Third Quarterly Progress Report

Ohio DOT Research

Third Quarter Ended on September 30, 2018

"Quarterly Report: State Job #31347"

For Quarter Ending:	September 30
Date Submitted:	**October 31**

Project Title:	Structural Design Methodology for Spray Applied Pipe Liners in Gravity Storm Water Conveyance Conduits				
Research Agency:	CUIRE/The University of Texas at Arlington				
Principal Investigator(s):	PI: Mohammad Najafi, Ph.D., P.E., F. ASCE, Professor and Director, CUIRE Co-PI: Xinbao Yu, Ph.D., P.E., Associate Professor				
State Job Number:	5501.03		Agreement Number:		31347
Project Start Date:	20 December 2017		Contract Funds Approved:		25 September 2017
Project Completion Date:	20 December 2019		Spent to Date:		$172,999.50
% Funds Expended:	43%	% Work Done:	40%	% Time Expired:	38%

List the ODOT Technical Liaisons and other individuals who should receive a copy of this report:

1. Jeffrey E. Syer, P.E. Ohio DOT
2. Brian R. Carmody, P.E. - NYSDOT
3. Matthew S. Lauffer, P.E. and Charles Smith P.E – NCDOT
4. Paul Rowekamp and Aislyn Ryan - MnDOT
5. Sheri Little, - PennDOT
6. Carlton Spirio, - FDOT
7. Jonathan Karam and Nicholas Dean - DelDOT

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Schedule of Research Activities Tied to Each Task Defined in the Proposal and Percentage Completion of the Research

Table 1: SAPL Research Project Schedule

Ohio Department of Transportation

Structural Design Methodology for Spray Applied Pipe Liners in Gravity Storm Water Conveyance Conduits

Project Schedule Sorted by Start date

Task	Responsibility	Description	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
			2017	2018												2019											
2	Dr. Mo Najafi	Literature Search/Participation Material Vendors							Deliver-able																		
11		Lab Testing			Vendor	Communication													Deliver-able								
11- A	Dr. Mo Najafi Dr. Xinbao Yu	Testing Coupons from Vendors																									
11 - B		Data Acquisition Setup																									
11 - C		Soil Box Test 1																									
11 - D		Soil Box Test 2																									
11- E		Soil Box Test 3																									
10	Dr. Xinabo Yu	Computational Modeling																	Deliver-able								
10 - A		Create and Verify Circular Reinforced Concrete Pipe W/O Liner W/O Crack in Granular Soil																									
10 - B		Evaluate FEM Models with Design Equations																									
10 - C		Calibrate FEM Models with LAB Tests																									
10 - D		Parametric Study of FEM																									
1	Dr. Mo Najafi	Survey of US DOT's and Canadian Agencies									Deliver-able																
7	Mr. Ed Kampbell	Field Data Collection and Assistance from DOT Partners										Deliver-able															
3	Mr. Ed Kampbell	Additional Reinforcement								Deliver-able																	
4	Mr. Ed Kampbell	Evaluation if Corrugations Needed to be Completely Filled by the Spray Applied Liner as Part of the Structural Design								Deliver-able																	
6	Mr. Ed Kampbell	Review the Cured In Place (CIPP) Design Equations											Deliver-able														
8	Dr. Firat Sever	Develop a Recommended Structural Design Equations													Lag	Lag	Lag	Lag		Deliver-able							
8 - A		Establish base equations																									
8 - B		Identify missing parameters																									
8 - C		Revise equations with field and lab data																									
8 - D		Verify and finalize equations																									
9	Dr. Firat Sever Mr. Ed Kampbell	Develop Performance Construction Specification													Lag	Lag	Lag	Lag		Deliver-able							
9 - A		Prepare Draft Specs for Polymeric Spray Applied Liners																									
9 - B		Prepare Draft Specs for Cementitious Spray Applied Liners																									
9 - C		Prepare Final Specs for Polymeric Spray Applied Liners																									
9 - D		Prepare Final Specs for Cementitious Spray Applied Liners																									
5	Dr. Mo Najafi	Life Cycle Cost Analysis																		Deliver-able							
13	Dr. Mo Najafi	Draft Final Report and Fact Sheet																					Deliver-able				
14	Dr. Mo Najafi	Final Report and Presentation																							Final Report		
12	Mr. Lynn Osborn	QA/QC																									Deliver-able

