Center for Underground Infrastructure Research and Education (CUIRE)

Equipment and Facilities

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Department of Civil Engineering
Introduction

The new 25,000 gross sq. ft. facility which houses Center for Underground Infrastructure Research and Education (CUIRE) is located in the west campus just south of the Maverick Stadium. The $9.8 million building houses new research labs in asphalt/pavement, construction engineering and geo-mechanics/geo-environmental areas. The materials/structures lab is also located in this new facility with expanded capabilities. The facility provides the department with much needed experimental growth space in teaching and research, and is useful in meeting the needs from increasing enrollment, faculty/staff numbers and research activities. Figure 1 illustrates the location of CUIRE.

Figure 1. Location of Center for Underground Infrastructure Research and Education (CUIRE)
The Center for Underground Infrastructure Research and Education facility is used for both research and teaching activities in the area of underground infrastructure. The lab consists of two primary areas: the physical testing lab and office/computer lab area. The physical testing lab is a 30-foot high-bay with partially open ground with select fill. The open ground is used for vertical and horizontal drilling. The lab accommodates a 10-ton bridge crane. The drilling area is a 10-feet deep and 10-feet long. The office/computer lab area has a computer lab, two offices, a conference room, a graduate student office, a reception/waiting area, and a workroom/storage. The computer lab accommodates 20 computer stations with latest construction engineering software and laboratory simulation software. Laboratories for the investigation of steel, concrete, masonry and composite materials are in the structural laboratories in CUIRE Rooms 129, 131, 136, 147 and 149. The labs consists of eight spaces: a reaction floor area, environmental room, concrete curing room, concrete mixing room, small specimen testing room, small specimen prep room, an experimental stress analysis lab and a non-destructive testing lab. Within these facilities, concrete, steel, timber, masonry and several other material tests for compressive strength, tensile strength, consistency are performed.

A list of equipment and facilities with their capacity and usage in the CUIRE structural testing laboratory are described below.

1) **Reaction Floor Area**

CUIRE includes a 1200 sq. ft. reaction floor. The room has a 30 ft. high bay and 3 ft. thick concrete slab reaction floor. This lab also houses two 17 ft. tall, 16 ft. wide, 800 kip capacity steel reaction frames for large to full scale structural testing. The steel reaction frames, in conjunction with hydraulic actuators, are used to perform full scale test. Concrete, steel, wood, masonry and composite specimens can be tested in full scale with extensive capabilities on test specimen dimensions and loading capacity. Loading conditions can include vertical, lateral, static and dynamic loads. The reaction floor has a 15 ton bridge crane that can be used to lift and carry full scale specimens. Figure 2 illustrates the Steel reaction frame and overhead crane in the reaction floor area and Figure 3 demonstrates full scale test using steel reaction frame and hydraulic actuator.
Figure 2. Steel Reaction Frame and Overhead Crane in the Reaction Floor Area

Figure 3. Full Scale Test Using Steel Reaction Frame and Hydraulic Actuator
2) Testing Equipment and Calibration Services Model C-1217DC Compression Machine

This machine is for compression testing only and is located in the small specimen testing lab. The capacity is 500 kips. Figure 4 illustrates the Model C-1217DC compression tester.

Figure 4. Model C-1217DC Compression Tester
3) Universal Baldwin Testing Machine

This universal testing machine is capable of performing tensile and compressive testing with appropriate testing fixtures. This 60 kip equipment is also located in the small specimen testing lab. Figure 5 shows the Universal Baldwin testing machine.

![Figure 5. Universal Baldwin Testing Machine](image)

4) Tinius Olsen SuperL Universal Testing Machine

This universal testing machine is located in the reaction floor room. It can generate up to a 400 kip force and can be used for both tensile and compressive testing with appropriate fixtures. Figure 6 illustrates the Tinius Olsen SuperL universal testing machine.
5) MTS Model 810 Testing Machine

This machine is for performing tensile tests only with appropriate tensile testing fixtures. This 55 kip machine is located in the reaction floor room. Figure 7 illustrates the MTS model 810 tensile testing machine.
6) MTS Series Hydraulic Actuators (100 kip and 300 kip capacities)

CUIRE has two hydraulic actuators. These actuators have fatigue-rated force generators targeted at long stroke and mid-level performance dynamic structural applications. Figure 8 shows the hydraulic actuator.

