6th Quarterly Progress Report

Ohio DOT Research

Fifth Quarter Ended on June 30, 2019

"Quarterly Report: State Job #31347"

For Quarter Ending:	June 30, 2019
Date Submitted:	**July 31, 2019**

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:	$373,669.85
% Funds Expended:	97%	% Work Done:	75%	% Time Expired: 75%

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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- Subcontractor: Dr. Firat Sever American Structurepoint, Inc. (ASI) 16
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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

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

CUIRE LEO Consulting, LLC STRUCTUREPOINT			Project Schedule Sorted by Start date (Current Schedule End by December 20, 2019)																																	
			2017	2018																	6th Quarter				2019											
								M*				M*				M*				M*				M*				M*			M*					M*
Task	Responsibility	Description	Dec	Jan	Feb	Mar	Apr	Quarterly Progress Report (April 30, 2018)	May	Jun	Jul	Quarterly Progress Report (July 31, 2018)	Aug	Sep	Oct	Quarterly Progress Report (October 30, 2018)	Nov	Dec	Jan	Quarterly Progress Report (January 30, 2019)	Feb	Mar	Apr	Quarterly Progress Report (April 31, 2019)	May	Jun	Jul	Quarterly Progress Report (July 31, 2019)	Aug	Sep	Draft Final Report and Draft Fact Sheet (August 20, 2019)	Draft Report Review (Due October 30, 2019)	Oct	Nov	Dec	End of Project (December 20, 2019)
2	Dr. Mo Najafi	Literature Search/Participation Material Vendors								Deliver-able																										
11	Dr. Mo Najafi Dr. Xinbao Yu	Lab Testing			Vendor	Communication																							Deliver-able							
10	Dr. Xinabo Yu	Computational Modeling																											Deliver-able							
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																											Deliver-able							
9	Dr. Firat Sever Mr. Ed Kampbell	Develop Performance Construction Specification																											Deliver-able							
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	

6th Quarter

Table 2: Completion Percentage of SAPL Research Project Tasks over the 1st, 2nd, 3rd, 4th, 5th and 6th 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	2nd Quarter	3rd Quarter	4th Quarter	5th Quarter	6th Quarter
		Dec 2017 through Mar 2018	*Apr 2018 through Jun 2018*	*Jul 2018 through Sep 2018*	*Oct 2018 through Dec 2018*	*Jan 2019 through Mar 2019*	*April 2019 through Jun 2019*
1	Survey of US DOT's and Canadian Agencies	29%	71%	100%	100%	100%	100%
2	Literature Search/Participation Material Vendors	57%	100%	100%	100%	100%	100%
3	Additional Reinforcement	0%	67%	95%	100%	100%	100%
4	Evaluation if Corrugations Needed to be Completely Filled by the Spray Applied Liner as Part of the Structural Design	0%	67%	90%	100%	100%	100%
5	Life Cycle Cost Analysis	0%	0%	0%	0%	35%	
6	Review the Cured in Place (CIPP) Design Equations	0%	0%	67%	80%	100%	100%
7	Field Data Collection and Assistance from DOT Partners	0%	40%	100%	100%	100%	100%
8	Develop a Recommended Structural Design Equations	0%	0%	0%	20%	30%	80%
9	Develop Performance Construction Specification	0%	0%	0%	0%	30%	82%
10	Computational Modeling	19%	38%	57%	60%	65%	70%
11	Lab Testing	19%	38%	43%	45%	50%	70%
12	QA/QC	17%	29%	38%	54%	65%	75%

Comparative Status of Actual Versus Estimated Expenditures

Table 3: The 6th 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 ($)	Percentage of Total Budget (%)	Percentage of Completion Based on Schedule (%)	Percentage Completed This Quarter (%)	Actual Amount Completed this Quarter ($)
1	Survey of US DOT's and Canadian Agencies	7	7	$25,751	6.44	100	0	0
2	Literature Search/Participation Material Vendors	7	7	$21,875	5.47	100	0	0
3	Additional Reinforcement	3	3	$2,100	0.52	100	0	0
4	Evaluation if Corrugations Needed to be Completely Filled by the Spray Applied Liner as Part of the Structural Design	4	4	$3,900	0.97	100	0	0
5	Life Cycle Cost Analysis	8	6	$29,123	7.28	75	38	$9,417.60
6	Review the Cured in Place (CIPP) Design Equations	5	6	$13,751	3.44	100	0	0
7	Field Data Collection and Assistance from DOT Partners	5	5	$26,752	6.69	100	0	0
8	Develop a Recommended Structural Design Equations	10	8	$34,081	8.52	80	30	$4,455.45
9	Develop Performance Construction Specification	11	9	$27,392	6.85	82	27	$4,010.00
10	Computational Modeling	20	18	$52,039	13	90	15	$7,805.85
11	Lab Testing	20	18	$67,001	16.75	90	15	$19,608.03
12	QA/QC	24	18	$8,000	2.00	75	13	$1,300.00
13	Draft Final Report and Fact Sheet	7	Not Started	$88,270	22.07	0	0	0
14	Final Report and Presentation	3	Not Started					
Total				$400,034	100	-	-	$46,596.93

Table 4: Expenditures Summery of SAPL Research Project in the 6th Quarter

Structural Design Methodology for Spray Applied Pipe Liners in Gravity Storm Water Conveyance Conduits	
Summary of Expenditures for the 6th Quarter (April through June 2019)	
Description	**Sum Amount**
Salaries and Benefits	
Students Salaries and Benefits	$16,431.6
Faculty Salaries will be Paid During Summer Months	$2,908.08
Subtotal	$19,339.68
Partner Companies	
American Structurepoint, Inc.	$8,465.35
Rehabilitation Resource Solutions	-
LEO Consulting	$1,300.00
Subtotal	$9,765.35
Supplies	
USB Extension Cables, Screw Terminal Adapter, Mask and Gloves, Power Adapter Kit, Water Proof LED Light, Cameras, Duct Tape, Power Switches and LEDs, Hex Bolt, Extension Cable (5 ft), Mobil DTE 25 Hydraulic Oil	$9,557.88
Subtotal	$9,557.88
Other Indirect Costs	
Indirect Costs	$7,874.02
Total	**$46,596.93**

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 5: Life Cycle Cost Analysis

- Performed a literature review of the life-cycle cost of CIPP and Sliplining.
- Determined the equation to convert all associated costs within the life span of the SAPL, CIPP, and Sliplining projects to the net present value.
- Identified the factors which have major impacts on the environmental and social costs of the SAPL, CIPP, and Sliplining.
- Determined the program to calculate the social costs of underground and infrastructure projects.
- Trained to work with SimaPro software to evaluate the environmental cost of the projects.
- Collected data and information from several open-source websites of different states for SAPL, CIPP, and Sliplining projects from 2010 to 2019.
- Collected SAPL, CIPP, and Sliplining data from 7 participating DOTs.

Task 11: Laboratory Testing

a) Soil Box Test Setup

- Designed, fabricated and installed the channel supports for partition walls.
- Designed, constructed and installed wooden end wall.
- Transported soil from depot to the CURE laboratory.
- Installed a sump pump at the bottom of the soil box.
- Placed a gravel layer at the bottom of the soil box to provide a leveled base.
- Covered the gravel layer at the bottom of the soil box with a plastic sheet to prepare an isolated surface.
- Sprayed a layer of oil to the concrete wall and placed a layer of polyethylene sheet to eliminate the friction.
- Designed, constructed and installed lower section of the wooden partition walls.
- Placed and compacted the foundation layer using concrete sand.
- Placed intact circular, invert-cut circular, and invert-cut pipe arch into the soil box.
- Installed strain gauges and earth pressure cells.
- Backfilled all cells with 2 passes of vibratory compactor at every eight inches.
- Excavated all cells due to high compaction and replacing the soil without any compaction.

