Re-rounding of Deflected Thermoplastic Conduit, Phase 1

Prepared by Shad Sargand, Andrew Russ, and Kevin White

Prepared for the Ohio Department of Transportation
Office of Statewide Planning and Research

State Job Number 135322

March 2017

Phase 1 Interim Report

RESEARCH

STATE OF OHIO DEPARTMENT OF TRANSPORTATION

U.S. Department of Transportation Federal Highway Administration

OHIO UNIVERSITY

Ohio Research Institute for Transportation and the Environment

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/OH-2017-12		
4. Title and Subtitle		5. Report Date
Re-rounding of Deflected Thermoplastic Conduit, Phase 1		**March 2017**
		6. Performing Organization Code
7. Author(s) (include ORCID ID)		8. Performing Organization Report No.
Shad Sargand (ORCID 0000-0002-1633-1045), Andrew Russ (ORCID 0000-0001-7743-2109), and Kevin White (0000-0002-2902-2524)		
9. Performing Organization Name and Address		10. Work Unit No. (TRAIS)
Ohio Research Institute for Transportation and the Environment (ORITE) 233 Stocker Center Ohio University Athens OH 45701-2979		
		11. Contract or Grant No.
		SJN 135322
12. Sponsoring Agency Name and Address		13. Type of Report and Period Covered
Ohio Department of Transportation 1980 West Broad Street, MS 3280 Columbus, Ohio 43223		**Phase 1 Interim Report**
		14. Sponsoring Agency Code
15. Supplementary Notes		
16. Abstract		
This study investigated the potential benefits of re-rounding of thermoplastic pipe, a process for reducing the deflection of installed pipes by drawing a vibrating mandrel through the pipe. A survey of state DOTs revealed that practice is used rarely, if ever, and the literature on the topic is very sparse, limited to reports on vendor demonstrations. Two contractors were contacted and results of the interviews are included. A plan for a detailed study under controlled conditions and in the field is presented.		
17. Keywords		18. Distribution Statement
Re-rounding, thermoplastic pipe, maximum deflection		**No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161**

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
Unclassified	**Unclassified**	**15**	

Form DOT F 1700.7 (8-72) **Reproduction of completed pages authorized**

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(°F-32)/9 or (°F-32)/1.8	Celsius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2 or psi	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius temperature	1.8°C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2 or psi

* SI is the symbol for the International Symbol of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

(Revised September 1993)

Re-rounding of Deflected Thermoplastic Conduit, Phase 1

Prepared by

Shad Sargand, Andrew Russ,

Ohio Research Institute for Transportation and the Environment
Russ College of Engineering and Technology
Ohio University
Athens, Ohio 45701-2979

and

Kevin White

E.L. Robinson Engineering of Ohio
1801 Watermark Drive, Suite 310
Columbus, OH 43215

Prepared in cooperation with the
Ohio Department of Transportation
and the
U.S. Department of Transportation, Federal Highway Administration

Interim Report
March 2017

Acknowledgements

The authors acknowledge the people who ensured the successful completion of Phase 1 of this project, starting with the Ohio Department of Transportation's Research Section. Kyle Brandon and Matt Cozzoli of ODOT's Office of Hydraulic Engineering and Hans Gucker of ODOT's Office of Construction Administration served as the subject matter experts, providing guidance on the technical aspects of the project.

Contents

List of Figures

List of Tables

Project Background

The AASHTO LRFD Bridge Construction Specifications, Section 30 on Thermoplastic Culverts indicates that pipes with deflections in excess of 7.5% should be remediated or replaced. This is the basis for the 7.5% deflection limit in the ODOT CMS Specification 611. Under Item 611, the method of remediation is left to the contractor and the independent registered engineer. Thermoplastic pipes that have experienced deflection in excess of this 7.5% limit, without buckling, cracking, or other structural defects are often remediated using a technique called re-rounding. Re-rounding is performed by placing a pneumatic vibratory compactor inside the pipe which then applies pressure against the pipe wall and vibrates to restore the shape of the conduit and consolidate the backfill. Re-rounding is a technique generally limited to the mid-western US States for drainage conduit but has been used sporadically across the US and Canada for remediating solid wall sanitary conduit. The re-rounding process has been utilized by contractors on ODOT construction projects as a method of remediating thermoplastic pipes with deflections in excess of 7.5% and requiring remediation in accordance with ODOT CMS Specification 611. Although the technique has been around since its introduction by Williams Testing in the early 1980s, independent research is needed to ascertain the use and impacts of re-rounding on thermoplastic pipes. The success of re-rounding is dependent on the factors contained in Table 1.

Table 1 Factors for assessing suitability of Re-rounding

Material Factors	Installation Factors
Pipe Diameter	Backfill Material
Type of Pipe Corrugation	Backfill Stiffness
Pipe Stiffness	Height of Backfill
	Pipe Shape
	Pipe Deflection

Besides the factors mentioned above, the maximum deflection that re-rounding can address has not been determined. Another set of unknowns is how re-rounding impacts the mechanical properties of the pipe, backfill, or surrounding embankment. Damage to pipe corrugations and surface depressions in overlying pavement have been reported in some cases. The long-term serviceability of re-rounded pipe installations has not been determined, and there is a concern the original level of deflection could return. Also to be determined are the assumptions, limits, and factors to use in modelling re-rounded pipe and the impacts on the strength-limit-state according to the AASHTO LRFD Bridge Design Specifications.

Objectives

To answer these questions and address the need for independent research, an investigation was conducted to validate the use of re-rounding thermoplastic pipes as a viable remediation technique for ODOT. This includes determining if and when re-rounding is a viable option for repairing pipe deflection (giving full consideration to the variables discussed above), and determining the maximum deflection for which the technique can be applied.

This report documents Phase 1 of a two phase project to address these objectives. In Phase 1, current practices in Ohio and other states are evaluated and relevant parameters determined. Equipment options for re-rounding are also investigated, and a plan is presented for field evaluation of re-rounding techniques.

A work plan for Phase 2 activities follows. It will consist of execution of this field test plan, should ODOT decide to move forward to Phase 2.

Outline of Study

The research team began by conducting a literature search and other investigation as needed to assess the current best practices for re-rounding. A survey of state departments of transportation was created and disseminated with the assistance of the ODOT Research Section, and the results compiled in this report.