Quarterly Progress Report (April 30, 2018) | Quarterly Progress Report (July 31, 2018) | Quarterly Progress Report (October 30, 2018) | Quarterly Progress Report (January 30, 2019) | Quarterly Progress Report (April 31, 2019) | Quarterly Progress Report (July 31, 2019) | Draft Final Report and Draft Fact Sheet (August 20, 2019) | Draft Report Review (Due September 30, 2019) | End of Project (December 20, 2019)

Table 2: Completion Percentage of SAPL Research Project Tasks over the 1st, 2nd and 3rd Quarters

Structural Design Methodology for Spray Applied Pipe Liners in Gravity Storm Water Conveyance Conduits				
Task Number	**Task Description**	**Percentage Completed by the end of 1st Quarter** *Dec 2017 through March 2018*	**Percentage Completed by the end of 2nd Quarter** *April 2018 through June 2018*	**Percentage Completed by the end of 3rd Quarter** *July 2018 through September 2018*
1	Survey of US DOT's and Canadian Agencies	29%	71%	100%
2	Literature Search/Participation Material Vendors	57%	100%	100%
3	Additional Reinforcement	0%	67%	95%
4	Evaluation if Corrugations Needed to be Completely Filled by the Spray Applied Liner as Part of the Structural Design	0%	67%	90%
5	Life Cycle Cost Analysis	0%	0%	0%
6	Review the Cured in Place (CIPP) Design Equations	0%	0%	67%
7	Field Data Collection and Assistance from DOT Partners	0%	40%	100%
8	Develop a Recommended Structural Design Equations	0%	0%	0%
9	Develop Performance Construction Specification	0%	0%	0%
10	Computational Modeling	19%	38%	57%
11	Lab Testing	19%	38%	43%
12	QA/QC	17%	29%	38%

Comparative Status of Actual Versus Estimated Expenditures

Table 3: The 3rd Quarterly Progress Work of SAPL Research Project

Structural Design Methodology for Spray Applied Pipe Liners in Gravity Storm Water Conveyance Conduits

Task Number	Task Description	Total Duration (Months)	Duration Completed (Months)	Budgeted Amount ($)	Percentage of Completion Based on Schedule (%)	Percentage of Total Budget (%)	Percentage Completed This Quarter (%)	Actual Amount Completed this Quarter ($)
1	Survey of US DOT's and Canadian Agencies	7	7	$25,751	100	6.44	28	$7,210
2	Literature Search/Participation Material Vendors	7	7	$21,875	100	5.47	0	0
3	Additional Reinforcement	3	3	$2,100	100	0.52	33	$693
4	Evaluation if Corrugations Needed to be Completely Filled by the Spray Applied Liner as Part of the Structural Design	3	3	$3,900	100	0.97	33	$1,287
5	Life Cycle Cost Analysis	3	Not Started	$29,123	0	7.28	0	0
6	Review the Cured in Place (CIPP) Design Equations	3	2	$13,751	67	3.44	67	$9,213
7	Field Data Collection and Assistance from DOT Partners	5	5	$26,752	100	6.69	60	$16,051
8	Develop a Recommended Structural Design Equations	5	Not Started	$34,081	0	8.52	0	0
9	Develop Performance Construction Specification	7	Not Started	$27,392	0	6.85	0	0
10	Computational Modeling	16	9	$52,039	56.25	13	19	$9,887
11	Lab Testing	16	9	$67,001	56.25	16.75	19	$12,730
12	QA/QC	24	9	$8,000	37.5	2.00	13	$1,040
13	Draft Final Report and Fact Sheet	7	Not Started	$88,270	0	22.07	0	0
14	Final Report and Presentation	3	Not Started					
Total				$400,034	-	100	-	$58,111

Table 4: Expenditures Summery of SAPL Research Project in the 3rd Quarter

Structural Design Methodology for Spray Applied Pipe Liners in Gravity Storm Water Conveyance Conduits		
Summary of Expenditures for the 3rd Quarter (July through September 2018)		
Description		**Sum Amount**
Salaries and Benefits		
Faculties Salaries and Benefits		$ 14,996.23
Students Salaries and Benefits		$ 19,434.56
Subtotal		$ 34,430.79
Partner Companies		
Leo Consulting		$ 1,300.00
Rehabilitation Resource Solutions, LLC		$ 12,975.00
American Structurepoint, Inc.		$ 6,537.38
Subtotal		$ 20,812.38
Supplies		
OLYMPUS Ultrasonic Thickness Measurement Gauge		$ 4,075.26
Travel Expenses		
CUIRE	Airfare and Car Rental	$ 7,927.34
	Accommodations, Food and Consumable Supplies	$ 7,777.75
Mr. Ed Kampbell	Expenses (Airfare, Car Rental)	$ 1,495.12
	Time (Inspection and Other Direct Costs)	$ 22,980.16
Subtotal		$ 40,180.37
Other Direct Costs		
Direct Costs		$ 1,217.45
Total		**$ 100,716.25**