- Measured the compaction rate by nuclear density measurement gauge (operated by HVJ) near the north and south ends of the pipe in both the east and west sides after each lift, for all 3 cells.
- The readings of density gauge testing showed the average density of 82%, 87% and 91% for invert-cut circular CMP, invert-cut arch CMP and intact circular CMP soil box setups respectively.
- Added a 1 ft. layer of gravel at the top to prevent soil failure.
- Conducted a literature search on soil box test loading rate.
- Prepared a summary report of loading rate in previous similar pipe testings and sent out to participating DOTs and consulting partners for their comments and recommendations on load rate.

b) Instrumentation

- Designed positioning of strain gauges, LVDTs, CDSs and Cameras.
- Calibrated the LVDTs and CDSs.
- Developed a data acquisition system for strain gauges, LVDTs, CDSs and cameras.
- Installed StrainSmart, digiCam and GL220_820APS Software.
- Developed a digital image correlation (DIC) system and tested.
- Installed strain gauges, LVDTs, CDSs and cameras.
- Tested different setup for the LVDT and CDS.
- Designed lighting for inside of the pipe.
- Designed and installed of the wirings.

<u>Participation in the Meetings during Conferences, Internal Meetings, Progress Meetings</u>

- Attended three monthly progress meetings with DOTs.
- Held internal meetings with CUIRE team and research partners (Dr. Xinbao Yu, Dr. Firat Sever, Mr. Ed Kampbell and Mr. Lyn Osborn).

Co-Principal Investigator: Dr. Xinbao Yu

The following are the tasks performed this quarter:

Task 10: Computational Modeling

- Prepared the CMP arch model.

Task 11: Laboratory Testing

Contributed with CUIRE research team on:

a) Soil Box Test Setup

- Construction and installation of wooden partition walls and wooden end walls.
- Adding a gravel layer at the bottom of the soil box and covering with a layer of plastic to prevent water from rising into the test setup.
- Placing and compacting the foundation layer of concrete sand.
- Placing intact circular, invert-cut circular, and invert-cut pipe arch into the soil box.
- Backfilling all cells with compaction at every eight inches.
- Talking with representatives from HVJ and Braun Intertec to have them send technicians for measuring field density using Nuclear Density Gauge.
- Excavation all cells to below the haunch levels due to high compaction and replacing the soil without any compaction.
- Adding a 1 ft. deep layer of gravel at the top.

b) Instrumentation

- Installation of strain gauges at the central cross-section for all CMPs.
- Installation of earth pressure cells at invert, springline and crown levels.
- Installation of cameras and setting up a remote operation to take regular pictures of the test setup and backfilling.
- Multiple communications with micro measurements (MM) to check the status of cable displacement sensors (CDS).
- Checking the LVDTs from Omega Engineering in addition to CDS from MM.
- Figuring out the necessary data acquisition system for use with the LVDTs.
- Communicating with Omega Engineering to obtain the quote and purchase 3 LVDTs.
- Performing sensor calibration for LVDTs and cable displacement sensors.
- Preparing drawings for installing the LVDTs and CDS inside the CMPs.
- Checking the compatibility of the cameras with the remote operation software for installation inside the CMP.

c) Nuclear Density Gauge Testing

- Day 1: Measurement by the first technician from HVJ on Cell 1 (CMP with removable invert).
  - The standard count of the density gauge was taken in the soil box, with the test block placed above the concrete sand backfill in cell 2.
  - Measurements were taken near the north and south ends of the pipe in both the east and west sides after each lift. The readings showed an average density close to 82%.
- Day 2: Measurement by the second technician from HVJ on Cell 2 (Arch pipe with removable invert)
  - The standard count of the density gauge was taken outside the laboratory and the test block was placed over a concrete surface.
  - Measurements were taken near the north and south ends of the pipe in both the east and west sides after each lift. The readings showed an average density close to 87%.
- Day 3: Measurement by technician from Braun Intertec on Cell 3 (Intact CMP)
  - The standard count of the density gauge was taken in the soil box, with the test block placed above the concrete sand backfill in cell 2.
  - Measurements were taken near the north and south ends of the pipe in both the east and west sides after each lift. The readings showed an average density close to 91%.

Subcontractor: Mr. Ed Kampbell
Rehabilitation Resource Solutions, LLC

Task 3 – Review of Additional Reinforcement

Began final update of the report based on the additional comments received from DOTs.

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

Began final update of the report based on the additional comments received from DOTs.

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

Update the report based on the additional comments received from DOTs.

Task 9 – Develop Performance Construction Specifications

No work will be performed on this task as it is no longer an RRS assigned task.

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

Subcontractor American Structurepoint, Inc. /Dr. Firat Sever has performed the following tasks in the 6th quarter:

- Attended conference calls with UTA and Ohio DOT.
- Reviewed the cementitious lining approach developed by Ed Kampbell.
- Analyzed beam vs. shell approach for designing cementitious lining.
- Met with cementitious geopolymer vendor on June 11, 2019 to discuss design and testing parameters and to review QA/QC protocol for cementitious liners.
- Conducted additional research and literature review on testing and QA/QC methods for liners. Reviewed cementitious liners specifications from INDOT, WDOT, Toronto, ODOT supplemental specification 833, New Chicago MWRD.
- Met internally at the WEF Collections Systems conference to discuss the project and next steps.

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.

Activities for Q6 include:

- Evaluated and responded to participating company questions regarding timing of polymer application. April 25, 2019.
- Reviewed the soil box testing plan, June 15, 2019.
- Attended the conference call on soil box testing plan, June 18, 2019.
- Attended the conference call on soil box loading rates, June 26, 2019.

Proposed Work for New Quarter

Table 5: SAPL Research Project Tasks for 7th Quarter (July 1 through September 30, 2019)

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 7th Quarter July1st through September 30st**		
			July	**August**	**September**
5	Dr. Mo Najafi	Life Cycle Cost Analysis	To be Continued		
8	Dr. Firat Sever Mr. Ed Kampbell	Develop a Recommended Structural Design Equations	To be Continued		
9	Dr. Firat Sever Mr. Lyn Osborn	Develop Performance Construction Specification	To be Continued		
10	Dr. Xinabo Yu	Computational Modeling	To be Continued		
11	Dr. Mo Najafi Dr. Xinbao Yu	Lab Testing	Control Test to be Completed Polymeric SAPL Test to be Started		
12	Mr. Lynn Osborn	QA/QC	To be Continued		

Principal Investigator: Dr. Mohammad Najafi

Task 5: Life Cycle Cost Analysis

- To present life-cycle cost analysis of SAPL at ICPTT 2019 conference in China.
- To combine all collected data and run the analysis.
- To collect data which are needed to evaluate environmental and social costs of SAPL, CIPP, and Sliplining projects.
- To develop a model and calculate the construction cost of SAPL projects.
- To validate the SAPL construction cost model with existing data.
- To use SimaPro software and evaluate the environmental cost of the SAPL projects.
- To analyze social costs of the SAPL projects by using social cost calculator (SCC) program.

Task 11: Soil Box Testing

- To complete soil box control tests of CMPs.
- To perform data analysis on the results of soil box control tests of CMPs.
- To prepare journal papers out of the results of soil box control tests of CMPs.
- To prepare the soil box test setup for polymeric SAPL material from Sprayroq.

Co-Principal Investigator: Dr. Xinbao Yu

Planned Task for the Next Quarter

Following are the tasks planned for the coming quarter:

Task 10: Computational Modeling

- To calibrate and verify the FEM model of bare CMPs using the test data from control tests.
- To prepare FEM models for lined CMPs.

Task 11: Soil Box Testing

- To contribute with CURE research team and complete control tests of the CMPs and complete soil box setup for testing of polymeric lined CMPs.

