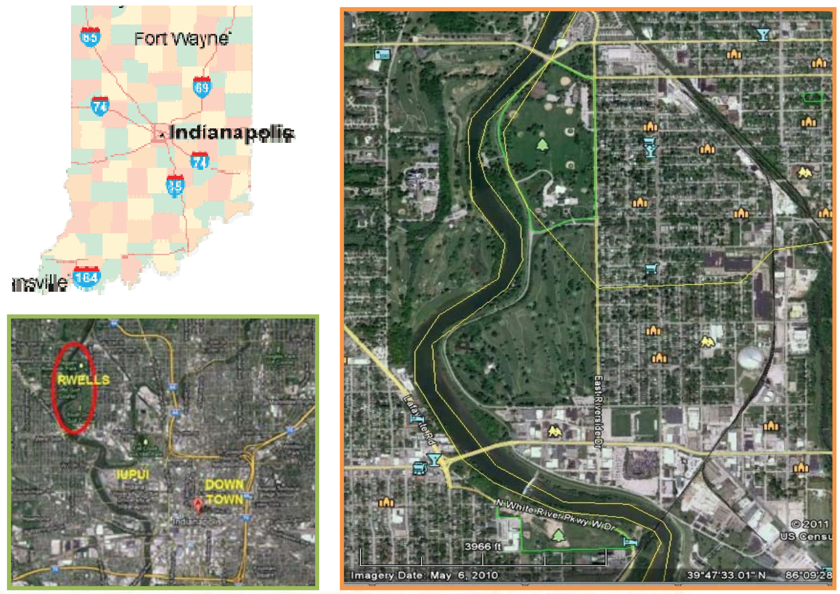
Action space for Living Labs along the technology adaption cycle



* MacDonald and Associates, 2004 ** Geoffrey A Moore: Crossing the Chasm, 1999

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM



Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

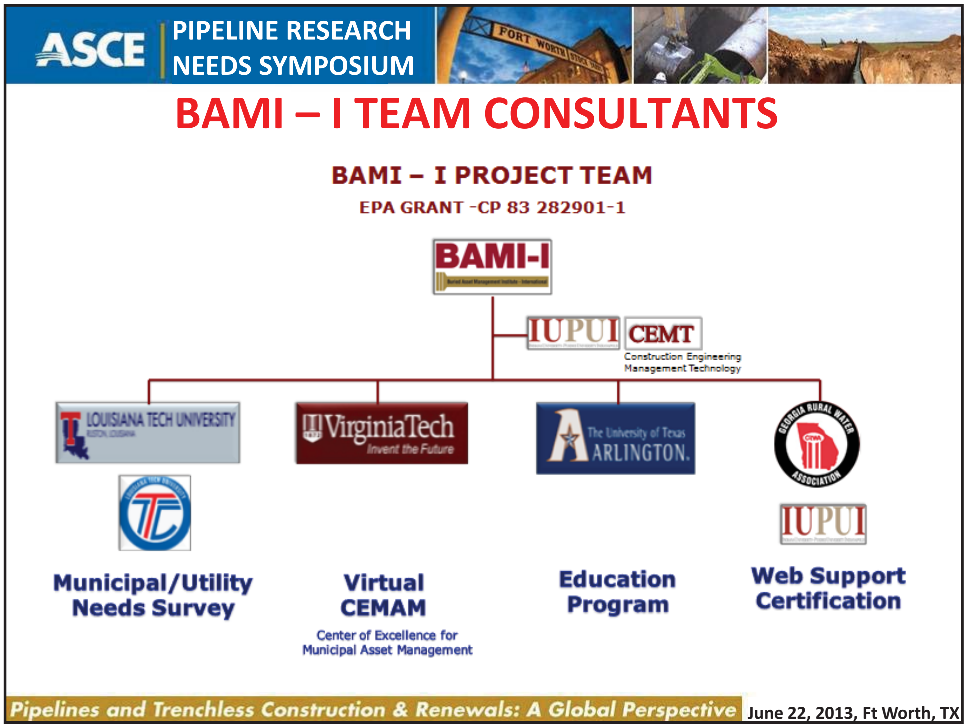
ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

AM: Origins in the Utility Industry

CTAM Certification of Training in Asset Management

- 1972 Clean Water Act *(PL 92-500)*
  - Launched NPDES *(National Pollutant Discharge Elimination System)*
  - First steps towards SSES *(Sewer System Evaluation Survey)*
- AM Continued Advancement
  - CMOM *(Capacity, Management, Operation, Maintenance Program)*
  - GASB 34 *(General Accounting Standards Board)* - requirements

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX


ASCE
PIPELINE RESEARCH
NEEDS SYMPOSIUM
BAMI – I TEAM CONSULTANTS
BAMI – I PROJECT TEAM
EPA GRANT -CP 83 282901-1
BAMI-I
IUPUI
CEMT
Construction Engineering
Management Technology
LOUISIANA TECH UNIVERSITY
VirginiaTech
Invent the Future
The University of Texas
ARLINGTON
GEORGIA RURAL WATER ASSOCIATION
IUPUI
Municipal/Utility
Needs Survey
Virtual
CEMAM
Center of Excellence for
Municipal Asset Management
Education
Program
Web Support
Certification
Pipelines and Trenchless Construction & Renewals: A Global Perspective
June 22, 2013, Ft Worth, TX


ASCE
PIPELINE RESEARCH
NEEDS SYMPOSIUM
Online training program for water utility infrastructure management professionals
Exclusive Four-Part Series in
Asset Management Certification
1
2
3
4
CTAM 300 – Managing an Asset Management Program
Launching December 2013
Why offer courses in Asset Management?
Levels of Certification
Benefits of the CTAM Series
CTAM-100 at a Glance:
CTAM-200 at a Glance:
CTAM
Certification of Training
in Asset Management
SEWER
For more information and
to register, call 330.467.7588,
e-mail, vlosh@benjaminmedia.com or
visit bami-i.com/certification-training-
asset-management.html.
BAMI-I
IUPUI
UIM
Pipelines and Trenchless Construction & Renewals: A Global Perspective
June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

CTAM
Certification of Training in Asset Management

CTAM 100 – Fundamentals
CTAM 200 – Developing
CTAM 300 – Implementing
CTAM 400 – Financing

BAMI-I Buried Asset Management Institute - International

BENJAMIN MEDIA

IUPUI Indiana University – Purdue University Indianapolis

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

BAMI-I Buried Asset Management Institute - International

2003	BAMI	COA-DWM
2004	BAMI-I	BOD
2006	BAMI-I	EPA Grant
2008	BAMI-I	Completes grant
2010	BAMI-I	Launches CTAM
2013	BAMI-I	Launches CTAM 200

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

BAMI-I

Buried Asset Management Institute - International

2013 BAMI-I

- Establishes the Water Asset Manager Certification Program
- Establishes the Certification Board
- Launch CTAM 300 & 400
- BAMI-I AWAM
- BAMI-I PWAM

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

QUESTIONS?