Brief Description of the Activities Accomplished by Each Member of the Research Team as Listed in the Project Budget

Principal Investigator: Dr. Mohammad Najafi

Task 1: Survey of U.S. DOTs and Canadian Agencies.

- Submitted final report to Ohio DOT.

Task 7: Field Data Collection and Assistance from DOT Partners.

- CUIRE research team completed jobsite visit inspection and field data collection.
- Submitted individual state DOT jobsite visit inspection and filed data collection draft and final reports to each DOT.
- Submitted a comprehensive jobsite visit inspection and filed data collection summary report to Ohio DOT.

Task 11: Laboratory Testing.

Soil Box Testing.

- Prepared final draft of the detailed Soil Box Testing Plan using CMP as follows:
  - Testing configuration.
  - Instrumentation procurement.
  - Density measurement and compaction equipment.
  - Actuator procurement.
  - Shop drawings for steel frame.

Participation in the Meetings during Conferences, Internal Meetings, Progress Meetings.

- Attended the 3 monthly progress meetings with DOTs.
- Presented at the "National Hydraulic Engineering Conference," August 28-31, 2018.
- Presented at the infrastructure workshop in Queen's University.
- Held meetings with Contech Engineered Solutions LLC.
- Held internal meetings with CUIRE team research partners (Xinbao Yu, Ed Kampbell, Lynn Osborn, and Firat Sever).
- Submitted two magazine articles (Trenchless Technology and Underground Construction) and five abstracts for conference papers (No-Dig Show and ASCE Pipelines).

Co-Principal Investigator: Dr. Xinbao Yu

The following are the tasks performed this quarter:

Task 2. Literature Review

- Performed literature review of various soil box test reports investigating the effects of wall friction and wall proximity on the test performance.
- Literature review of available works on numerical modeling of soil box testing of corrugated metal pipes.

Task 11. Laboratory Testing

a) Soil Box Test Plan

- Performed analysis of theoretical soil pressure on the partition wall to evaluate the feasibility of wooden partition wall.
- Recommended using Poorly Graded Sand (SP) as the backfill/embedment material in the soil box.
- Estimated the quantities of sand required for the soil box test.

b) Instrumentation

- **Nuclear Density Gauge**
  - Researched licensing requirements for nuclear density gauge.
  - Contacted several density gauge vendors for the availability of rental gauges.
  - Obtained information regarding the rental policy from Qal Tech.
  - Obtained required information including the type of radioactive isotope, amount of radioactive material, etc. on the density gauge from Humboldt Scientific.
  - Contacted Radiation Safety Office (RSO) of UTA to add the density gauge to the University's license.
  - Checked the possibility of renting license-exempt gauges.
  - Checked the requirements to obtain the permit for using nuclear density gauge from Environment Health and Safety Office of UTA.
- **Strain Gauges**
  - Estimated the length of lead wires required for each gauge.
  - Studied the gauge size of biaxial gauges and compared them with the corrugation sizes to check if bi axial gauges could be used in the entire section. The corrugation size did not permit the use of biaxial gauges.
  - Contacted Texas Measurements Inc. (TMI) to check if adjustments could be made to fit the biaxial gauge to the corrugation valleys and crests.

  - Contacted TMI for the prices of different strain gauges for CMP, cementitious and polymeric surfaces. Obtained recommendations on gauge sizes, adhesive types, surface preparation, etc.
  - Contacted Micro Measurements (MM) for the price of strain gauges as well as other add-on items like adhesive, surface preparation chemicals, lead wires, gauge coatings, etc.
  - Obtained and compared the quotations from TMI and MM including their respective lead periods. Chose MM as the vendor after Dr. Najafi's approval.
- **Cable Displacement Sensors**
  - Checked the available lengths of Cable Displacement Sensors from Vishay.
  - Obtained the price of different models of the cable displacement sensors for comparison.
  - Checked with vendors about the accuracy of different models and the possible reduction in accuracy after adding additional length of wire to the sensors.
  - Obtained a quote for 50" cable displacement sensors (CDS-50) for purchase.
- **Earth Pressure Cells**
  - Estimated the length of wires needed for earth pressure cells.
  - Obtained updated quotes from GeoKon for earth pressure cells and submitted the quotes for purchase.
  - Ensured that earth pressure cells will include a calibration document.