Subcontractor: Mr. Ed Kampbell
Rehabilitation Resource Solutions, LLC

Task 3 – Review of Additional Reinforcement

Will complete update of the report based on the additional comments received from DOTs.

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

Will complete update of the report based on the additional comments received from DOTs.

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

Will complete update the report based on the additional comments received from DOTs.

Task 8 – Develop Recommended Design Equations

Will work with Dr. Firat Server to finalize a proposed design analysis method based on existing literature and the results of the product testing being conducted in the UTA load cell.

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

The following tasks are to be performed by American Structurepoint/Firat Sever in the next quarter:

- To work with Ed Kampbell on establishing the overall design approach with the base equations.
- To modify the current base equations based on experimental data and computational modeling with FEA being performed by UTA.
- To improve the draft specifications with the information gathered from other DOTs and cities - work with Lynn Osborn on specification development.
- To attend periodic team conference calls as requested.
- To review any interim work and reports.

Subcontractor: Mr. Lynn Osborn
LEO Consulting, LLC

<u>Task 12. QA/QC.</u>

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):

- Request for additional time and fund has been submitted due to changes from service load to ultimate load conditions in the soil box testing and additional field inspection costs.
- Due to rescheduling the soil box testing, the SAPL soil box tests will start in August.

Equipment Purchased (if any):

N/A

Contacts and Meetings

Progress Meeting

Table 6: SAPL Progress Meeting during the 6th Quarter
April 1 through June 30

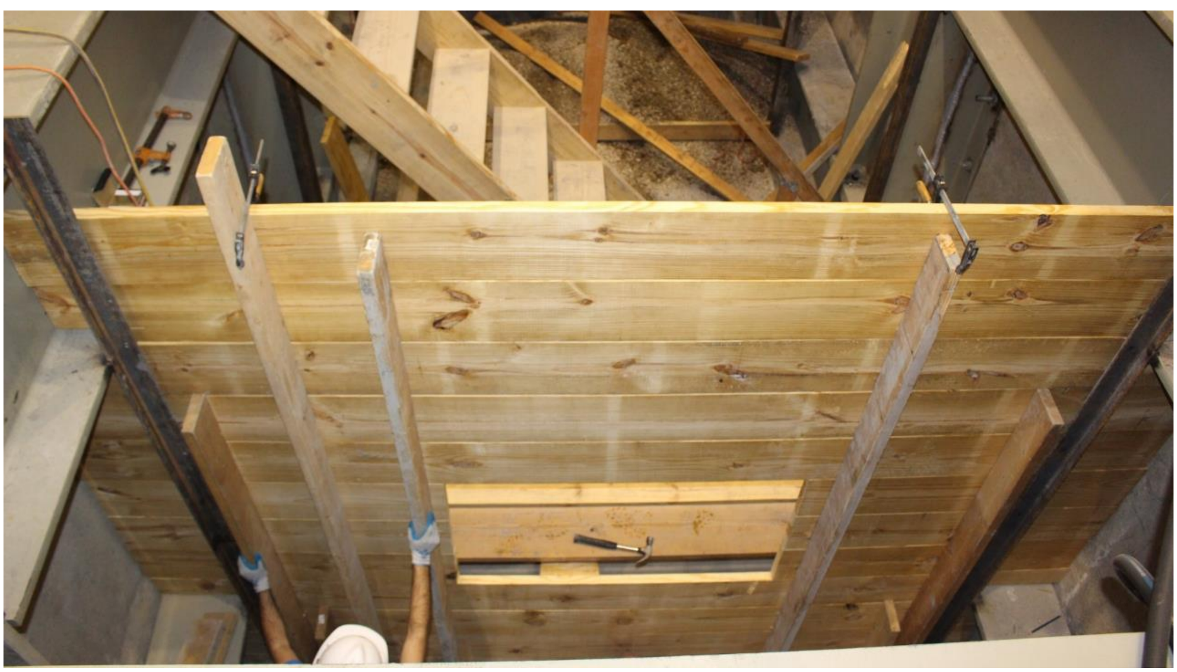
No.	Progress Meeting Agenda	Date
15	• Schedule Update • Completion of Steel Frame Installation • Completion of Actuator Installation • Task 9 – Development of Performance Construction Specification (Presented by Dr. Sever)	April 9, 2019
16	• Schedule Update • Soil Box Upodate • Minutes of Conference Call with Mr. Chip Johnson and His Team from Sprayroq • Mr. Thomas Birnbrich Travel from Ohio DOT to CUIRE/UTA to Visit the SAPL Control Test • Updates on Task 5 – Life Cycle Cost Analysis • Updates on Additional Budget Request	May 14, 2019

17	• Schedule Update
	• Soil Box
	   - Progress on SAPL Control Test Setup
	   - Anticipated SAPL Control Test Date: June 20, 2019
	• Discussion on Polymeric SAPL Soil Box Test Setup with Mr. Chip Johnson from Sprayroq
		June 11, 2019

Appendix A

Soil Box Test Setup for CMP Control Tests Photos

(a)



(b)

Figure A 1, (a) and (b): End Wall Installation

Figure A 2: Partition Walls Installation

(a)

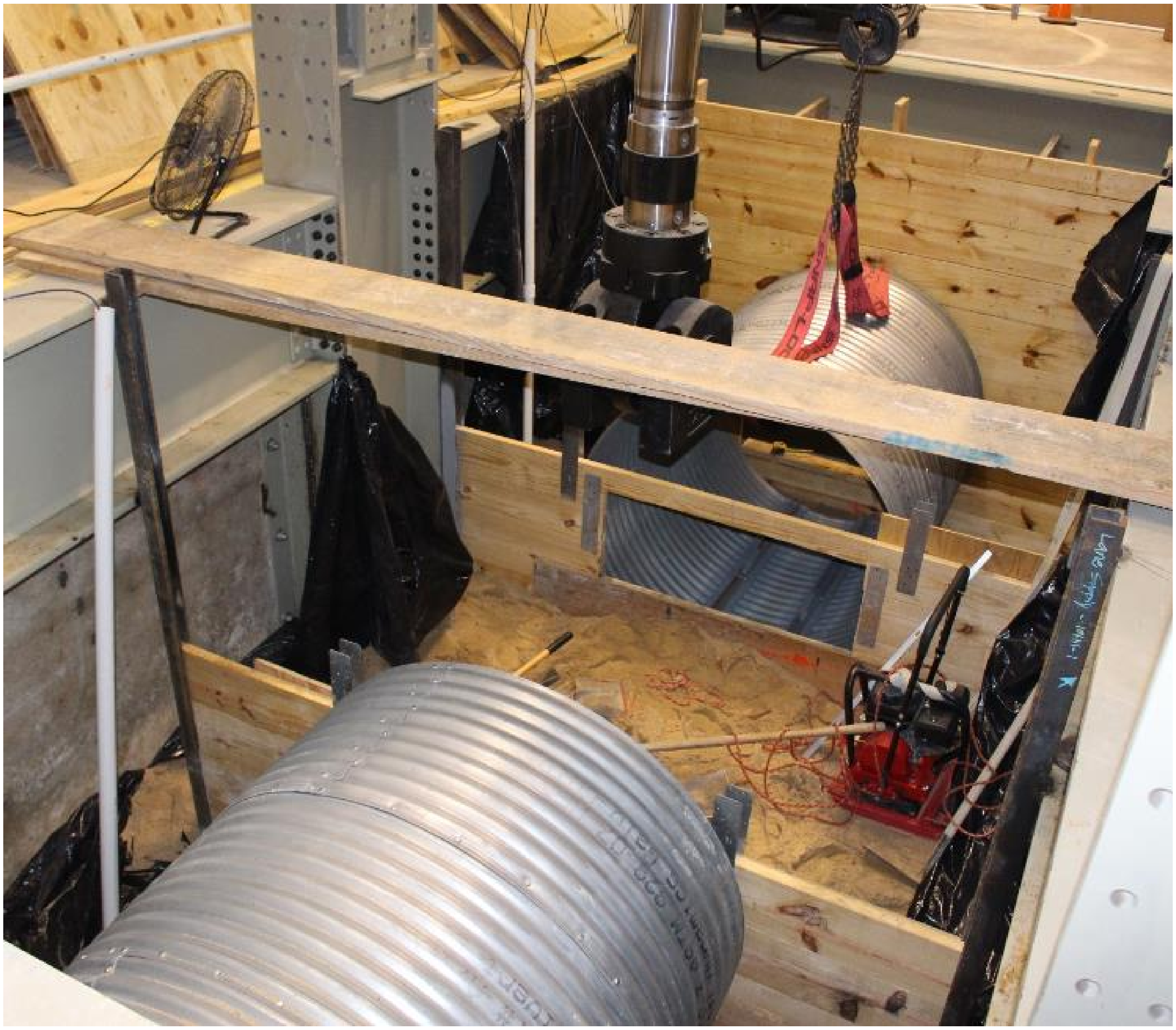
(b)