Tom Iseley, Ph.D., P.E.

Professor, Purdue School of Engineering & Technology, IUPUI

Chair, Buried Asset Management Institute-International

Tel.: (317) 278-4970

E-mail: dtiseley@iupui.edu

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

14th INTERNATIONAL TRENCHLESS TECHNOLOGY RESEARCH COLLOQUIUM

June 3 to 4, 2012
Scotia Bank Convention Centre, Niagara Falls, Canada

Dr Mark Knight
University of Waterloo
Centre for Advancement of Trenchless Technologies

UNIVERSITY OF WATERLOO

Trenchless Research Colloquium (TRC)

- A small group of invited national and international experts from industry, academia and public sector
- International Society of Trenchless Technology (ISTT) supported activity

UNIVERSITY OF WATERLOO

Trenchless Research Colloquium (TRC)

- The purpose is to promote and accelerate national and international trenchless technology research by bringing recognized researchers and industry and public sector leaders together for in-depth discussions of research issues, new and emerging technologies, future research needs and opportunities.

UNIVERSITY OF WATERLOO

TRC History

- The first trenchless research colloquium was organized and hosted by Dr. Raymond Sterling Trenchless Technology Center (TTC), Ruston Louisiana, USA in 1998.
- This colloquium consisted of Professors from France, United Kingdom, Germany, United States and Canada, as well as, recognized leaders from industry and government.

UNIVERSITY OF WATERLOO

TRC History

- 2nd 1998 Trenchless Technology Center, Ruston, Louisiana, USA
- 3rd 1999 Nuremberg & Münster, Germany
- 4th 2000 Vancouver, Canada
- 5th 2001 University of Birmingham, Birmingham, UK
- 6th 2003 Arizona State University, Tempe Arizona, USA
- 7th 2004 University of Waterloo, Waterloo, Canada
- 8th 2005 Delft University of Technology, Delft, The Netherlands
- 9th 2006 Sydney Water, Sydney, Australia
- 10th 2007 Rome, Italy
- 11th 2009 Queen's University, Kingston, Canada
- 12th 2010 NTU, Singapore
- 13th 2011 Beijing, China
- 14th 2012 Niagara Falls, Canada
- 15th 2014 Madrid, Spain

UNIVERSITY OF WATERLOO

14th 2012 Niagara Falls, Canada

Two main goals:

1. Identify water and wastewater research needs and gaps
2. Investigate the possibility of International research collaborations with international research funding

UNIVERSITY OF WATERLOO

Participants

- Canada, USA, United Kingdom Researchers
- Water Utility leaders
- Consultants
- Key industry representatives

UNIVERSITY OF WATERLOO

Process

Group decided to divide into two separate breakout groups to research needs and gaps for:

1) Pressure Pipelines - Dr. Mark Knight Chair

2) Gravity Pipelines – Dr. Samuel Ariaratnam Chair

UNIVERSITY OF WATERLOO

Pressure Pipelines
INSPECTION TECHNOLOGIES

- Acoustic correlation
  - External and Internal
  - Leaks
  - Wall thickness
- Impact Echo -> Internal
- CCTV -> Internal
- Eddy Current -> Internal
  - Wire Break
  - Wall thickness
- Broadband electromagnetics
  - External
  - Pipe wall thickness
- Ultrasound
  - External and internal
  - Wall thickness
- Laser -> Internal and External
- Infrared Thermography
  - Leak Detection External
  - Thermal changes
- JD7 Wachwater
- Long range guided ultrasonics
- Pure Smart ball
- Pure/WRc Sahara

UNIVERSITY OF WATERLOO

Pressure Pipelines

Pipe Condition Indicators

- Historical Records
  - Break history
  - Pipe materials
  - Age
  - Soils and water
- Water quality and chemistry
- Flow tests -> C factor
- Pressure monitoring
- Flow monitoring
- Dye testing
- Coupon sampling

Condition Assessment Issues

- Political impact of collecting condition assessment data
- Locating challenges

UNIVERSITY OF WATERLOO

Pressure Pipelines
Condition Assessment Limitations

- A gap exists between measurements and pipe performance
- Limited verification of data and standards
- No "WRc/PACP" standard pipe condition coding and condition grading system for pressure pipes
- Lack of education and training

UNIVERSITY OF WATERLOO

Pressure Pipelines
Condition Assessment
Relevance of Measurements

- Where do they work?
- Cost and value of information
- Large diameter
- Material specific
- Technology specific
- Technology and data owned by company
- Most need line to be shut down (bypassed)
- Calibration
  - Often requires removal of pipe section
- Access and disinfection
- Distance of inspection
- Cheaper to put inspection $ into renovation

UNIVERSITY OF WATERLOO

Pressure Pipelines
Technologies -> Rehab/Renovation

Nonstructural

- Improve water quality
- cement
- epoxy coating
- fast setting polymers

Structural

- CIPP, fold and form, close fit, loose fitting liners
- Carbon fiber
- Hose liners
- Spray in place?
- Grout in place (MainSaver)?
- Melt in place?
  - Aqualiner
- Sliplining
  - (grouted and non-grouted)

UNIVERSITY OF WATERLOO

Pressure Pipelines
Technologies -> Limitations

- Service connections
- Definitions /terminology
- Service reinstatements -> bond vs. non bond
- Bond of liner to host pipe -> pipe cleaning
- Design standards
- Construction imperfections
  - Design to strain vs. design to stress
  - Wrinkles, folds, gaps
  - Quality Assurance and Quality Control
  - End seals
- Cost – too high compared to replacement

UNIVERSITY OF WATERLOO

Pressure Pipelines
Technologies -> Limitations

- Liner/Pipe Fatigue
  - Service connections
  - Liner ends
  - Gaps/joints
  - Load cycles
- Gathering and understanding pressure pipe operation data
  - Water velocity, surge, operational, total and negative pressures

UNIVERSITY OF WATERLOO

Pressure Pipelines
Technologies -> Major Gap

- Do not understanding how pipes fail and information needed to predict failure and remaining life

UNIVERSITY OF WATERLOO

Pressure Pipelines
New Construction Methods

- HDD, open cut, boring (MT, TBM), auger boring and Pipe Jacking
  - New pipe material properties
  - Obstacles and soil conditions
  - Design methods
  - Education/training of designers and field inspectors
  - Quality Assurance/Quality Control procedures

  - Same issue as Gravity Pipelines Group...