The research team then identified conditions and parameters relevant to re-rounding, including severity of deflection or deformation, type and condition of backfill, height of cover, diameter of the pipe, etc.

The research team also investigated the equipment available to conduct re-rounding and if necessary, assess which equipment is best suited for further investigation. There are two Ohio based companies performing conduit re-rounding, and the research team visited and interviewed both.

The information gathered from the preceding task was used to develop an evaluation plan and budget for Phase 2, in close collaboration with ODOT. The plan includes testing methods, number of sites, and evaluation criteria.

Literature Review

An early report by R. Germann [1982] for Williams Testing evaluated the effect of re-rounding PVC pipe used in sewer lines. PVC pipe with diameters of 8 in (20 cm) and 15 in (38 cm) were each installed in a load cell and a downward load of 900 psi (6.2 MPa), equivalent to a burial depth of 27 ft (8.2 m), where the deflection was 10% before re-rounding. The re-rounder was applied through the length of the pipe with the load held constant. After subsequently increasing the load to 1000 psi (6.9 MPa) or 30 ft (9.1 m) depth equivalent, the deflection stayed below 1%. Then at 3000 psi (21 MPa), or 88 ft (27 m) depth equivalent, deflection was under 3%. Deflection results after re-rounding compaction were similar for bedding consisting of crushed limestone, bank run gravel, or sand. Compaction measurements after re-rounding were made in the fill 30 in (76 cm) above the pipe centerline and at 12 in (30.5 cm) from the center at the springline. For the 8 in (20 cm) diameter pipe, the top density was measured at 95.46% with 5.6% moisture (optimum was 9%); at the springline the density was 91% at 7.2% moisture; and 96% density at 4.3% moisture was measured in the pipe bottom or cradle. For the 15 in (38 cm) pipe, these values were 91.0% density at 7.2% moisture at the top, 89.8% density at 5.3% moisture at the springline. Thus, the author concludes that re-rounding can facilitate installation of PVC pipe by achieving suitable levels of compaction in four different broad classes of soils, including manufactured sand (Class I), clean sand and gravel (Class II), sand with gravel and fines (Class III), and silt and clay (Class IV).

A more recent investigation was conducted by Advanced Drainage Systems, Inc. [ADS, 2009] at two sites with HDPE pipe. The first case was a 60 in (152 cm) diameter pipe under at least 20 ft (6.1 m) of #57 crushed stone backfill in Cleveland, which had been re-rounded ca. 1999. The original re-rounding process increased the minimum vertical diameter from 51 in (130 cm or 15% diameter decrease from the original size) to 55 in (140 cm, or 8.3% diameter decrease). At an inspection in March 2009, the vertical diameter ranged from 55 in (140 cm) to 57 in (145 cm, 5% decrease). The pipe was ‘slightly racked”, but the deflection did not increase after re-rounding.

The second case studied in the ADS [2009] report was a July 2009 re-rounding demonstration at Williams Testing using their 1980s method. The specimen of 24 in (61 cm) pipe was placed in the load cell and manufactured sand placed as backfill to a height of 3 ft (91 cm). Loads were applied of 1200 psi (8.3 MPa), 1800 psi (12.4 MPa), and 700 psi (4.8 MPa). Re-rounding was then performed under a load of 500 psi (3.4 MPa) and the cell loaded to 1100 psi (7.6 MPa) and 1800 psi (12.4 MPa) before applying a load of 1400 psi (9.7 MPa) and performing a second re-rounding procedure at 900 psi (6.2 MPa). The second load (1800 psi (12.4 MPa)) led to a 6%-11% deflection that was reduced to 1% or less by the first re-rounding operation. After the additional load stages reached a second application of 1800 psi (12.4 MPa), the deflection in the pipe reached 1.75%-4%, and the second re-rounding operation reduced that to 2% or less. The consolidation from the first 1800 psi (12.4 MPa) load was maintained or increased during the re-rounding procedure, as the deflection under load afterwards was not as large as before. The pipe was removed from the cell after testing and inspected for damage, of which none was observed; highly compacted sand remained in the pipe corrugations.

Other than the above reports, no literature on the re-rounding of thermoplastic pipes could be located.

Ohio Vendor Interviews

There are currently two companies based in Ohio that perform conduit re-rounding. These are Williams Testing, Inc., located in Harrod, and Dreier and Maller, Inc. located in Reynoldsburg. Williams Testing uses in-house developed equipment while Dreier and Maller uses equipment purchased from Hurco Technologies, Inc. located in Harrisburg, SD.

Both system manufacturers utilize very similar equipment. For pipes 15 in (38 cm) in diameter and smaller, both systems utilize a ram head connected to a high frequency pneumatic vibrator. The ram head with a diameter equivalent to the target conduit diameter is then drawn through the conduit via a cable winch or other similar device. The process utilizes a constant tension on the winch. However, the rate or travel through the conduit can greatly vary depending on the deflection of the conduit.

For pipes greater than 15 in (38 cm) in diameter both manufacturers utilize an expanding bladder mechanism which is used in a discrete step-wise process. The Hurco system utilizes a hydraulic vibration mechanism while the Williams vibratory system is pneumatic.

The Williams system uses relatively more power to drive the vibrator than the Hurco system. Because of this, it may be necessary to make two passes through the conduit to fully re-round the conduit when using the Hurco system whereas the Williams system can usually re-round the conduit with a single pass.

Dreier and Maller can currently remediate conduits with diameters up to 24 in (61 cm). They indicate that Hurco manufactures equipment to re-round larger conduit, but they have not acquired the equipment. Williams Testing has indicated that their equipment can re-round conduits up to 60 in (152 cm) in diameter, but the best success is achieved with conduits less than 54 in 137 cm) in diameter. Williams Testing has indicated that the best success is achieved when the conduit is backfilled with aggregate such as AASHTO #57, or sand. Dreier and Maller has indicated that they do not see much difference in the effort required or the success of re-rounding based on backfill material.

Both vendors have indicated that a few feet of cover to the pavement subgrade is required for the successful re-rounding of the conduit without damaging the pavement above the conduit. Both vendors recommend 15% as the maximum deflection that is suitable for re-rounding. Both vendors have re-rounded deflected conduit on ODOT projects installed in accordance with CMS 611.

According to both vendors, the cost of re-rounding is very dependent on site-specific parameters including severity of deflection, access to the pipe, and length of the pipe. They were not able to provide a single representative per foot cost for the process.