Figure A 3, (a) and (b): Sand Delivery

Figure A 4: Compaction

Figure A5: Vibratory Plate Compactor

Figure A 6: Plastic Sheets Installation



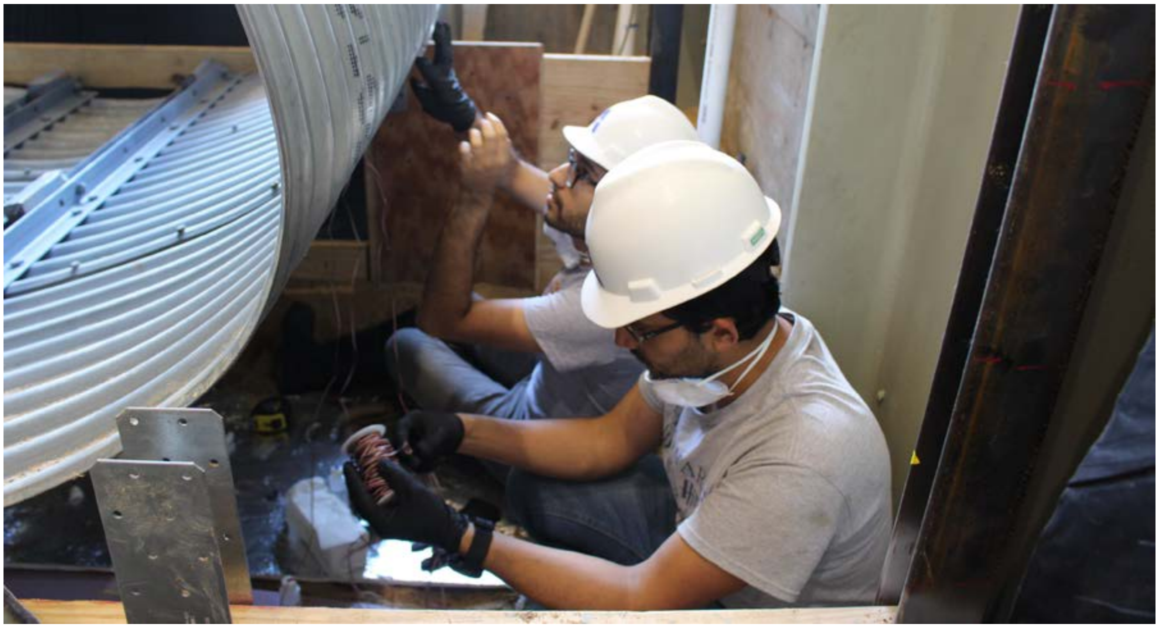
(a)

(b)

Figure A 7, (a) and (b): Placing Circular CMPs

Figure A 8: Instrumentation (Strain gauges)

Figure A 9: Surface Preparation for Attaching Strain Gauges



(a)

(b)

Figure A 10, (a) and (b): Attaching Strain Gauges

(a)

(b)

Figure A 11, (a) and (b): Wiring of Strain Gauges

(a)

(b)

Figure A 12, (a) and (b): Preparation of Middle Cell for Placing the Arch CMP

Figure A 13: Placing Arch CMP

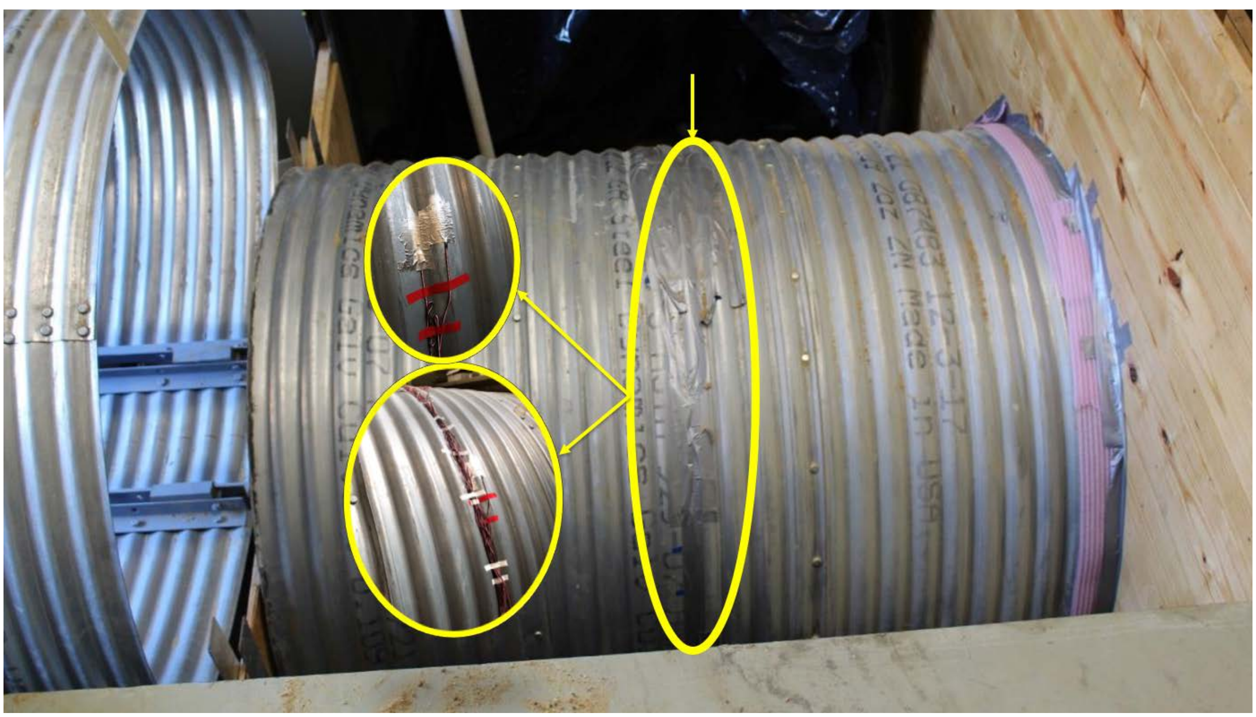


Figure A 14: Physical Protection of Strain Gauges by Aluminum Tape

(a)

(b)

Figure A 15, (a) and (b): Partition Walls Opening and Wiring

Figure A 16: 3 CMPs inside the Soil Box

Figure A 17: Completion the Installation of Partition Walls and Placing Plastic Sheets