UNIVERSITY OF WATERLOO

Pressure Pipelines
Polices

- Financial sustainability Revenues = expenses over short or long-term
- Energy water nexus

UNIVERSITY OF WATERLOO

Gravity Pipelines
Condition Assessment - Tools

- CCTV
- Digital pipe scanning
- Multi-Sensor (Laser, GPR, LIDAR, Sonar, etc.)
- Robotic Tools
- Electro-scanning

UNIVERSITY OF WATERLOO

Gravity Pipelines
Condition Assessment - Limitations

- Access for large diameters (900mm>)
- Length limitation up to 11,000 ft.
- Lighting for 900mm> (CCTV only)
- Locating of MHs/pipes. (Buried MHs)
- Large Diameter Cleaning
- Inspections of Siphons
- Flow (amount, velocity)
- Soil Voids
- Damage limitation
- Quality of data

UNIVERSITY OF WATERLOO

Gravity Pipelines
New Construction- Methods

- Microtunnelling
- Pipe Jacking
- PTMT
- Auger Boring
- Horizontal Directional Drilling
- Open-Cut
- VMT
- Tunneling (hand/machine)
- Pipe Ramming

UNIVERSITY OF WATERLOO

Gravity Pipelines
New Construction- Limitations

- Accuracy of grade for non-laser based systems
  - (HDD, ramming)
- Obstacles (buried utilities)
- Geotechnical site investigation (accuracy)
- Access
- Cost
- Curved pipe sections
- Length of laser
- Geotechnical conditions
- Post-installation conditions

UNIVERSITY OF WATERLOO

Gravity Pipelines Rehab/Renovation- Methods

Structural	Non-Structural
• CIPP	• Spray on
• Sliplining	• Spiral wound
• Fold and Form	• Grouts
• Panel liners	• Crack injection

UNIVERSITY OF WATERLOO

Gravity Pipelines Rehab/Renovation- Limitations

- Host pipe conditions
- Access
- MH spacing
- Groundwater
- Inconsistent geometry
- Flow control - bypassing
- Soil voids

UNIVERSITY OF WATERLOO

Gravity Pipelines Replacement- Methods

- Pipe Bursting

UNIVERSITY OF WATERLOO

Gravity Pipelines Replacement- Limitations

- Diameter upsize
- Host pipe conditions
- Surface/ground movement
- Utilities/obstacles
- Lateral reinstatement

UNIVERSITY OF WATERLOO

Key Research Needs

- Long-term performance and failure mechanisms of post-installed pipes
- Performance of renovated pipes
- Predictive failure modeling
- Data mining, management and analysis
- Objective condition assessment
- Decision-making tools
- Smart pipes
- Infrastructure financing tools

UNIVERSITY OF WATERLOO

Key Research Needs

- Working on two position papers that identify research needs and gaps

UNIVERSITY OF WATERLOO

Appendix B

Breakout Sessions

Session 1 Breakout Report
Pipeline Failures

Group Leader - Mr. John Black

Students

1. Andrew Makardetsh
2. Milad Haneen
3. Nick Spinden
4. Jacob Elias
5. Alex Rafiqui
6. Claudio Segovia
7. Jay Bui
8. Quadri Akamo
9. Espinosa S. McDonald
10. Pizarro
11. J. Ramirez

Kick-off Points

- Construction related failures.
- Broken strands on prestressed concrete pipes.

Terms of Failures

- Most are slow leaks.
- Few blow outs due to corrosion.

Causes

- Drilling rigs
- Uninformed contractors
- Poor inspection

PVC Not Used in US

- Has a property that degrades and burns below processing temperature.
- High cost for large PVC.
- Expected life of PVC 50 years (?)
- In service in Germany before war.

Pipe Failure due to Series of Interacting Situations

- Need data, training, observation of known environments which cause failure.

HDPE up to 36"

- Joints on Cast Iron pipes (Concerns)
- Barrel of Pipe is in good condition.
- Could be used substitute during war.
- Lead was used for productions

Where do Failures Start?

- Point of Stress Concentration
    - Defects
    - Oxidation layers
    - What causes that point of stress concentration?

What are Long-term Effects on Composite Pipe?

PVC is not manufactured to be very tough in the US

- Manufacturers do not identify what happen and try to prevent it.
- Manufacturing can introduce inclusions such as dirty resin, burnt carbon.

Cast Iron Made Thinner Over the Years

- Reduce variance in quality.
- Reduce likelihood with defect.
- Strength improvement but fight on corrosion not imposed.
- Contractors not treating pipes well during installation.

Session 2 Breakout Report
Pipeline Inspection and Monitoring

Group Leader - Mr. Gerhard Muenchmeyer

Students
Xiangjie Kong
Jim Geisbash
Neil Gaukstad
Charles Herchis
Marin Roubal
Gen Nielsen
Kelly Wood
Alex Rafqui

Inspection and Monitoring

- **MR**
  Elbows and reducers are weak points. Good reason to monitor the weak points first.
- **Sensors on Fittings**

Currently being done on a gas line in Western Australia. Could be done on water pipelines. Linked in through cellular networks.

- **Kong**

Technology is available for pipe inspection. The challenge is getting the equipment in the pipe. Delivery vehicle, as well.

- Failure mode of different types of pipe to help choose appropriate technology
- Categorize infrastructure
- EPA and the trades need to come up with some standard terminology, reporting etc.