Based on these interviews along with an investigation of the available equipment, both systems appear to be suitable for further investigation.

Survey of State DOTs

A survey questionnaire for state department of transportation (DOT) professionals in the area of thermoplastic pipes was drawn up by the research team in consultation with the ODOT subject matter experts. The questions are given in Appendix A. The ODOT research office set up an online form via Formstack and disseminated the link via their contacts across the United States on November 1. As of November 15, responses had been gathered from sixteen states: AL, CA, CT, DE, GA, IL, ME, MI, MN, MT, NE, ND, TN, UT, VA, WA (N=16).

Figure 1 compiles responses to the first question of the survey, which asked if the state used deflection as a quality control check on thermoplastic pipe installations. Three quarters (75%, 12 states) said that they did, and the rest said they did not.

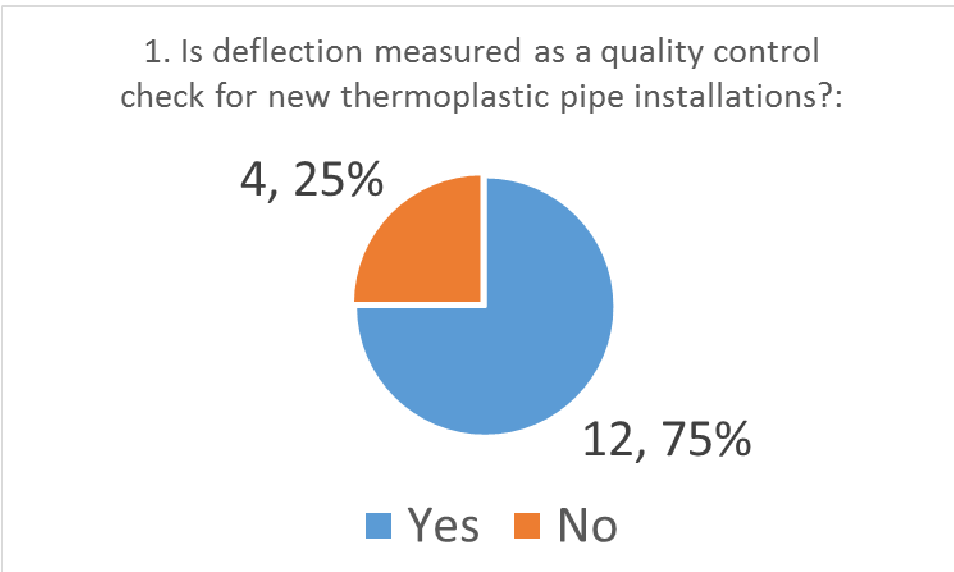

Figure 1. Responses to Question 1 of the survey.

The next question asked what was the maximum deflection permitted in thermoplastic pipe installations. Of the sixteen states, two thirds (69%, 11 states) indicated 5% deflection was the maximum. One of these (IL) stated "the mandrel is 95% of the base inside diameter", which was interpreted to mean the same thing, while another (GA) stated "When pipe deflection exceeds 5% of the nominal diameter, Engineer reviews installation. GDOT remediates or replaces pipe when pipe deflection exceeds 7.5% of the nominal diameter", which could be interpreted as 5% or 7.5%. Utah (UT) made a similar statement in amplifying their response: "Between 5% and less than 7.5% the contractor can propose corrective action." One state (6.67% of responses, MT) specified 7%, and another (VA) specified 7.4%, with reduced payments for deflections "up to 7.4%". Another state (CT) was counted at 6%, though they actually do not allow installation of thermoplastic pipe under the travel pathway; visual inspections and mandrel tests are used to determine acceptance, and if a maximum deflection criteria were used, the agency would follow the AASHTO LRFD specification of 6%. Another state (CA) had no specified maximum, but added "Obviously, if the pipe deflection is substantial that would be considered a failure. We do have leakage requirements. Deflections at the joints would be a failure." One state (AL) provided a response inconsistent with the question, which was categorized as "N/A" in this analysis.

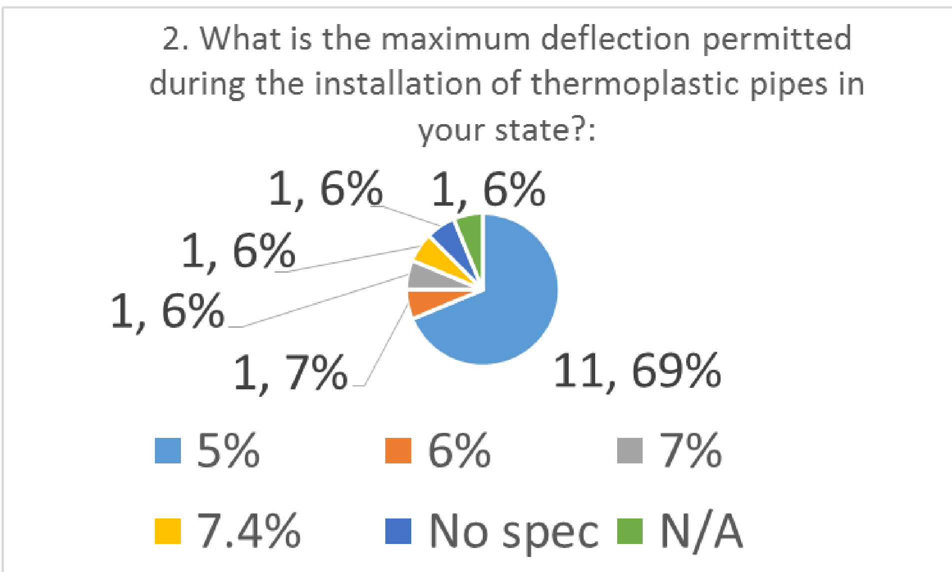

Figure 2. Responses to Question 2 of the survey.

Responses to Question 3, regarding action taken when maximum deflection is exceeded, are charted in Figure 3. Three quarters (75%, 12 states) indicated the pipe was replaced when the maximum deflection was exceeded. Two states (12.5%, AL, WA) answered "No", but one (WA) did so with the qualification: "Normally no, depending on severity of deflection, and results of air test". That leaves two states (12.5%, MN, NE) with qualified responses categorized as "sometimes": MN indicated the decision was made on a case-by-case basis, and NE indicated the decision was "At the discretion of the Engineer". Some of the Yes responses could be construed as sometimes, as for DE, GA, and UT, where pipes deflected between 5% and 7.5% are subject to an engineering evaluation and possible deduction.