Figure A 18: Sand Cone Test and Nuclear Density Measurement

Figure A 19: Inside View of CMPs for Control Test

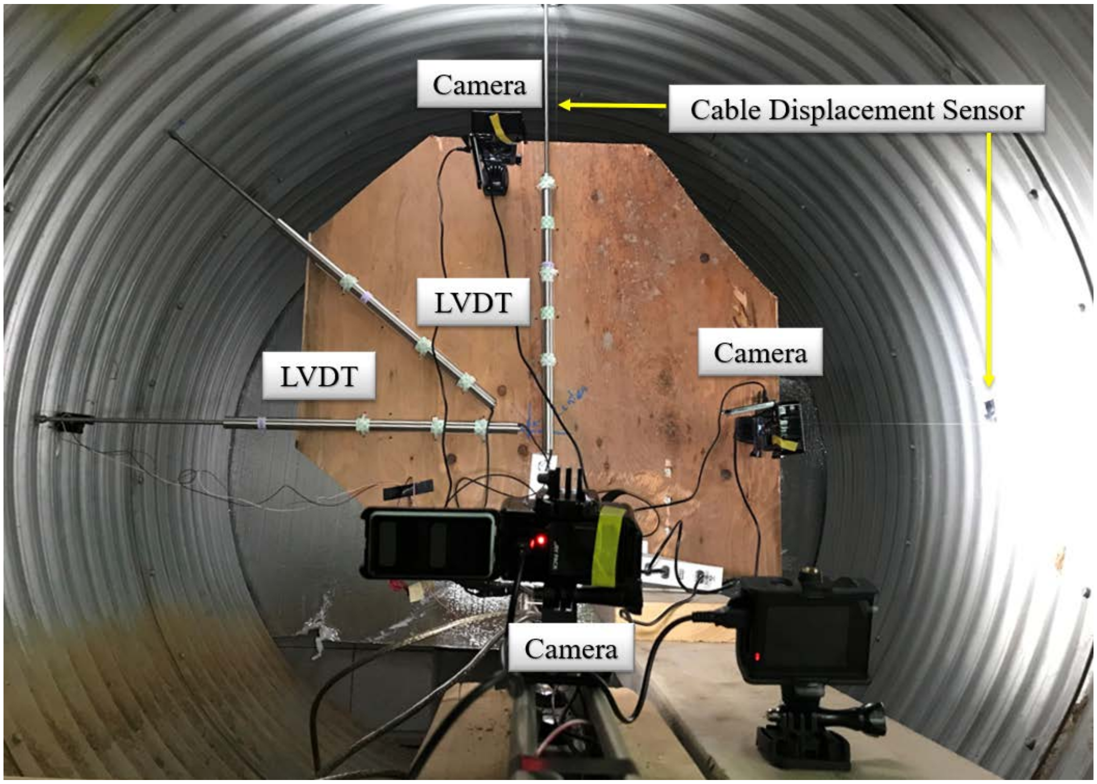
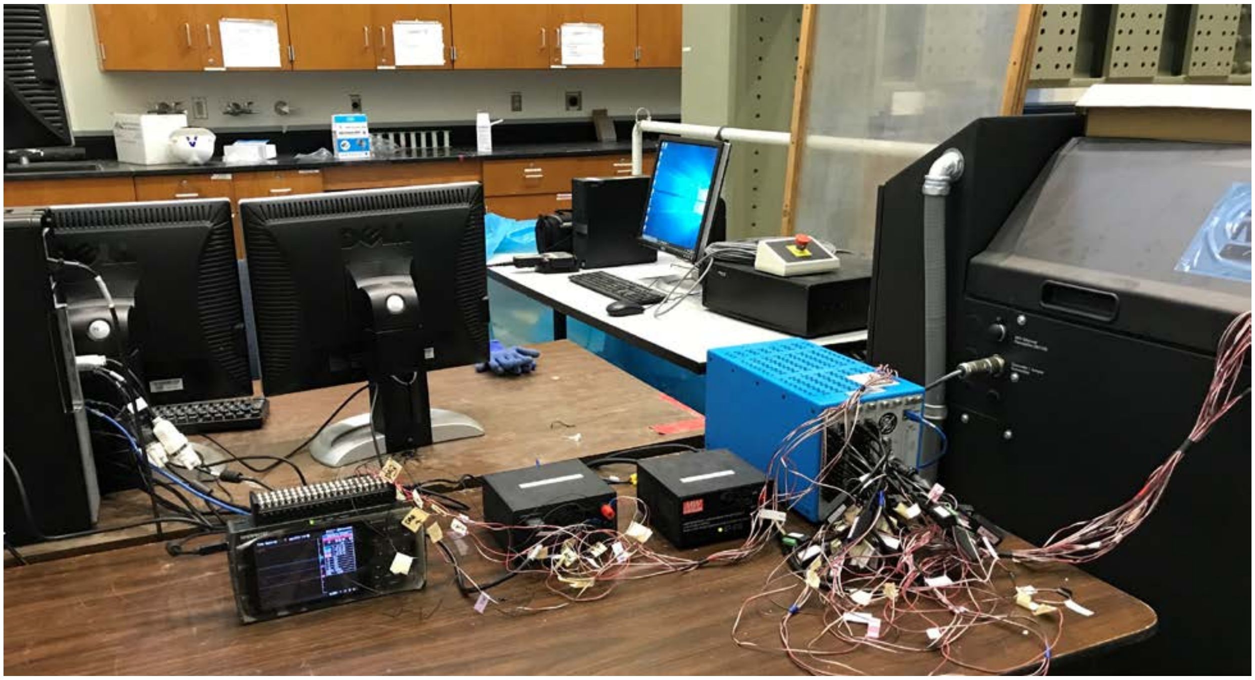
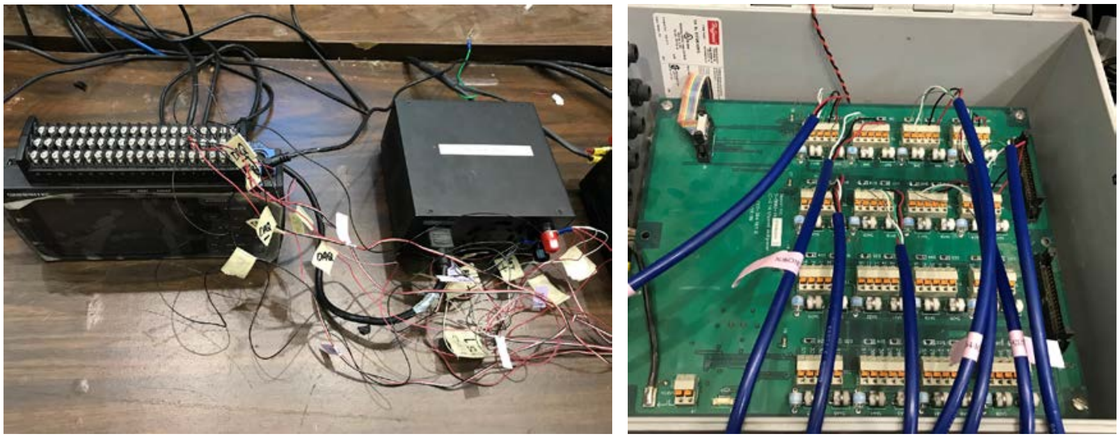


Figure A 20: Instrumentation (LVDTs, CDSs and Cameras) Inside the Pipe

(a)



(b)



(c)