Session 3 Breakout Report
Pipelines Materials, Corrosion and Biofilm

Group Leader - Mr. Frank Blaha

Students

1. Inigo Azofra
2. Leonardo Pena
3. Omar Pena
4. Eduardo Reyes
5. Divyashree Divyashree
6. Michelle C Sherman
7. Franklin Cheng
8. Carlos Saldana
9. Rodolfo Guerra
10. Edie Lopez Humberto
11. Johnson Alejandro
12. Pino Bravo

- Polyurethane and other new corrosion coatings add to long-term performance. Degradation of coatings is expensive to UV. How sensitive: Just put on thicker?
- Standard and Accepted Protocol for Accelerated Life-span testing of Corrosion Coatings Materials.
- Longevity: Assessment and design factors, case studies for new pipe materials and liner materials.
    - Basic performance
    - Thrust resistant
    - Deterioration resistant for GRP, CIPP, SIPP Liners
- CML life extension and composition modes for improved life extension/ biofilm control.
- Biofilm work impacts corrosion, pumping costs, control measures

Session 4 Breakout Report
Pipeline Asset Management and Sustainability

Group Leader - Dr. Tom Iseley

Students

1. Laura Villa
2. Eric Rocha
3. Chetan Patel
4. David Trejo
5. Bryson Ewing
6. Charles Kist
7. Mahran Zatar
8. Reece Bierhalter

GAPS

- Cost to Implement Asset Management Program
    - Need backing from upper management.
    - At what point is it more cost effective to just replace?
    - See WRF study.
    - Rehab initiative is 47% to total system replacement.
- Risk Reduction and Reducing Negligence Claims
- How to Pay for Rehabilitation Costs?
- Cost for Asset Management
- Making a Decision what to rehabilitate
    - 3600 assets
    - 240 year life cycle
- Replacement
    - 4% of replacement cost to conduct
- Occur to inform
- Negligence
- Driver Emergency
- Non Preventive Water
    - TX negative water audit annually
- Standards for Reliability
    - Cannot benchmark
    - Useful life
    - Estimate useful life
    - ISI- embodied energy
    - PCA- How to get finance
- How to Deal with Pipe at the End of Useful Life
- Extent of Sustainability such as 200 Years

DRIVER FOR UTILITY TO IMPLEMENT AM PLAN

- Reliability

- Funding (Tied to have plans)
- Core Values + Vision Needed
- Emergency Management
- Cost Savings, Building a Business Case
- Reducing Water Loss/ Conservation
- Reducing Response Time
- Budgeting Process
- Not a Standard for Rehabilitation
    - Can’t benchmark
    - Can’t develop best management properly
- No Standard for Useful Life
- How do you estimate Useful Life?
- Defining Terms
- Benchmarking
- Embodied Energy + CO_2
- Follow On to GASBY and Push towards Sustainability, Do we want?

Session 5 Breakout Report
Trenchless Technologies

Group Leader - Dr. Mark Knight

Students

1. Ivette Aguilar
2. Jorge Almendares
3. Pooja Patel
4. Elena Soto

Major Knowledge-Gaps

- Pressure pipe for potable water: Lack of design standards (none)
- Pressure pipe for potable water: No AWWA accepted replacement
- We don’t know how the systems really work: velocities, surge cycles
- Qualifications for design engineers (lack of professional training)
- Service-lateral reconnections: How do you address those connections?
- Rehabbing the main and not entering into private-property
- Technology improvements needed to fix service connection to the building
- Established contractors with enough work to create programs

Major Limitations / What’s Holding Back Trenchless Technology

- Perception that it’s more expensive; lacking critical mass of data
- Education lacking
- Engineering community holding it back, very conservative
- Operational repairs and fixes for mixed material systems

Major Limitations / What’s Holding Back Condition Assessment

- Develop better technology for inspection and assessment
- Many owners do not recognize value of money saved by understanding their system
- Too many technologies that are oversold
- Technology is sometimes sold on a 1-off basis instead of an entire pipeline repair project

Summary of Breakout Sessions

By

Dr. Firat Sever, P.E.

GROUP # 1: PIPELINE FAILURES
Mr. John Black

1. **Composite Pipes**
2. **Failures, RCC Pipes – Large Pipelines Failure – Large damage – more costly**
3. **HDPE Pipes – Not common in states, very big in rest of world**
4. **PVC has good reputation in States – 1. Heat Stabilizer**
5. **GRP – all of the failures arises from stress during installation**
6. **Series of failure with PVC pipe in NZ**

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

GROUP # 2: PIPELINE INSPECTION AND MONITORING

Mr. Gerhard Muenchmeyer

1. Australia –Gas Pipelines –Put Sensors in valves which is translated to cell phone or computer
2. Quite Few Technologies available for which standard needs to be developed
3. Standardization
4. Terminology Standardization, Specifications Standardization, Monitoring System should be installed on high consequence line
5. Inspection device during installation
6. Best Practices – Should be developed
7. Technology Transfer

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

GROUP # 3: PIPELINE MATERIALS, CORROSION AND BIOFILM

Mr. Frank Blaha

1. Testing of polyurethanes – UV exposure and degradation
2. Establish standard protocols for accelerated testing on corrosion
3. Longevity analysis of new pipe materials and internal linings – design factors associates with them
4. Cement mortar lining life extension. Improved life, biofilm growth control measures. Biofilm effects on material durability

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

GROUP # 4: PIPELINE ASSET MANAGEMENT AND SUSTAINABILITY

Dr. Tom Iseley

1. How does cost affect asset management plan? Rehabilitation could cost substantially less than replacement
2. How to develop effective rehabilitation/replacement programs?
3. Perception – if the condition is unknown then there may not be an intent for condition assessment and rehabilitation
4. Asset management plans help secure funding for capital investment
5. Emergency management plan could be incorporated into an asset management plan
6. Asset management as a business plan (broad spectrum)
7. Asset management program could reduce water loss
8. Standard practices/benchmarks needed (e.g. how do you determine useful life?)
9. Timeframe for a sustainability program (60, 70, 100 yrs?)

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

ASCE | PIPELINE RESEARCH NEEDS SYMPOSIUM

GROUP # 5: TRENCHLESS TECHNOLOGY

Dr. Mark Knight

1. Need design standards for increasing the use of trenchless technologies
2. Qualifications of engineers – need training on trenchless design.
3. Wastewater – lateral lining: Reliability, durability of materials and techniques. Service restoration issues.
4. Perception – Trenchless more expensive than conventional replacement? Need to address lack of knowledge on the cost.
5. Operation standpoint: Operators like to have same type of material in the system that they feel comfortable with.
6. Selling new technologies (e.g. condition assessment) to the utilities is difficult eve if they save money
7. Need to identify the goal for using TT. (e.g. reducing I/I)

Pipelines and Trenchless Construction & Renewals: A Global Perspective June 22, 2013, Ft Worth, TX

Appendix C

Biography of Speakers

Mr. Frank John Blaha
Senior Account Manager
Water Research Foundation
Phone: 303-347-6244
Email: fblaha@waterrf.org

Thirty years of experience in the water and environmental field. Mr. Blaha primarily worked as a consulting engineer until he joined the Water Research Foundation 17 years ago. While at the Water Research Foundation his focus has primarily been on distribution systems and buried infrastructure concerns.