![Figure 8. Hydraulic Actuator](image)

The hydraulic actuators are connected with MTS 505 hydraulic pump. CUIRE also has several hydraulic cylinders with force generating capacities ranging from 400 kips to 650 kips. All hydraulic machines use the MTS 505 pump with 20 gpm flow rate. Figure 9 illustrates the Hydraulic pump for the actuators and cylinders.
A MTS FlexTest® 40 data control system called for general testing applications is also available. This system provides real-time closed-loop control, with transducer conditioning and function generation for both the MTS series actuators and MTS 810 testing machines. Figure 10 demonstrates the MTS FlexTest® 40 data control system and Figure 11 illustrates the creep test for plastic pipes.
Figure 10. MTS FlexTest® 40 Data Control System

Figure 11. Creep Test for Plastic Pipes
Sample Project

Testing and Evaluation of Statically Loaded Large Diameter Steel Pipe with Native Backfill

In May 2010, TRWD entered into an agreement with CUIRE to investigate the potential reuse of native soils with or without modifications. CUIRE attended portions of the Value Engineering (VE) workshop in May 2010 and reviewed the VE report. CUIRE was contracted to provide research on soil reuse, conduct a soil-box test as well as perform research on additional topics. In late 2010, CUIRE developed and proposed the soil-box test methodology. CUIRE and TRWD discussed many ideas and eventually decided that a static load test of a 72-inch diameter steel pipe, provided by Northwest Pipe, would be conducted inside a unique soil box located at the CUIRE Facility at UT Arlington. An amendment to the original contract was approved in December 2010 arranging for three additional static load tests with alternate backfill materials such as lime stabilized native soil, cement stabilized native soil, and CLSM. This report presents the results from the first soil-box test and associated FEM analysis for Test #1 using untreated native soil backfill (embedment). CUIRE submitted three additional reports at the conclusion of each future static load test, as well as a comprehensive final report. Each test took approximately four months for setup and data collection. Table 1 presents embedment types for Test 1 – 4.

<table>
<thead>
<tr>
<th>Test</th>
<th>Backfill Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1</td>
<td>Native</td>
</tr>
<tr>
<td>Test 2</td>
<td>6% Lime Modified</td>
</tr>
<tr>
<td>Test 3</td>
<td>Cement Modified</td>
</tr>
<tr>
<td>Test 4</td>
<td>CLSM</td>
</tr>
</tbody>
</table>

Table 1. Embedment Types for Test 1 – 4

As Table 1 indicates, above tests performed to observe behavior of steel pipe embedded in untreated and treated/stabilized native soil and subjected to static load. The results obtained
from the tests used to calibrate and validate the related FEM. The validated FEM provided
design engineers with a methodology to analyze the pipe soil/interaction throughout the
alignment of the project. The intent was to develop the methodologies for finite element models
that can run scenarios with varying pipe diameters and trench cross sections, but more
importantly alternate backfill and embedment materials.

This research was supervised by Dr. Mohammad Najafi, P.E., an Assistant Professor of
Civil Engineering and CUIRE Director. The installation of the test setup, data collection,
analyses, interpretation and presentation of data was conducted by doctoral student and CUIRE
Research Associate, Jwala Sharma, with assistance from several CUIRE Research Assistants:
Bhaumi Chaurasia, Lalit Chilana, Babak Haji Mohammad Hasan, Moksha Kizhakke, Saeed
Rahjoo and civil engineering graduate students: Joshua Avalos, Chris Lectenburg, Daniel Siringi,
and Hossein Tavakoli. The Finite Element Model that supports the Soil-Box Test #1 was
developed by CUIRE Faculty Research Associate, Zhen Zheng. The research was coordinated by
CUIRE Faculty Research Associate/Program Manager, Abhay Jain.

**Soil-Box Test**

TRWD considered Pre-stressed Concrete Cylinder Pipe (PCCP), Steel Pipe (SP), and
Bar-Wrapped Concrete Cylinder Pipe (BWCCP) for the IPL Project. TRWD is familiar with the
performance of existing PCCP pipelines at Richland Chambers and Cedar Creek. CUIRE
investigated the aforementioned interaction of steel pipe with native and modified native soils
under application of external static load. Therefore, PCCP and BWCCP were not within the
scope of this research. When subjected to external load, steel pipe relies heavily on pipe-soil
interaction as a composite system. The research on steel pipe performance with native or
modified native soil was limited and not well understood.
Appropriate embedment selection and compaction is crucial in the design and construction of steel pipes because steel is flexible and relies heavily on soil support. Installation of steel pipe would typically call for either granular embedment or CLSM embedment. The IPL pipeline alignment consists of areas with clayey native soils. Sixteen soil borings from the Fugro report were reviewed by the UT Arlington Geotechnical team. For Test #1, Boring B6 was selected for use as embedment in the soil box used around the pipe.