Figure A 21, (a), (b) and (c): Data Acquisition System

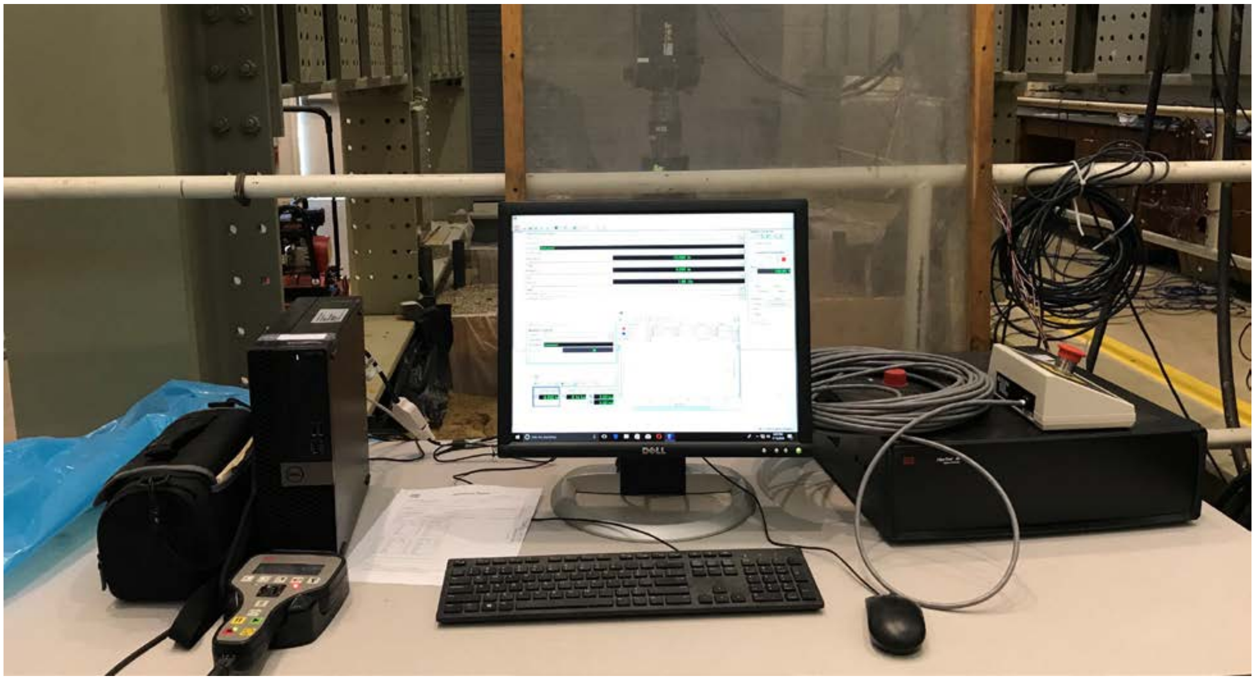


Figure A 22: Actuator Control Station

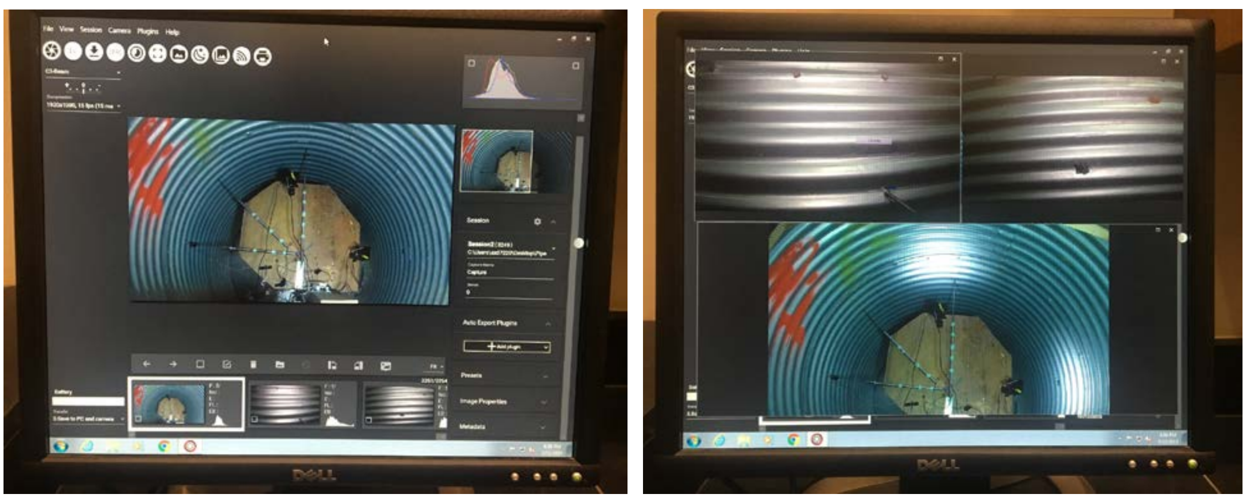


Figure A 23: Live View from 3 Cameras inside the Pipe

Appendix B

Soil Box Control Tests Compaction Report

The compaction measurement is conducted through a nuclear density measurement gauge. The measured maximum proctor density is 115.2 pcf, obtained from the standard proctor compaction test. The measurements have carried out in 6 layers at two repetitions for both east and west side of the pipe. The measured values for each sets of measurement are demonstrated in the figure bellow.

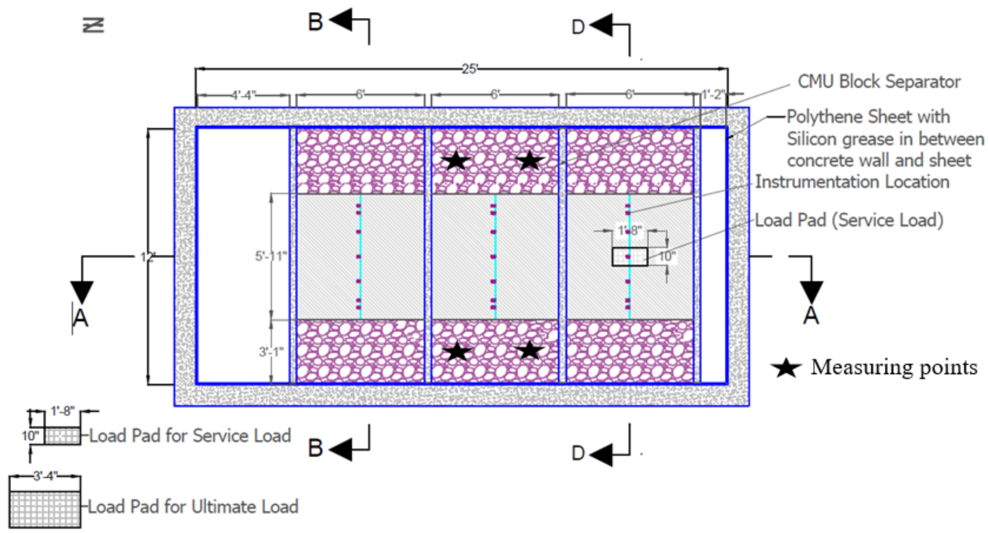


Figure B 1: Plan View of Arch CMP Cell and Location of Nuclear Density Measurements