Mr. Michael D. Royer
Physical Scientist
U.S. Environmental Protection Agency
Phone: 732-321-6633
Email: Royer.michael@epa.gov

Currently, Mr. Royer is project manager for EPA-WERF Cooperative Agreement on aging water infrastructure. Previously he was project manager for EPA task orders on condition assessment of water mains. He is contributor to EPA/ORD aging water infrastructure research program development.

Mr. Robert Smith
Research Program Manager
U.S. DOT/PHMSA
Phone: 919-238-4759
Email: robert.w.smith@dot.gov

Robert graduated from the Pennsylvania State University in 1997 with a BS in Petroleum and Natural Gas Engineering. He coordinated and managed the offshore pipeline and human factors research program at the Bureau of Safety and Environmental Enforcement (formerly U.S. Minerals Management Service) from 1997 to 2003. Since 2003, he is currently the R&D Manager and leads several strategic initiatives for the Pipeline and Hazardous Materials Safety Administration.

Mr. James Hart
Oil and Gas Program Manager
NACE International
Phone: 281-228-6226
Email: jim.hart@nace.org

As Oil and Gas Program Manager for NACE International he is the industry and staff liaison for all NACE, Oil & Gas related programs worldwide. Mr. Hart work with all NACE internal departments from Conferences, Education, and Membership, to Standards and Government Relations. He also works with all external stakeholder groups to develop and promote NACE programs and benefits.
Prior to joining NACE International in July of 2011, he was Publisher of Pipeline and Gas Technology Magazine at Hart Energy and have over 25 years' related experience in publishing, product development and communications.

Dr. Kesi You
Engineer
Shanghai Municipal Engineering Design Institute Co., Ltd.,
Phone: 86+021+51299343
Email: youkesi@smedi.com

Currently, Dr. You is Engineer with Shanghai Municipal Engineering Design Institute Co., Ltd. He recently completed his Ph.D. in Transportation Engineering from Southeast University.

Mr. Jonathan Faughtenberry
Senior Facility Engineer & Project Manager
Oasis Petroleum, Inc
Phone: 330-232-0219
Email: faughtenberry@yahoo.com

Mr. Faughtenberry has served 4 years as an Engineer and Project Manager at Freese and Nichols, Inc. He has also served 5 years at Chesapeake Energy as a Project Manager in the Barnett and Utica Shale Locations. Currently, he serves as a Senior Facility Engineer & Project Manager for Oasis Petroleum overseeing the design, installation, and operations of their Bakken Shale saltwater, freshwater, and gas gathering system.

Mr. David Marshall
Engineering Services Director
Tarrant Regional Water District
Phone: 817-720-4250
Email: david.marshall@trwd.com

Mr. Marshall is a registered professional engineer in Texas and has 34 years of experience in water resources. He worked for the U.S. Forest Service for five years in research of biological control of insect pests. He worked with the U.S. Geological Survey for five years as a hydrologic technician and hydrologist starting when he began his master's degree. He spent five years with Alan Plummer and Associates, Inc., where he was involved in many different types of water and environmental projects. He has been with the District since 1988 (25 years), he has been involved in a wide range of water quality and engineering projects. He started as Western Division Water Quality Manager for the District. As Engineering Services Director, his current role, his responsibilities include management of the District's water resources, including flood control and raw water supply. He also oversees major maintenance and capital improvement projects. He is currently part of the integrated pipeline team, a joint effort of TRWD and Dallas to build a 149 mile, $2.3 billion dollar transmission pipeline.

Mr. Xiangjie Kong
Director of R&D
Pure Technologies Ltd
Phone: 905-624-2436
Email: xiangjie.kong@puretechltd.com

Mr. Kong has over 15 years' experience in developing innovative condition assessment solutions for the water industry. As the Director of R&D at Pure Technologies, he is responsible for departmental leadership and technical management of all R&D activities. He has led the development of some of the most advanced water pipeline inspection techniques and tools. Mr. Kong holds a B.Sc. (1996) in Physics from Peking University in china and a M.Sc. in Physics (1998) from Queen's University in Canada.

Mr. Martin Roubal
Managing Director
Rock Solid Group Pty Ltd
Phone: +61 39335 6122
Email: mroubal@rocksolidgroup.com.au

Martin Roubal has been the managing director for the Rock Solid group of companies for the past 26 years and during this time has acquired extensive experience in various aspects of Non-Destructive Testing, geophysical surveying & geotechnical engineering.

Mr. Marc Bracken
President/CEO
Echologics Engineering Inc.
Phone: 905-672-3246
Email: MBracken@echologics.com

Marc Bracken is the Vice President and General Manager of Echologics Engineering. Marc received Bachelor's and Master's Degree in mechanical engineering with a specialization in acoustics from the University of Toronto. He started Echologics in 2003, and since this time the company has become a significant contributor to the advancement of water pipe leak detection and condition assessment technology. Echologics was acquired in 2011 by Mueller Water Products.

Mr. John Raymond Black
Principal Environmental Engineer
Opus International Consultants
Phone: 0064 274 844 886
Email: John.r.black@opus.co.nz

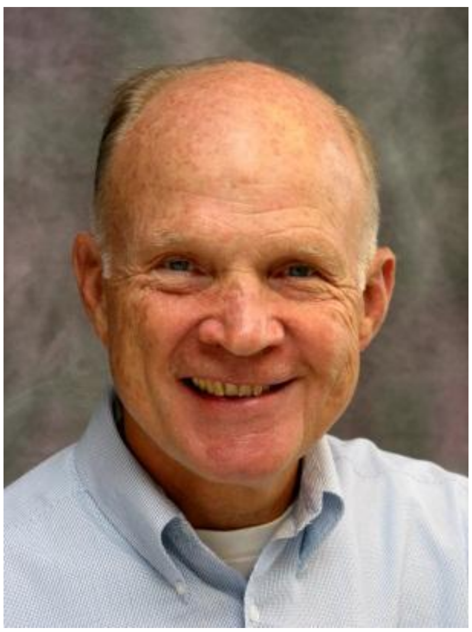
John has a passion for pipes and has been known as a "Pipe Whisperer" for many years. He became "Chief Whispers to Pipes" in 2007 and while he seldom talks to pipes, they definitely communicate their story to him. John has had over 50 years of engineering experience, with over 40 years involvement with water supply and drainage system design, construction and operation. He was a member of the pipelines task group 7A for the University of Canterbury's Centre for Advanced Engineering project report, "Lifelines in Earthquakes - Wellington Case Study" 1991.