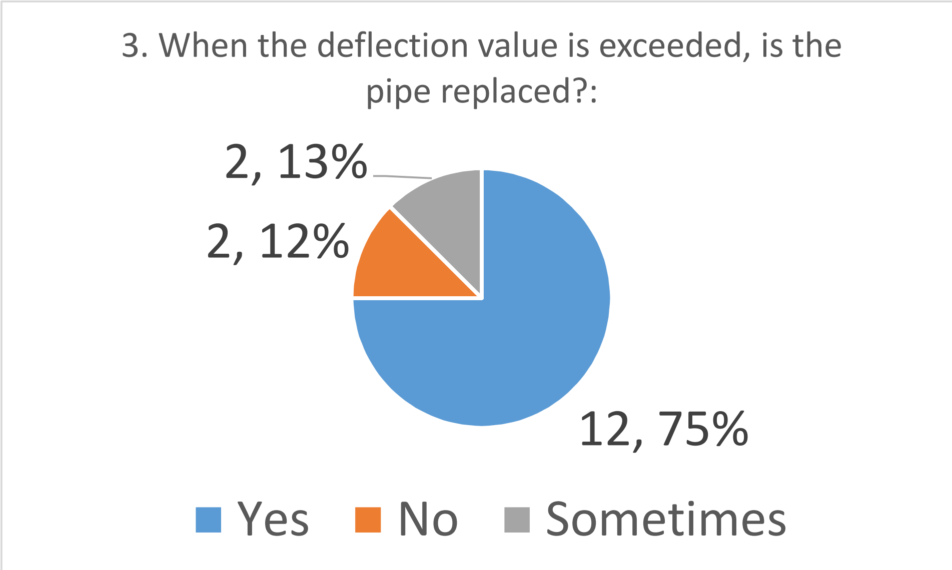

Figure 3. Responses to Question 3 of the survey.

Question 4 responses are presented in Figure 4, which indicates 94% of states (15) do not use re-rounding. The one state (6.25%, AL) that answered the question in the affirmative did not provide any further information.

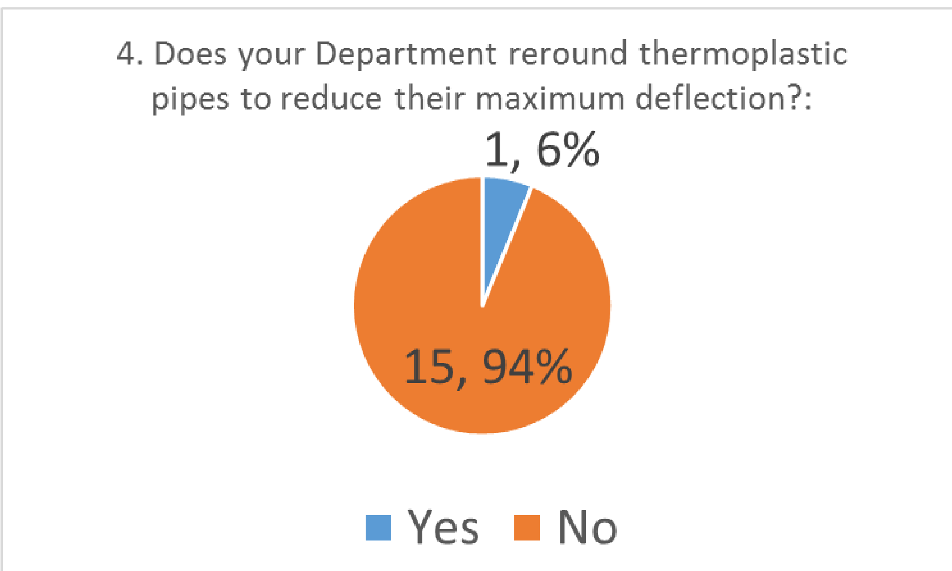

Figure 4. Responses to Question 4 of the survey.

Question 5, asking about guidelines, also got one yes response, again from AL, but they did not provide any further information, link, or copy of any documents. The other 15 states (94%) did not have any guidelines.

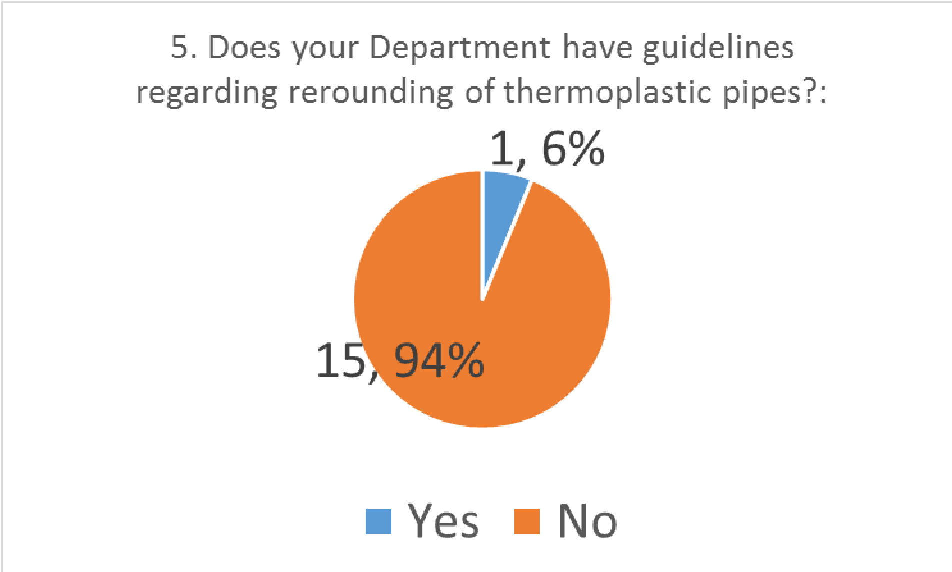

Figure 5. Responses to Question 5 of the survey.

Conclusions and Recommendations

The survey showed that re-rounding is rarely if ever used in other states for transportation infrastructure. The literature review found only two studies, one by a vendor and the other based on a vendor demonstration, so the effects of the method have not been carefully measured. Re-rounding does have the promise to provide a significant impact on the performance of deflected thermoplastic pipe, so the idea does deserve to be explored further, as proposed in a separate proposal accompanying this report.