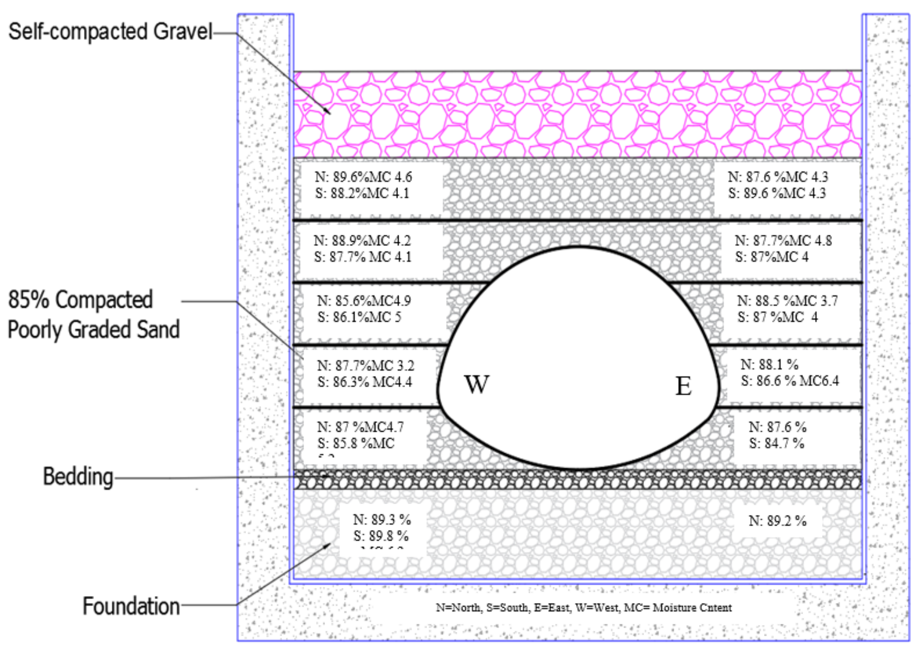


Figure B 2: Compaction Rate of Arch CMP Cell in Different Layers

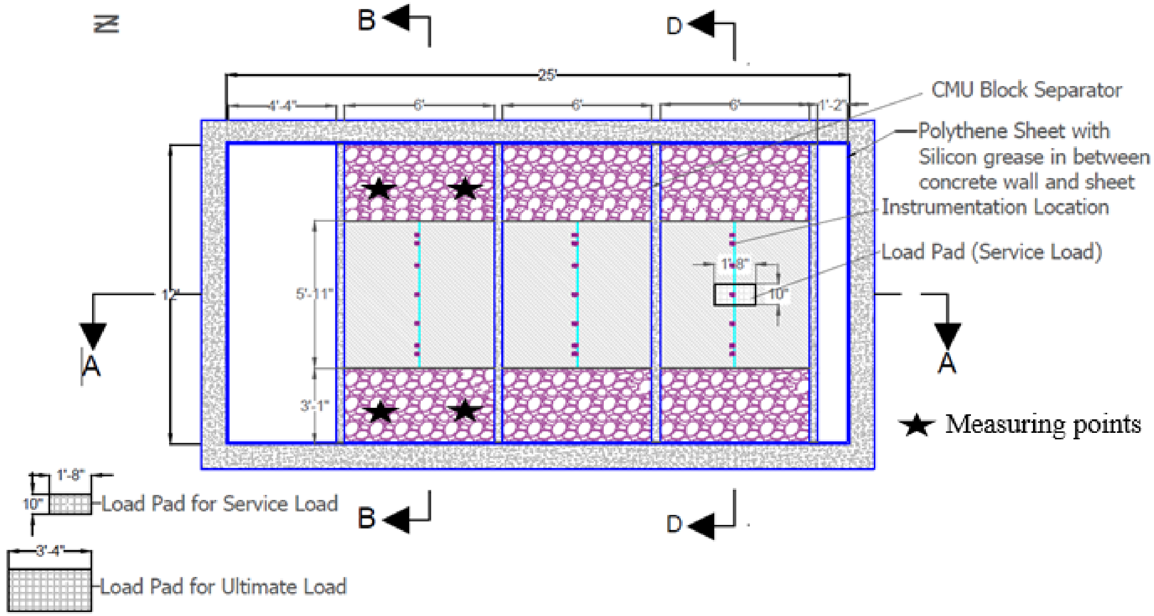


Figure B 3: Plan View of Invert-cut Circular CMP Cell and Location of Nuclear Density Measurements

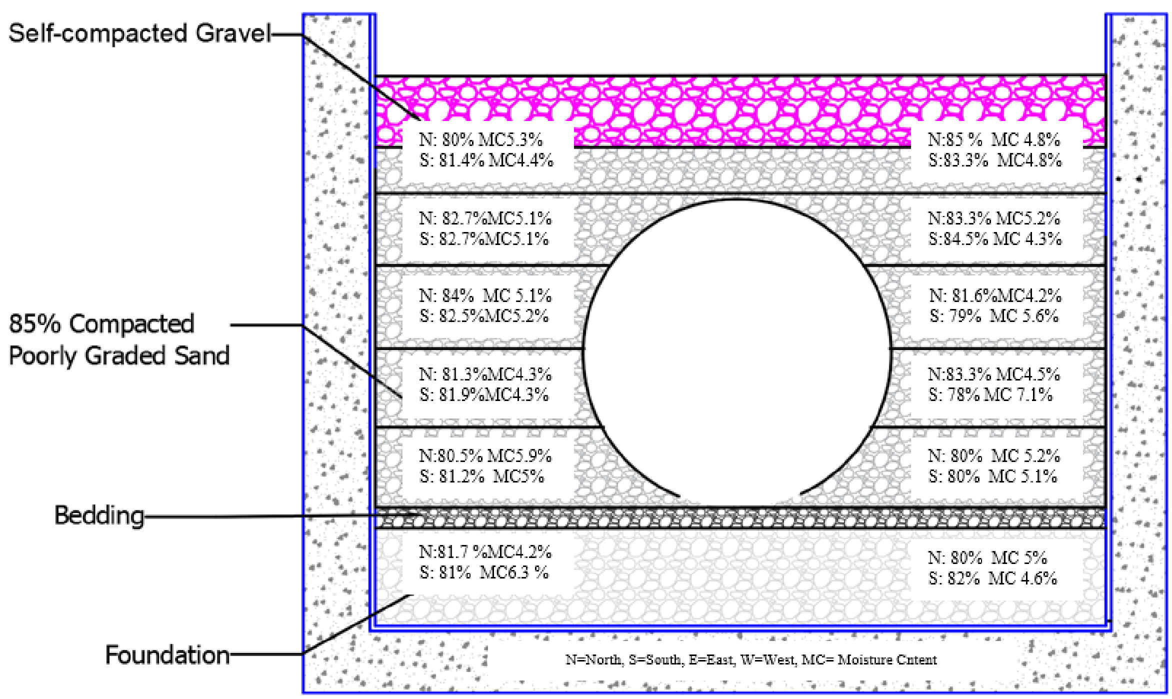


Figure B 4: Compaction Rate of Invert-cut Circular CMP Cell in Different Layers

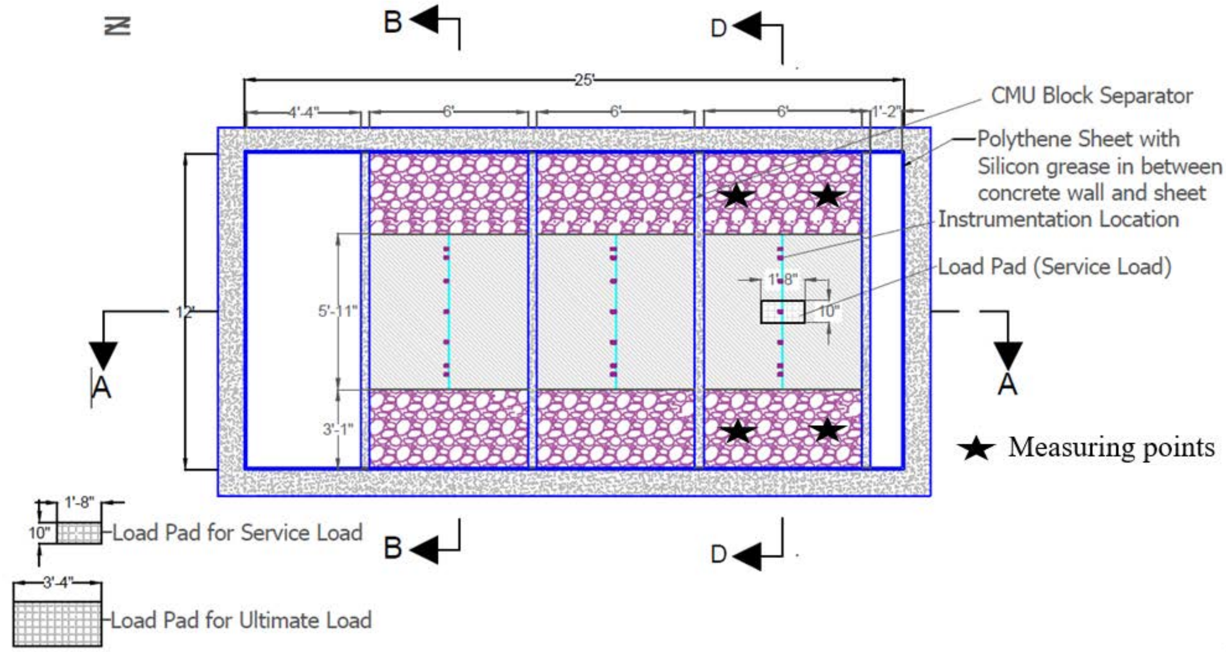


Figure B 5: Plan View of Intact Circular CMP Cell and Location of Nuclear Density Measurements