He has a good understanding of most pipeline materials from clay (ceramic) pipes to wood-stave and cast iron pipes from the 1860's, through to the modern plastics pipe materials. This understanding has been honed through experience with condition assessment and pipe failure investigations. John regularly undertakes condition assessment of pipes of all materials (especially asbestos cement).

He has developed a number of pipe condition assessment techniques including the use of computed tomography (CT) scanning for measuring the depth of deterioration of AC pipes. CT scanning can also be useful for detecting inclusions and flaws in PVC and PE pipe materials. He has been (and continues to be) a participating member of three joint Australia/New Zealand standards committees PL/6, (polyolefin pipes), PL/21, (PVC, ABS and Polyamide pipes) and PL/45 (test methods) since 1993.

John has provided independent technical and practical advice regarding the selection of pipeline materials for earthquake recovery and new works to the local authorities that have been directly affected by the Canterbury earthquakes (Waimakariri and Selwyn District Councils and Christchurch City) as well as many other authorities around New Zealand.

Dr. Neil Grigg
Professor of Civil and Environmental Engineering
Colorado State University
Phone: 970-491-3369
Email: neilg@engr.colostate.edu



Dr. Grigg is a Professor in the Department of Civil and Environmental Engineering at Colorado State University, where he has also been Head of the Department of Civil Engineering and Director of the Colorado Water Resources Research Institute. He holds a Ph.D. (1969) from Colorado State (Hydraulic Engineering), an M.S. (1965) from Auburn University (Hydraulic/Structural Engineering), and a B.S. (1961) from the US Military Academy (Engineering).

His recent experience has focused on urban water and utility management, with a special emphasis on data management and risk assessment. He teaches a graduate course in pipeline engineering and hydraulics at Colorado State. His Water Research Foundation projects include: integration of cost of failure into risk assessment, dual water systems, and secondary effects of corrosion control on distribution systems, integrity of water distribution systems, predicting main breaks, and surviving disasters in water utilities. He also worked with the WaterRF toward implementing the National Mains Failure Database. He was an expert advisor to WaterRF's Research Advisory Committee on water supply infrastructure. He is also currently a member of the Editorial Advisory Board for the Journal, AWWA. His published book titles include Water and Sewer Infrastructure Management (second edition) and Urban Water Infrastructure, as well as about a dozen other books on water and infrastructure engineering and management.

He has worked extensively in public works and utility engineering. He was co-founder and a principal of Sellards & Grigg Inc., Denver and participated in a number of municipal engineering projects involving water supply, stormwater, and public works. He has also been a state official and regulator in his role as Assistant Secretary for

Natural Resources and Director of Environmental Management (1979-80), State of North Carolina. He was responsible for managing the Clean Water Act programs in permitting, enforcement, and construction grants. He also had responsibility for river basin water quantity and quality, and groundwater management.

He is a Life Member and Fellow of the American Society of Civil Engineers, a Life Member of the American Water Works Association and American Public Works Association (Board of Directors, 1992-95). He is a former president of the Fort Collins Water Board and former two-term member Fort Collins Transportation Board. He is a registered professional engineer in Colorado, Alabama, and North Carolina.

Mr. Ernest Lever
R&D Director, Infrastructure
Gas Technology Institute
Phone: 847-544-3415
Email: Ernest.Lever@gastechnology.org

More than twenty years of experience in the plastics piping field. Specific expertise in molded fittings, electrofusion, butt-fusion, using the finite element method to model the behavior of plastic systems and the slow crack growth behavior of PE piping assemblies. Developed proprietary FEA tools for the modelling of transient non-linear heat transfer as applied to heat fusion of polymer assemblies.

Experienced in multi-physics, probabilistic and statistical simulations of physical systems. Currently involved in developing risk models that focus on threat interactions and their influence on probability of failure of infrastructure systems.

Dr. Graham Bell
Principal Professional Associate and Senior Vice President
HDR Engineering, Inc.
Phone: 909-841-6729
Email: Graham.Bell@hdrinc.com

Dr. Bell received his Engineering degrees from the UCLA School of Engineering and Applied Sciences. He has more than 30 years of experience in designing, testing, assessing and forensic evaluation of damage on civil engineering and water works projects. He has been the co-principal investigator for nine AWWA/WaterRF Research Projects. He has more than 65 peer reviewed journal and conference publications and presentations.
Dr. Bell is the past Chairman of AWWA Corrosion Committee; Member of AWWA Concrete Pressure Pipe Committee; Past Chair or Vice Chair of NACE International Committee on Corrosion Control for Ductile Iron Pipe and Cathodic Protection of PCCP and Cement Mortar Coated Pipe.

Dr. Sri Rajah
Senior Structural Engineer
HDR Engineering, Inc.
Phone: 425-450-6269
Email: sri.rajah@hdrinc.com

Dr. Rajah has over 25 years of experience in civil engineering in research, teaching, and consulting in the areas of pipelines, geotechnical, structural, and hydraulic engineering. He has more than 40 peer reviewed journal and conference publication and presentations.

Dr. Tom Iseley, P.E.
Professor & Director
Construction Engineering Management Technology
IUPUI-Purdue School of Engineering & Technology
Phone: 317- 278 -4970
Email: dtiseley@iupui.edu

Dr. Tom Iseley has over 35 years of experience in the planning, design, and construction of underground infrastructure systems. From 1982, he served on the faculty of Mississippi State University, Purdue University, and Louisiana Tech University. During the past 25 years, he has maintained an international leadership position in trenchless technology. In 1989, Dr. Iseley established the Trenchless Technology Center (TTC) at Louisiana Tech University. He is a founding director of the North American Society for Trenchless Technology (NASTT).

Dr. Mark Knight
Associate Professor Department Civil and Environmental Engineering Executive Director Center for Advancement of Trenchless Technologies (CATT)
University of Waterloo
Phone: 1 519 581-8835
Email: maknight@uwaterloo.ca

Dr. Knight worked as a Geotechnical Consultant for six year prior to going back to complete Master and Doctorate degrees in Civil Engineering. He joined University of Waterloo as a professor in 1997. He developed NASTT CIPP Good practice course along with number pipeline condition assessment, construction and renovation course using trenchless technology. He is also the founding member of the International Research Trenchless Technology Advisory Committee and Developer of industry leading pipeline software programs: BOREAID, PPI-BOREAID, PPI-PACE and CIPPCALC.