References

Advanced Drainage Systems, Inc. (ADS), 2009, “Summary of July 09 Testing”, summary of informal results of re-rounding testing on HDPE pipe.

R. Germann, 1982, “Procedure to Reround Flexible PVC Pipe and Consolidate Soil in the Pipe Zone”, Performance and Test Report of Pneumatic Vibrator Compactor, Owens Technical College in Cooperation with Williams Testing, Inc., Harrod, Ohio, June 1982.

Appendix A: Survey questionnaire

Formstack

Formstack Submission for form Research Survey - Rerounding of Deflected Thermoplastic Conduit

Submitted at 11/01/16 2:30 PM

1. Is deflection measured as a quality control check for new thermoplastic pipe installations?:

1a. How is it measured?:

1b. Who performs the deflection measuring?:

1c. When is the deflection measured?:

2. What is the maximum deflection permitted during the installation of thermoplastic pipes in your state?:

3. When the deflection value is exceeded, is the pipe replaced?:

3a. If pipe is not replaced, what other options can be considered?:

4. Does your Department reround thermoplastic pipes to reduce their maximum deflection?:

4a. If the rerounding technique proved to be viable, would your state's DOT consider using it?:

5. Does your Department have guidelines regarding rerounding of thermoplastic pipes?:

5a. Please include a copy of, or link to, the relevant guidelines or specifications.:

6. Identify any specific companies your agency has employed to perform rerounding work?:

7. What successes or failures has your state's DOT had with rerounding?:

Name:

Title:

Title - Copy:

State:

Phone:

Email:

ORITE • 151 Stocker Center • Athens, Ohio 45701-2979 • 740-593-1470
Fax: 740-593-0625 • orite@ohio.edu • http://www.ohio.edu/orite/

Appendix B: Phase 2 Work Plan

Problem Statement

AASHTO LRFD Bridge Construction Specifications, Section 30 on Thermoplastic Culverts indicates that pipes with deflections in excess of 7.5% should be remediated or replaced. This is the basis for the 7.5% deflection limit in the ODOT CMS Specification 611. Under Item 611, the method of remediation is left to the contractor. Thermoplastic pipes that have experienced deflection in excess of this 7.5% limit, without buckling, cracking, or other structural defects are often remediated using a technique called re-rounding. Re-rounding is performed placing a pneumatic vibratory compactor inside the pipe which then applies pressure against the pipe wall and vibrates to restore the shape of the conduit and consolidate the backfill. Re-rounding is a technique generally limited to the mid-western US States. The re-rounding process has been allowed by ODOT as an acceptable method of remediating thermoplastic pipes with deflections in excess of 7.5% and requiring remediation in accordance with ODOT CMS Specification 611. Although the technique has been around since its introduction by Williams Testing in the early 1980s, independent research is needed to ascertain the use and impacts of re-rounding on thermoplastic pipes.

The success of re-rounding depends on many factors, including pipe diameter, the type of corrugation, the type and height of backfill, the shape of the pipe, the magnitude of deflection, stiffness of pipe, stiffness and quality of the backfill, and the elapsed time after installation. Also, the maximum deflection that re-rounding can address has not been determined. Another set of unknown is how re-rounding impacts the mechanical properties of the pipe, backfill, or surrounding embankment. Damage to pipe corrugations and surface depressions in overlying pavement have been reported in some cases. The long-term serviceability of re-rounded pipe installations has not been determined, and there is a concern the original level of deflection could return. Also to be determined are the assumptions, limits, and factors to use in modelling re-rounded pipe and the impacts on strength-limit-state AASHTO LRFD Bridge Design Specifications.

Goals and Objectives of the Study

To answer these questions and address the need for independent research, this project is proposed to validate the use of re-rounding thermoplastic pipes as an option for ODOT. This includes determining if and when re-rounding is a viable option for repairing pipe deflection (giving full consideration to the variables discussed above), and determining the maximum deflection for which the technique can be applied.

The project encompasses two phases. In Phase 1, current practices in Ohio and other states were evaluated and relevant parameters determined. Equipment options for re-rounding were also investigated, and a plan devised for field evaluation of re-rounding techniques. Phase 2 will consist of execution of the field test plan. This proposal is focused on Phase 2.

Research Context

An early report by R. Germann [1982] for Williams Testing evaluated the effect of re-rounding PVC pipe used in sewer lines. PVC pipe with diameters of 8 in (20 cm) and 15 in (38 cm) were each installed in a load cell and a downward load of 900 psi (6.2 MPa), equivalent to a burial depth of 27 ft (8.2 m), where the deflection was 10% before re-rounding. The re-rounder was applied through the length of the pipe with the load held constant. After subsequently increasing the load to 1000 psi (6.9 MPa) or 30 ft (9.1 m) depth equivalent, the deflection stayed below 1%. Then at 3000 psi (21 MPa), or 88 ft (27 m) depth equivalent, deflection was under 3%. Deflection results after re-rounding compaction were similar for bedding consisting of crushed limestone, bank run gravel, or sand. Compaction measurements after re-rounding were made in the fill 30 in (76 cm) above the pipe centerline and at 12 in (30.5 cm) from the center at the springline. For the 8 in (20 cm) diameter pipe, the top density was measured at 95.46% with 5.6% moisture (optimum was 9%); at the springline the density was 91% at 7.2% moisture; and 96% density at 4.3% moisture was measured in the pipe bottom or cradle. For the 15 in (38 cm) pipe, these values were 91.0% density at 7.2% moisture at the top, 89.8% density at 5.3% moisture at the springline. Thus the author concludes that re-rounding can facilitate installation of PVC pipe by achieving suitable levels of compaction in four different broad classes of soils, including manufactured sand (Class I), clean sand and gravel (Class II), sand with gravel and fines (Class III), and silt and clay (Class IV).

A more recent investigation was conducted by Advanced Drainage Systems, Inc. [ADS, 2009] at two sites with HDPE pipe. The first case was a 60 in (152 cm) diameter pipe under at least 20 ft (6.1 m) of #57 crushed stone backfill in Cleveland, which had been re-rounded ca. 1999. The original re-rounding process increased the minimum vertical diameter from 51 in (130 cm or 15% diameter decrease from the original size) to 55 in (140 cm, or 8.3% diameter decrease). At an inspection in March 2009, the vertical diameter ranged from 55 in (140 cm) to 57 in (145 cm, 5% decrease). The pipe was ‘slightly racked”, but the deflection did not increase after re-rounding.