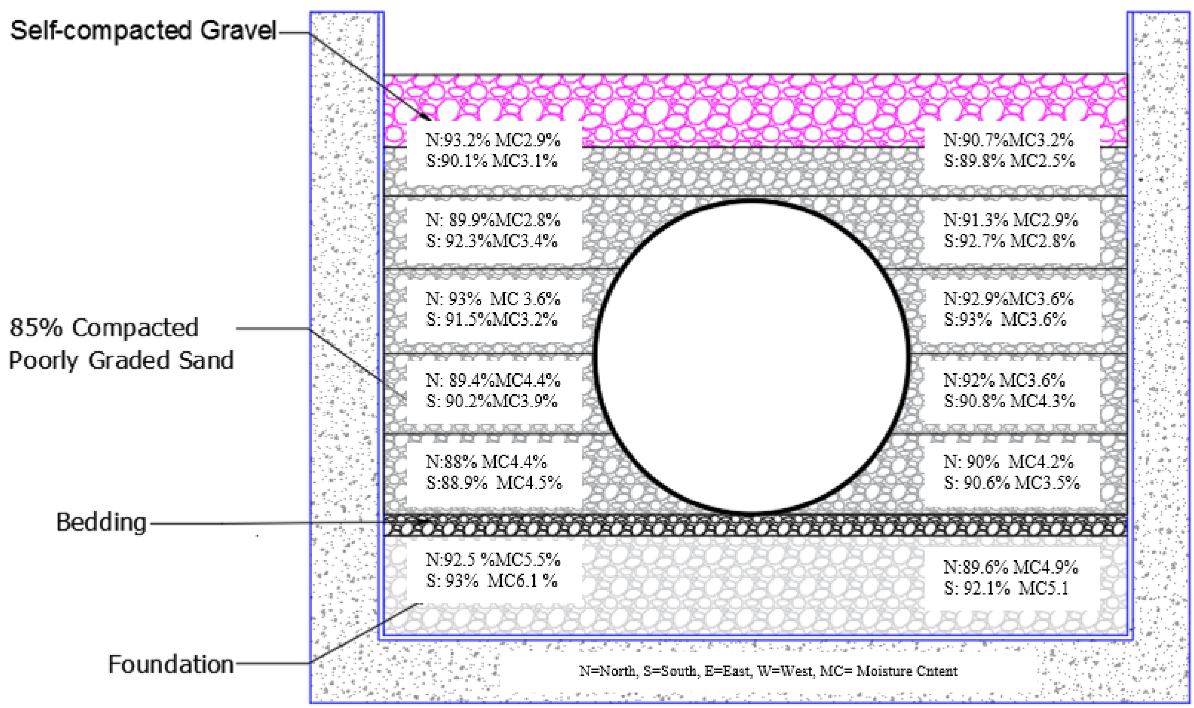


Figure B 6: Compaction Rate of Intact Circular CMP Cell in Different Layers

Appendix C

SAPL Revised Schedule for Time Extension Request

Ohio Department of Transportation

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

Project Schedule Sorted by Start date (Extended Schedule End by December 20, 2020)

Task	Responsibility	Description	Completion In 2017 & 2018	2019																2020																
								6th Quarter					M*				M*				M*				M*				M*			M*				M*
				Jan	Quarterly Progress Report (January 30, 2019)	Feb	Mar	Apr	Quarterly Progress Report (April 30, 2019)	May	June	Jul	Quarterly Progress Report (July 31, 2019)	Aug	Sep	Oct	Quarterly Progress Report (October 31, 2019)	Nov	Dec	Jan	Quarterly Progress Report (January 31, 2020)	Feb	Mar	Apr	Quarterly Progress Report (April 30, 2020)	May	June	Jul	Quarterly Progress Report (July 31, 2020)	Aug	Sep	Draft Final Report and Draft Fact Sheet (August 20, 2020)	Oct Draft Report Review (Due October 31, 2020)	Nov	Dec	End of Project (December 20, 2020)
2	Dr. Mo Najafi	Literature Search/Participation Material Vendors	Delivered																																	
11	Dr. Mo Najafi Dr. Xinbao Yu	Lab Testing	In-progress																											Deliver-able						
10	Dr. Xinabo Yu	Computational Modeling	In-progress																											Deliver-able						
1	Dr. Mo Najafi	Survey of US DOT's and Canadian Agencies	Delivered																																	
7	Mr. Ed Kampbell	Field Data Collection and Assistance from DOT Partners	Delivered																																	
3	Mr. Ed Kampbell	Additional Reinforcement	Delivered																																	
4	Mr. Ed Kampbell	Evaluation if Corrugations Needed to be Completely Filled by the Spray Applied Liner as Part of the Structural Design	Delivered																																	
6	Mr. Ed Kampbell	Review the Cured In Place (CIPP) Design Equations	Delivered																																	
8	Dr. Firat Sever	Develop a Recommended Structural Design Equations	In-progress												Milestone															Deliver-able						
9	Dr. Firat Sever Mr. Ed Kampbell	Develop Performance Construction Specification	In-progress												Milestone															Deliver-able						
5	Dr. Mo Najafi	Life Cycle Cost Analysis	In-progress																Deliver-able																	
13	Dr. Mo Najafi	Draft Final Report and Fact Sheet																																		
14	Dr. Mo Najafi	Final Report and Presentation																																	Final Report		
12	Mr. Lynn Osborn	QA/QC																																		Deliver-able	

6th Quarter

* Milestone

Task	Deliverables
1	Identify use and locations where spray applied linings have been installed.
2	Obtain and review of existing methodologies
3	Literature review to investigate the benefits of incorporating non-metallic tensile reinforcement
4	Provide a Report for Structural Capacity of Spray Applied Liner Filled the Corrugated Host
5	Provide Life cycle cost analysis with considering durability of material
6	A review of ASTM F1216 and the new ASCE design concept for flexible liners including design spreadsheets
7	To measure and visualize the in-situ deflections, de-bonding, spalling, cracks and holes, corrosion, pavement surface settlements and cracks for of spray applied liners to validate how the structure is performing in agreement with the design it was built
8	Two design procedures, one for polymeric flexible liners, and the other for semi-rigid cementitious liners including Excel spreadsheet for structural design of spray applied pipe liners in gravity storm water conveyance conduits
9	Design equations for structural design equations for spray applied pipe liners in gravity storm water conveyance conduits that allow the users to modify based on project objectives.
10	A report documenting the mathematical modeling of soil structure system used to validate the proposed design methodologies presented in Task5
11	A report documenting the qualifications based type testing to validate the results from the task 6 computational modelling that was used to validate the proposed cementitious liner design equations of task 4.
12	Monitor the progress and QA/QC of the project and developing inspection protocols for spray applied lining
12-A	Design & Development Planning, Design & Development Inputs, Design & Development Control, Design & Development Output, General Project Oversight
12-B	Recommendations for QC/QA procedures when installing spray applied liners
13	Submit Draft report and fact sheet
14	Conduct presentations to ODOT as well as at statewide and national conferences.