Dr. Ali Abolmaali
Department Chair
University of Texas at Arlington
Phone: 817-272-3877
Email: Abolmaali@uta.edu

Dr. Abolmaali is a Professor in structural and applied mechanics at the University of Texas at Arlington. He is the Founding Director of UT-Arlington Center for Structural Engineering Research and the Professor-in-Charge of the Structural Simulation Laboratory at UTA. Professor Abolmaali has intensive research experience and ongoing research projects in computational structural engineering and full scale structural testing of civil, aerospace, and underground structural systems including research in fluid structure interaction problems. As a Principal Investigator, Dr. Abolmaali has secured over $30M in research and development funds from states, federal and private agencies. These funding agencies include but not limited to the National Science Foundation, departments of transportation, Federal Highway Administration, and others to conduct basic and applied research in structural engineering and mechanics. Professor Abolmaali's ongoing research projects focus on developing coupled nonlinear finite element algorithms and full-scale experimental testing to simulate the nonlinear behavior of structural systems subjected to static and dynamic loadings up to collapse. Dr. Abolmaali is the author and co-author of over 105 refereed technical journal papers and conference proceedings in structural engineering and finite element method. Dr. Abolmaali has given over 110 technical presentations nationally and internationally.
Dr. Abolmaali has conducted several high profile failure investigation research projects for the National Transportation Safety Board examples of which are the Boston Tunnel collapse (Big Dig Tunnel), Minneapolis Bridge collapse, and Big Spring's Nebraska Bridge collapse.

Appendix D

Symposium Attendee List

Sharon Hamilton, P.E.
City of Austin - Water Utilities
625 E. 10th Street, Suite 400
Austin, TX 78701
Phone: 512-972-1170
Fax: 512-972-0228
Cell: 512-695-3263
Email: Sharon.hamilton@austintexas.gov

Randy D. Randolph, P.E.
Engineering Managere
Central Arizona Project
23636 North Seventh Street
Phoenix, AZ 85024
Phone: 623-869-2260
Fax: 623-869-2249
Cell: 602-717-8286
Email: rrandolph@cap-az.com

John A. Economides, P.E.
Economides Consulting
310 Via Andalusia
Encinitas, CA 92024
Phone: 619-985-4066
Fax: 760-652-4849
Email: johnecono@aol.com

Alan C. Hutson, P.E.
Principal/Manager
Freese and Nichols
10497 Town and Country Way, Ste. 600
Houston, TX 77024
Phone: 713-600-6847
Fax: 713-600-6801
Cell: 817-891-4695
Email: alan.hutson@freese.com

Anna Pridmore, Ph.D.
Vice President - Pipe Solutions
Structural Technologies
1332 N. Miller Street
Anaheim, CA 92806
Cell: 714-869-8824
Email: apridmore@structural.net

Raymond E. Asuquo
Regional Discipline Lead - Pipelines
Shell Petroleum Development Company
P.O. Box 263
Port Harcoust, Rivers Nigeria
Phone: +234-8070339041
Email: Raymond.asuquo@shell.com

Jain Zhang
Research Manager
Water Research Foundation
6666 W Quincy Ave
Denver, CO 80235
Phone: 303-347-6114
Email: jzhang@waterrf.org

Veysel F. Sever
Senior Engineer
Benton & Associates
1970 W. Lafayette
Jacksonville, IL 62650
Phone: 217-245-4146
Fax: 217-245-4149
Email: fserver@bentonassociates.com

Ahmad Habibian
National Practice Leader
Black & Veatch
18310 Montgomery Village Ave #500
Gaithersburg, MD 20879
Phone: 301-556-4382
Fax: 301-556-4452
Email: habibiana@bv.com

Kelly W. Wood
Engineer VI
Freese and Nichols, Inc.
4055 International Plaza Suite 200
Fort Worth, TX 76133
Phone: 817-735-7317
Fax: 817-735-7491
Email: kww@freese.com

Charles Herckis
Senior Project Manager
TDW Services

201 S. Maple Ave Unit 308
Oak Park, IL
Phone: 630-234-7412
Email: charles.herckis@tdwilliamson.com

Jim Geisbush
Engineer
Central Arizona Project
23636 N. 7th St
Phoenix, AZ 85024
Phone: 623-869-2696
Email: jgeisbush@cap-az.com

William Skerpan
VP – Chief Construction Services
Beta Group Inc.
6 BlackstoneValley Place
Lincoln, RI 02865
Phone: 401-333-2382
Fax: 401-333-9225
Email: bskerpan@beta-inc.com

Neil J. Gankstad
Civil Engineer
Central Arizona Project
23636 N 7th St
Phoenix, AZ 85024
Phone: 623-869-2258
Email: ngankstad@cap-az.com

John H. Bambei
Chief of Engineering
Denver Water
1600 W. 12th Ave
Denver, CO 80204
Phone: 303-628-6669
Fax: 303-628-6851
Email: john.bambei@denverwater.org

Elizabeth R. Blackwelder
Project Manager
Freese and Nichols, Inc.
4055 International Plaza
Fort Worth, TX 76109
Phone: 817-735-7339
Email: erb@freese.com

Camille G. Rubeiz
Director of Engineering
PPI
2839 Maple Ln
Fairfax, VA 22031
Phone: 469-499-1050
Email: crubeiz@plasticpipe.org

Andy Dettmer
Senior Project Manager
Pure Technologies
6630 Roundrock Rd
Dallas, TX 75248
Phone: 214-236-5728
Email: andy.dettmer@puretechltd.com

Michael E. Grilli
CEO
Beta Group
6 Blackstone Valley Place
Lincoln, RI 02865
Phone: 401-333-2382
Email: mgrilli@beta-inc.com

Ricky W. Wu
Design Engineer
Hanson
1003 N MacArthur Blvd
Grand Prairie, TX 75050
Phone: 972-266-7505
Fax: 972-264-6236
Email: ricky.wu@hanson.com

Henry H. Bardakjain
Consultant
1331 N Maryland Ave
Glendale, CA 91107
Phone: 818-502-0676
Email: hbardakjain@gmail.com

Hubert W. Barker, P.E.
Barker & Associates Inc.
820 State Road 48
Durant, OK 74701
Phone: 580-931-9045
Email: wbarker@barkerengineers.com

Jain Xu
Researcher
University of Texas at Austin
3500 Greystone Drive
Austin, TX 78731
Phone: 512-576-4160
Email: jainxu@utexas.edu

Kesi You, Ph. D.
Urban Traffic and Underground Space Design Institute
No 98 Guoynan Road
Shandhai, China 200432
Denver, CO 80204
Phone: 13951753757
Email: youkesi@smedi.com