The second case studied in the ADS [2009] report was a July 2009 re-rounding demonstration at Williams Testing using their 1980s method. The specimen of 24 in (61 cm) pipe was placed in the load cell and manufactured sand placed as backfill to a height of 3 ft (91 cm). Loads were applied of 1200 psi (8.3 MPa), 1800 psi (12.4 MPa), and 700 psi (4.8 MPa). Re-rounding was then performed under a load of 500 psi (3.4 MPa) and the cell loaded to 1100 psi (7.6 MPa) and 1800 psi (12.4 MPa) before applying a load of 1400 psi (9.7 MPa) and performing a second re-rounding procedure at 900 psi (6.2 MPa). The second load (1800 psi (12.4 MPa)) led to a 6%-11% deflection that was reduced to 1% or less by the first re-rounding operation. After the additional load stages reached a second application of 1800 psi (12.4 MPa), the deflection in the pipe reached 1.75%-4%, and the second re-rounding operation reduced that to 2% or less. The consolidation from the first 1800 psi (12.4 MPa) load was maintained or increased during the re-rounding procedure, as the deflection under load afterwards was not as large as before. The pipe was removed from the cell after testing and inspected for damage, of which none was observed; highly compacted sand remained in the pipe corrugations.

Work Plan

The information obtained during Phase 1 of this project make it clear that while re-rounding appears to have been successfully utilized to rehabilitate deflected thermoplastic pipe, there is very little information on the impact of the process on either the pipe corrugation, or the surrounding backfill material. Additionally, all information on limit states for the process are based on equipment operator experience.

ODOT CMS 611 requires repair or replacement of plastic conduits with deflections in excess of 7.5%. The re-rounding process is often utilized by contractors to repair deflected conduit with deflection in excess of the 7.5% threshold. The increased use of the re-rounding process coupled with the significant unknowns associated with its use support the continuation of the project to include the Phase 2 work.

Field Study

The Phase 2 work includes a field study to document and analyze the effects of re-rounding. The field work will include determining the site conditions before and after re-rounding, installation of pipes with varying site parameters using contractor developed installation plans which define the materials and installation techniques. In addition, a cost-benefit analysis will be conducted that will include a comparison of costs and assessment of risks for re-rounding versus replacement of the conduit. The majority of cost-benefit analysis will focus on assessing and quantifying the risk to ODOT if a re-rounded pipe remains in service. The field component would follow the following steps, subject to modification depending on results of Phase 1, with measurements as summarized in Table 2:

Table 2. Summary of measurements to be made for field test.

	Measurement	Device	efore	uring	fter	M onthly
Field and control	Ground surface settlement					x
	Backfill stiffness over crown	CPT				
	Backfill stiffness at sides	CPT				
	Pipe shape	Pipe profiler/crawler				x
	Pipe deflection					x
	Corrugation shape					x
	Particle velocity	Accelerometer				
Control only	Soil pressure in backfill	Pressure cells				
	Movement in backfill	Forensic study				

Task 1: Select field sites

The research team will select, in cooperation with ODOT, a maximum of 5 sites to be re-rounded, with conduits large enough to be instrumented and monitored from the inside. During a prior experiment, there was some difficulty in locating a sufficient number of field sites. This difficulty is partially mitigated with this study because of the longer duration. The research team has contacted local government agencies in Ohio that routinely utilize the re-rounding process. The team has contacted the two re-rounding companies as well as several large contractors to help in locating suitable sites.

Task 2: Instrument pipe and make preliminary measurements prior to re-rounding

At each site, measure the backfill stiffness before re-rounding using the cone penetration test (CPT) at crown and both sides of pipe, as shown in Figure 6. CPT measurements at either side of pipe will reach into the bedding below the bottom level to obtain information on the bedding. Measure shape of pipe before re-rounding, including diameter and shape of corrugation, using a laser profiler, shown in Figure 7. Install sensors inside the pipe to measure shape of the conduit before re-rounding along with the condition and level of strain on the corrugation.

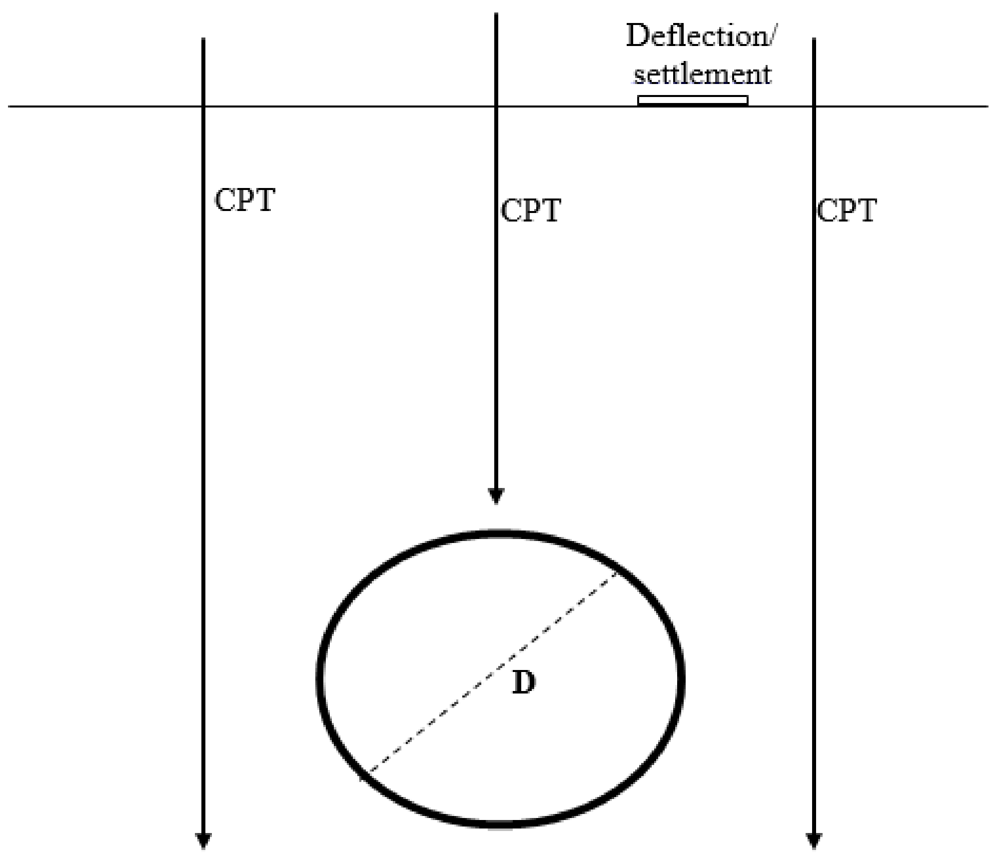

Figure 6. Diagram of field test setup showing locations where cone penetrometer test (CPT) will be conducted, above crown and also adjacent to pipe down into the bedding.