Task 10. Computational Modeling

- Created a general 3D model of soil box test with plain steel pipe to study the pipe behavior in longitudinal direction. It is concluded that pipe deformation in the longitudinal direction is negligible.
- Converted the CMP to an equivalent plain pipe to be used in the FEM model.
- Created a 3D FEM model of intact equivalent plain pipe buried in the soil box, as per the test conditions.
- Performed mesh sensitivity analyses.
- Studied the model behavior under service load conditions and identified soil failure loads. The loads were compared with bearing capacity of soil obtained through both theoretical calculation for verification of soil behavior.

Subcontractor: Mr. Ed Kampbell
Rehabilitation Resource Solutions, LLC

Task 3 – Additional Reinforcement.

A review of the comments received from the various DOT partners on the project were considered and the report was finalized and sent to CUIRE on 08/20/2018. Completion of this report required a donation of time by RRS of $2,325.00.

Task 4 – Evaluation if Corrugations Needed to be Completely Filled by the SAPL as Part of the Structural Design

This report was also essentially complete as of June 30 and given to the CUIRE for their review. The comments received by the DOT partners were reviewed and edits made to the report. I requested assistance from CUIRE to produce moment of inertia calculations for the lining and the host pipe materials to make a statement as to the structural impact of lining the corrugation valleys first and then applying the lining. This information was received on 09/28/2018.

Task 7 – Field data collection and Assistance from DOT Partners

I participated in the inspections of pipes in Ohio, Pennsylvania, New York, Delaware, and North Carolina. I was unable to participate in the inspections performed in Florida and Minnesota due to a significant shortfall in the budgeted amount of money for my participation in this task. I was also unable to participate in the writing of the reports regarding what was found during these inspections. It was my understanding that these visits were to evaluate the quality of the installation practices by the various installers using the current DOT partners' specifications. Additionally, we would also have the opportunity to evaluate the performance of these installations beyond the time frame for short-term shrinkage cracking. Given that the current state of the art of these liners does not include steel or macro-fibers for the control of any potential long-term shrinkage cracking, the project sites I had chosen to be evaluated were at least three years old.

From the inspections I did participate in, the following observations can be made:

- Design submittals on the liner systems themselves must be required to verify that the performance of the fiber reinforcement package and other admixtures do perform as needed; i.e., short and long-term shrinkage crack resistance, autogenous healing of larger cracks, etc.
- Control of the finished thickness is currently lacking and needs to be addressed in the upcoming performance specifications.
- There is a need to have a standard detail on the project plans to reinforce the intent to fill the valleys of the corrugations first if that is chosen as the standard by the DOT's.

Subcontractor: Dr. Firat Sever
American Structurepoint, Inc. (ASI)

Subcontractor American Structurepoint, Inc. /Dr. Firat Sever has performed the following tasks in the 3rd quarter:

- Attended two conference calls with CUIRE.
- Identified some of the base design equations (ongoing) for cementitious and polymeric SAPLs.
- Started on a draft report for design equations development. When completed the report will include the following
  - Material properties of the commonly used SAPLs
  - List of equations used today, and descriptions of the parameters used in these semi-empirical equations/models
  - Overall approach on developing semi-structural design equations based on past experience, computational modeling (FEA), and lab tests
  - ASI has prepared a rough draft outline for the performance specification for the cementitious SAPLs.

Subcontractor: Mr. Lynn Osborn
LEO Consulting, LLC

Task 12. QA/QC.

As QA/QC Reviewer, much of my work depends upon the work and progress of other team members and items that require quality checks. No documents were presented for review this quarter.