Anthony Parente
Manager, Capital Works
Region of Peel
10 Peel Centre Dr. 4th flr Suite B
Brampton, ON
Phone: 416-577-0597
Email: anthony.parente@peelregion.ca

Jim M. Williams
Engineering Manager
Meers Group Inc.
14411 West Rd
Houston, TX 77041
Phone: 832-851-7876
Email: jim.williams@mears.net

Ali Alavinasab
Design Engineer - Head of Structural Department – Pure Technologies
3322 State Route 22 West Suite 902 Bldg 9
Branchburg, NJ 08876
Phone: 908-809-3080
Fax: 908-526-9900
Email: ali.alavinasab@puretechltd.com

Sri Rajah
Senior Structural Engineer
HDR Engineering, Inc.
500 108th Ave NE, Suite 1200
Bellevue, WA 98009
Phone: 425-450-6269
Email: sri.rajah@hdrinc.com

Soheil Eslaamizaad
Senior Specialist
Enbridge
635 Dartmouth Point
Edmonton, AB T6M2R8
Phone: 780-297-6438

Jason C. Gehrig
Engineer
TRWD
808 E. Northside Dr.
Fort Worth, TX 76102
Phone: 817-335-2491
Email: Jason.gehrig@trwd.com

Dorian French
Senior Vice President
Brown and Gay Engineers
500 W 7th Street, Suite 1800
Fort Worth, TX 76102
Phone: 512-470-7240
Email: dfrench@browngay.com

Aharon Ran
Director of Engineering
Mekorot Water Company
G Lincoln St
Tel Aviv, Israel 61201
Phone: +972 36230663
Fax: +972 36230889
Email: aran@mekorot.co.il

Jonathan C. Faughtenberry
Senior Engineer
Oasis Petroleum
537 Darlington TR
Fort Worth, TX 76131
Phone: 330-232-0219
Email: faughtenberry@yahoo.com

Andrew J. Whelton
Assistant Professor
University of South Alabama

3142 Shelby Hall, Department of Civil Engineering
Mobile, AL 36527
Phone: 540-230-6069
Email: ajwhelton@southalabama.edu

Mark Dollins
Managing Engineer
Austin Water Utility
3907 South Industrial Blvd
Austin, TX 78744
Phone: 512-972-1028
Email: mark.dollins@austintexas.gov

John R. Black
Technical Principal Pipeline Materials
Opus International Consultants
20 Moorhouse Avenue
Christchurch, NZ 8140
Phone: 0064274844886
Email: john.r.black@opus.co.nz

Marty S. Paris
Vice President
Kimley-Horn and Associates
12750 Merit Drive, Suite 1000
Dallas, TX 75251
Phone: 972-776-1732
Email: marty.paris@kimley-horn.com

Michael D. Royer
Physical Scientist
U.S. EPA
2890 Woodbridge Ave. (MS-104)
Edison, NJ 08837
Phone: 732-321-6633
Email: royer.michael@epa.gov

Fox Steven
Vice President
HDR
2022 Calle Cantora
El Cajon, CA 92019
Phone: 619-520-8712
Email: sfox@hdrinc.com

Carl Sharkey
Regional Sales Manager
Echologics
297 18th Ave
San Francisco, CA 94121
Phone: 415-819-7270
Email: carlshark@yahoo.com

Students:

Oifeng Yu
Student
Catholic University of America
620 Michigan Ave NE
Washington, DC 20064
Phone: 202-319-5629
Email: yuqfseu@gmail.com

Michelle Sherman
Program Manager
Center for Underground Infrastructure Research & Education
1221 West Mitchell Street
Arlington, TX 76010
Phone: 817-272-9177
Fax: 817-272-2630
Email: msherman@uta.edu

Divyashree
Graduate Research Assistant
University of Texas at Arlington
1600 W. 12th Ave
1221 West Mitchell Street
Arlington, TX 76010
Phone: 817-272-9177
Fax: 817-272-2630
Cell: 817-917-0174
Email: divya.sm14@gmail.com

Armando Espinosa
Student
UTA
701 S. Nedderman Dr.
Arlington, TX 76019
Email: armando.espinosa@mavs.uta.edu

Mahran M. Zatar
Student
UTA
5201 Bryant Irvin Rd Apt# 3136
Fort Worth, TX 76132
Phone: 817-744-0501
Email: mahran.zatar@mavs.uta.edu

David M. Trejo
Student
UTA
701 Nedderman Dr
Arlington, TX 76019
Email: dtrejo@mavs.uta.edu

Armando Espinosa
Manager, Capital Works
Region of Peel
10 Peel Centre Dr. 4th flr Suite B
Brampton, ON
Phone: 416-577-0597
Email: anthony.parente@peelregion.ca

Pejman Rezakhani
PhD Student
UTA
Arlington, TX 76019
Phone: 682-217-4489
Email: pejman.rezakhani@mavs.uta.edu

Alimohammad Entezarmahdi
Student
UTA
815 W. Abram Apt# 112
Arlington, TX 76013
Phone: 817-885-9082
alimohammad.entezarmahdi@mavs.uta.edu

Appendix E

List of Acronyms

LIST OF ACRONYMS

WRF	Water Research Foundation
USEPA	U.S. Environmental Protection Agency
PHMSA	Pipeline and Hazardous Materials Safety Administration
TRWD	Tarrant Regional Water District
BEM	Broadband Electro- Magnetics
WaterRF	Water Research Foundation
AWWA	American Water Works Association
FAC	Focus Area Council
PAC	Project Advisory Committee
NAS	National Academy of Sciences
RTCR	Revised Total Coliform Rule
RICP	Research and Information Collection Partnership
MOU	Memorandum of Understanding
PSW	Partnership for Safe Water
PCP	Pneumatic Capsule Pipeline
AGV	Automated Guided Vehicle
UCFT	Underground Container Freight Transport
UCM	Underground Container Mover
UCTS	Underground Container Transportation System
DOT	Department of Transportation
PHMSA	Pipeline and Hazardous Materials Safety Administration
ILI	Inline Inspection
NDT	Non-Destructive Testing
ROV	Remotely Operated Vehicles
PIG	Pipeline Inspection Gauges
HSK	Hand Scanning Kit
SCG	Slow Crack Growth
CI	Cast Iron
CT	Computed Tomography
PVC	Polyvinyl chloride
ABS	Acrylonitrile Butadiene Styrene
NASTT	North American Society for Trenchless Technology
CATT	Center for Advancement of Trenchless Technologies