Figure 7. ORITE pipe crawler with laser profiler.

Task 3: Make measurements during and immediately after re-rounding

Measure particle velocities during re-rounding as a function of depth from the ground surface by wave propagation using accelerometers. At each site, measure the backfill stiffness after re-rounding using the cone penetration test (CPT) at crown and both sides of pipe, as before. Measure shape of pipe after re-rounding, including diameter and shape of corrugation, using a laser profiler. Collect data from sensors inside the pipe to measure shape of the conduit after re-rounding along with the condition and level of strain on the corrugation. Determine ground surface settlement after re-rounding.

Task 4: Follow-up measurements at sites

Once per month during first year afterwards measure surface settlement, pipe deflection, shape of pipe, and shape of corrugation.

Task 5: Experimental study

Phase 2 will also include an experimental portion dedicated to understanding the mechanism and impacts of re-rounding on the pipe system and backfill in a controlled and systematic manner. The experiments will be conducted at ORITE's load frame facility where pipes can be installed under a matrix of controlled conditions, including three types of backfill (Structural Backfill Type 1, 2, and 3), and two target deflection levels (10% and 15%). Backfill would be fully characterized in terms of gradation and uniformity before and after each re-rounding operation. Sensors would be installed to monitor mechanical characteristics in the system throughout the experiment, including dynamic gauging near the surface to measure vibration intensity and frequency during re-rounding, which will be used to determine the possible effects of re-rounding on pavement at the surface when applied in the field.

A total of 6 pipes will be tested following the matrix in Table 3. Pipes will consist of a 20 ft (6.1 m) section with joints at either end connecting to additional lengths of at least 10 ft (3.0 m), all placed in specified backfill to a depth of twice the diameter and then covered to a depth of 10 ft (3.0 m) of fill dirt, as shown in Figure 8. All pipe installations will include joints. Three pipes will be 36 in (91 cm) diameter double wall with a target of 10% deflection before re-rounding. Each will be installed according to figure; backfill will be Structural Backfill Type 1, Type 2, and Type 3. The other three pipes will be 18 in (46 cm) diameter double wall. Two pipes will be buried both in Structural Backfill Type 3 – one with a target of 10% deflection before re-rounding and the other with a target of 15% deflection. The third 18 in (46 cm) pipe will be placed in Structural Backfill Type 2 with 10% deflection. One pipe test will include a joint gap set to the maximum permitted by the manufacturer so the impact of re-rounding on joint gaps can be measured. If the gap is found to increase due to re-rounding, a smaller maximum gap value may need to be established for sites to be re-rounded.

Instrumentation will include pressure cells as shown in Figure 9: below pipe, above crown, and on both sides at the spring line. All parameters measured in field test will be monitored before, during, and after re-rounding. Once those measurements are complete, a forensic study will be conducted to determine the movement of backfill material in response to the vibration.

Table 3. Matrix of experimental tests of re-rounding.

Pipe diameter (in)	(cm)	Pipe Wall	Structural Backfill	Target Deflection
36	1	double	Type 1	10%
36	1	double	Type 3	10%
18	6	double	Type 3	10%
18	6	double	Type 3	15%
36	1	double	Type 2	10%
18	6	double	Type 2	10%

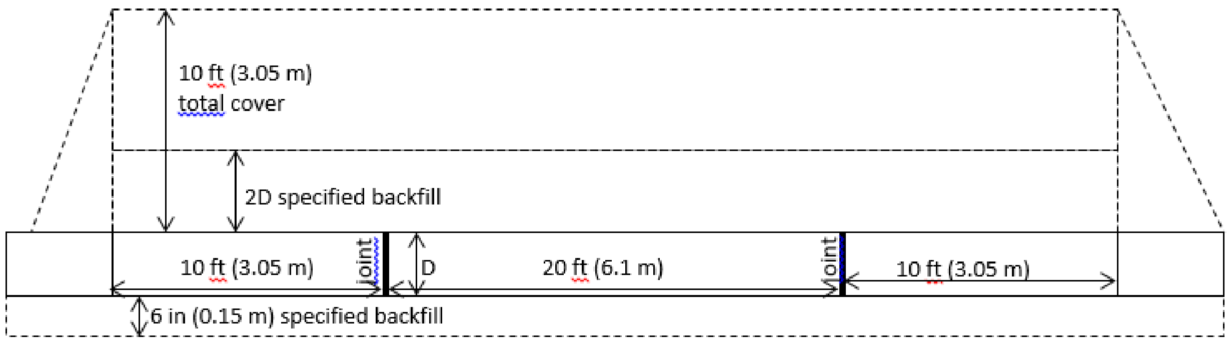

Figure 8. Profile diagram of experimental pipe installation. D is the pipe diameter.