Proposed Work for New Quarter

Table 5: SAPL Research Project Tasks for 4th Quarter (October 1 through December 31)

Structural Design Methodology for Spray Applied Pipe Liners in Gravity Storm Water Conveyance Conduits					
Task Number	**Responsibility**	**Task Description**	**Percentage of Work to be Completed by the end of 4th Quarter**		
			October 1st through December 31st		
			October	**November**	**December**
3	Mr. Ed Kampbell	Additional Reinforcement			To be Completed
4	Mr. Ed Kampbell	Evaluation if Corrugations Needed to be Completely Filled by the Spray Applied Liner as Part of the Structural Design			To be Completed
5	Dr. Mo Najafi	Life Cycle Cost Analysis	-	-	To be Started
6	Mr. Ed Kampbell	Review the Cured in Place (CIPP) Design Equations	To be Delivered	-	-
8	Dr. Firat Sever	Develop a Recommended Structural Design Equations	-	To be Started	To be Continued
9	Dr. Firat Sever Mr. Ed Kampbell	Develop Performance Construction Specification	To be Started	To be Continued	
10	Dr. Xinabo Yu	Computational Modeling	To be Continued		
11	Dr. Mo Najafi Dr. Xinbao Yu	Lab Testing	To be Continued		
12	Mr. Lynn Osborn	QA/QC	To be Continued		

Principal Investigator: Dr. Mohammad Najafi

Task 3: Additional Reinforcement

- Submit final report.

Task 4: Evaluation if Corrugations needed to be Completely Filled by the Spray Applied Liner as Part of the Structural Design

- Submit final report.

Task 5: Life Cycle Cost Analysis

- Start life cycle cost analysis.

Task 11: Soil Box Testing

- Make delivery of CMP.
- Complete steel framing.
- Start soil box testing.

Co-Principal Investigator: Dr. Xinbao Yu

Planned Task for the Next Quarter

- Test the data acquisition system and get the setup ready for the tests.
- FEM modeling of bare circular CMP with cut invert.
- FEM modeling of bare intact and invert cut Arch CMP.
- Start FEM modeling of SAPL lined circular and Arch CMPs (one type of SAPL material).

Subcontractor: Mr. Ed Kampbell
Rehabilitation Resource Solutions, LLC

Task 4 – Evaluation if Corrugations Needed to be Completely Filled by the SAPL as Part of the Structural Design

Final adjustments will be made to the report based upon the comments received from the DOT's review of the submitted report and the help from UTA on the moment of inertia calculations, which will be used to compare the relative stiffness of the lined versus the unlined structure.

Task 6 – Review the Cured in Place (CIPP) Design Equations

The report on the review of how CIPP is designed is currently due by the end of October.

Task 9 – Develop Performance Construction Specifications

A draft performance specification will be developed for; (1) polymeric sprayed in place liners and (2) cementitious sprayed in place liners. These drafts are currently shown to be done by the end of October; however, their completion due to the need to collaborate with others will likely come sometime in November.

Subcontractor: Dr. Firat Sever
American Structurepoint, Inc.

- Continue on identifying existing equations in relevant design and literature review.
- Coordinate ASI task on technical specifications development.
- Prepare tables of physical and mechanical properties of cementitious and polymeric SAPLs based on 3rd party data (Utilize the WERF project data acquired by the project team previously).
- Prepare the outline for polymeric SAPL technical specifications.
- Achieve 70% completion for the cementitious SAPL technical specifications.
- Attend periodic team conference calls (internal).

Subcontractor: Mr. Lynn Osborn
LEO Consulting, LLC

Task 12. QA/QC.

QA/QC reviews will continue on design and development planning, inputs and control. This will include general project oversight as required.

Implementation (if any):

N/A

Problems & Recommended Solutions (if applicable):

Due to changes in the soil box testing process, the start date will be in November, 2018.

Equipment Purchased (if any):

N/A

Contacts and Meetings

Progress Meeting

Table 6: SAPL Progress Meeting during the 3rd Quarter
July 1 through September 30

No.	Progress Meeting Agenda	Date
6	• SAPL Overall Schedule Update • SAPL Site Visit Plan 3. Task 7 – SAPL Site Visit Schedule • SAPL Soil Box Testing Layout Plans • Additional Budget Request • Evaluation if Corrugations Needed to be Completely Filled by SAPL	July 10, 2018
7	• Schedule Update • Soil Box Testing Plan (Discussion on Comments) • Update on Site Visit Plan • Survey of US DOT's and Canadian Agencies First Quarterly Report • Additional Reinforcement • Evaluation if Corrugations Needed to be Completely Filled by the Spray Applied Liner as Part of the Structural Design • Discussion on Budget and Schedule	August 14, 2018
8	• Schedule Update • Field Data Collection Update • SAPL Soil Box Testing Plan Update • Survey of US DOT's and Canadian Agencies (Comments on Draft Final Report)	September 11, 2018