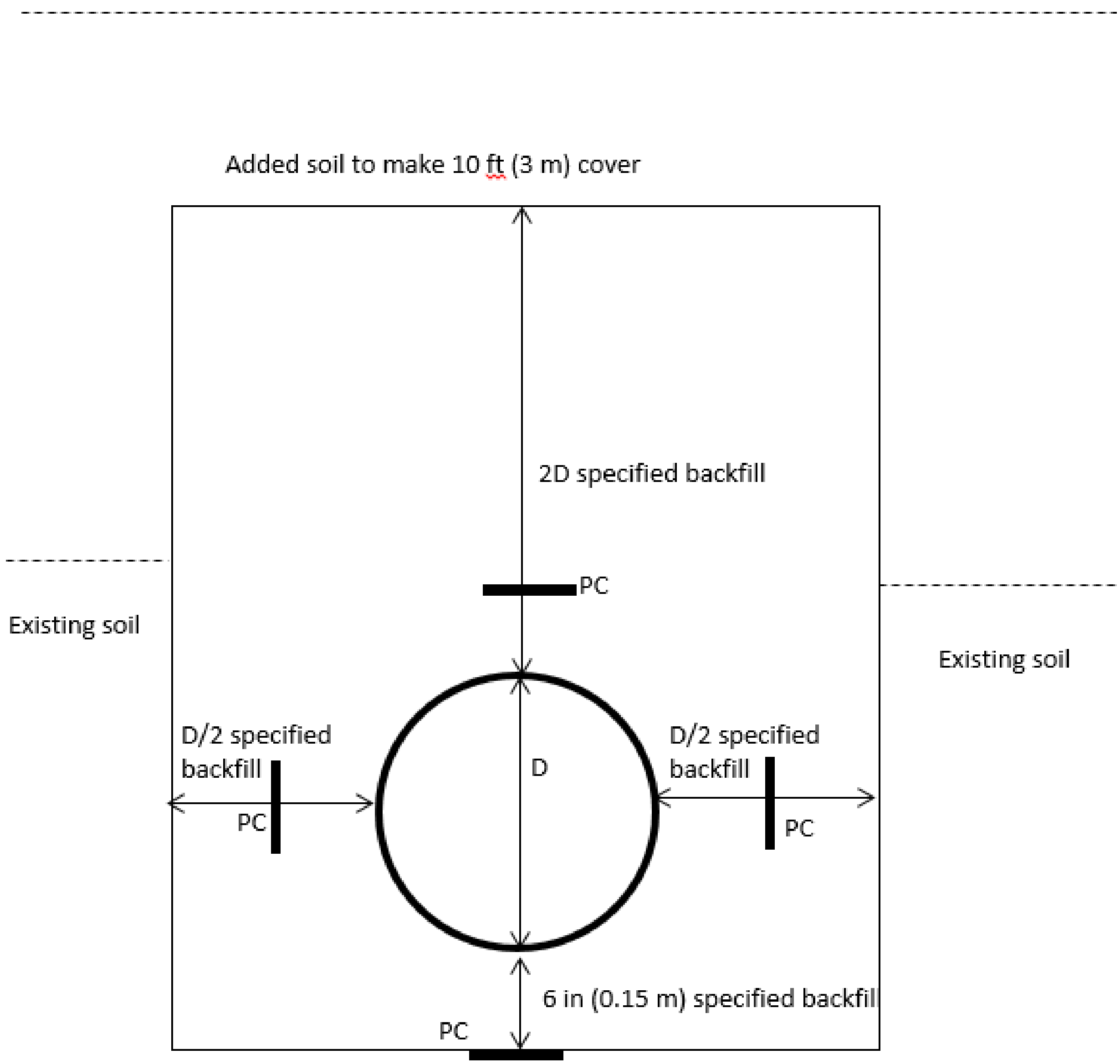

Figure 9. Diagram of experimental pipe installation with pressure cells. D is the pipe diameter. PC indicates location of a pressure cell.

Task 6: Prepare Report

A report will be written that will summarize findings, draw conclusions, and document results. The draft report and fact sheet will be delivered by the end of Month 24. The report and fact sheet will be revised in the last month after receiving comments from ODOT.

Role of subcontractor in this project

Kevin White of E.L. Robinson has been deeply interested in re-rounding for over 15 years. He has followed the development of the technology and has been the verification engineer for several re-rounding efforts associated with ODOT CMS 611. The subcontractor will play a major role in Phase 2, where his understanding of conduit installation, in-field performance of conduits, pipe mechanics, and computer modeling of the buried pipe problem will be extensively used.

Ohio University and E.L. Robinson Engineering have a long-standing positive relationship coupling the real-world practice design knowledge of E.L. Robinson with the highly experienced researchers and state-of-the-art research facilities of Ohio University. The team has successfully collaborated on four ODOT research projects, including the successful Structures Research On Call and Hydraulics Research On Call projects.

E.L. Robinson Engineering (ELR) will perform the following work items as a subcontractor to Ohio University in this project:

- Task 3 – Field Measurements

ELR will attend each field study and will provide technical guidance to the research team. In addition, ELR will work with the research team in data collection and field inspections. We will attend meetings with ODOT as necessary.

- Task 4 – Follow-up Measurements

On a limited basis ELR will attend field sites to collect and interpret field recorded data.

- Task 5 – Experimental Study

ELR will assist in the experimental setup and design. ELR will attend each pipe experiment and will aid in data collection and data interpretation. We will attend meetings with ODOT as necessary.

- Task 6 – Prepare Report

ELR will work with Ohio University staff in the preparation of the Final Report. We will also work with Ohio University in addressing ODOT comments. We will attend meetings with ODOT as necessary.

Assistance from the Department

ODOT assistance requested during Phase 2 is as follows:

- Aid in the location of potential re-rounding sites
- Provide maintenance of traffic during collection of data at re-rounding sites.

Benefits/Potential Application of Research Results

Benefits of this project are as follows:

- This research ties well with ODOT's mission as it will "*Take care of what we have*" and "*Improve Safety*" and ODOT's Research Mission as it will "…*assist Ohio in establishing a world class transportation system*".
- This research ties well with ODOT's Strategic Research Focus Areas "Transportation Asset Management" and "Transportation Safety" as it will extend the service life and reduce the life cycle costs of thermoplastic pipes

To benefit from this research, it is expected ODOT will incorporate recommended changes in Item 611 of its *Construction and Materials Specifications*.

Research Deliverables

The anticipated research results of this study include:

1. Discussion and analysis of results.
2. Recommendations for changes to CMS Item 611, if appropriate.

The deliverables of this research project will include:

1. Quarterly progress reports.
2. Word and PDF copies of a draft final report and fact sheet 120 days before the end of the project
3. Five copies of the final project report and executive summary, plus electronic copies in pdf and doc formats.
4. A two-page article for the ODOT R&D newsletter, with jpg graphic.
5. Participation in project start-up meeting, review session (as requested), and research results presentation.

References

Advanced Drainage Systems, Inc. (ADS), 2009, "Summary of July 09 Testing", summary of informal results of re-rounding testing on HDPW pipe.

R. Germann, 1982, "Procedure to Reround Flexible PVC Pipe and Consolidate Soil in the Pipe Zone", Performance and Test Report of Pneumatic Vibrator Compactor, Owens Technical College in Cooperation with Williams Testing, Inc., Harrod, Ohio, June 1982.