The steel pipe used for the soil box test was a 20-ft long, 72-inch nominal diameter pipe without any coatings and linings. The soil box is a 25-ft long, 12.5-ft wide and 10-ft deep concrete load cell. To provide working space in the soil box and to place an adequate dead load on the pipe, some modifications to the soil box were made. A large wooden frame was built on the North side of the load cell to shorten the length of the load cell to 21 ft. This allowed 4 ft. of working space to access the instruments placed inside the pipe sample. The wooden frame was also constructed at the ground level for approximately 8 ft. to increase the overall height of the soil box to 18 ft.

The steel pipe was instrumented with earth pressure cells, convergence meters and strain gauges. These pressure cells and convergence meters were installed at three locations along the longitudinal length of the pipe, one at the center, and two at 5-ft offset from the pipe center. The earth pressure cells monitored load changes, while the convergence meters measured pipe deflection, and strain gauges measured pipe strain. The instruments were calibrated prior to loading, and data was recorded throughout the testing via a data logger.

First a 12-inch layer of pea gravel bedding was placed under the pipe sample, and then native backfill soil imported from the project alignment (soil boring # 6) was used as the embedment soil. The native soil was placed up to one foot above the pipe crown, and was
compacted in 6-inch lifts to 95% of standard proctor density. The sand cone method was used to measure density and moisture content.

To simulate static loading in actual field conditions, three feet of native soil and seven feet of additional pea gravel load were placed on top of the pipe. The achieved loads were equivalent to a load of approximately 11 feet of native soil cover with an average density of 110 pcf. The embedded pipe section was kept under constant static load for nine weeks while pipe deflection, loads and pipe wall strains were recorded (see Figure 12 for the soil box and finite element modeling).

![Figure 12. Soil Box and Finite Element Modeling](image)

**Results & Findings**

The pipe deflections (changes in actual vertical and horizontal diameters) were recorded with installation of each layer of native soil embedment. Convergence meters recorded the increased in the vertical pipe diameters and decreased in the horizontal pipe diameters. This was due to lateral pressure from the embedment as well as an increase of bedding angle as the embedment layers were placed. As was expected, the final surcharge loads caused a decrease in the vertical pipe diameter and corresponding increase in the horizontal pipe diameter. However, deflections at the three cross sections were slightly different. These variations at the three cross sections (north, south, and center) may have been due to differences in actual pipe diameters at
these three cross-sections at the start of the test, and/or due to variations in soil, and/or achievement of different compacted soil densities along the length of the soil box even with identical compaction effort.

The data collected from the soil box test was used to calibrate the related FEM. Finite element analysis of the pipe-soil model was carried out using ABAQUS software (version 6.10). This pipe-soil model includes plasticity behaviors, a 12-layer compacted soil component, and considerations for interfaces of soil and pipe. Stress analysis was carried out on the model, and the calibrated FE model was used to study the influence of the soil box’s concrete walls, pipe and soil contacts and deformation prediction for modified native soil. The measured and FEM deflections were less than calculated deflections based on AWWA and other guidelines, and the results of testing showed that native backfill can be considered as a viable option for the IPL project subject to field constructability limitations.

A two-dimensional (2D) half symmetric pipe-soil model under static load was studied. Plastic soil material, elastic-plastic steel material and frictional interaction between pipe and soil were introduced in the FE model. Results from the full-scale testing were used to calibrate the FEM. The deformations and strain values for the FEM and laboratory testing matched each other in an acceptable level. The FEM represented the full-scale testing and could be used for further investigations. After comparison of lab testing data, FEA and design calculations were made, and it showed that finite element analysis (FEA) predicted deflections of pipe more accurately than design equations.
Appendix A

Organization Chart
Figure A.1. — CUIRE Organization Chart

Director
Dr. Mohammad Najafi, P.E.

The University of Texas at Arlington

Program Manager
Ms. Sahar Habibzadeh

Lab Manager
Timothy Kruzic

Project 1
Graduate Students

Project 2
Graduate Students
Appendix B

Biographies
DR. MOHAMMAD NAJAFI, P.E., F.ASCE
Professor and Director, Construction Engineering & Management
Director, Center for Underground Infrastructure Research & Education (CUIRE)
Department of Civil Engineering - The University of Texas at Arlington

Box 19308; 428 Nedderman Hall
Arlington, TX 76019

1. Overview

Dr. Najafi has more than 30 years of experience encompassing engineering, educational, research, consulting, and management activities. Prior to starting his academic career, Dr. Najafi spent more than 13 years working on various construction projects. Dr. Najafi is the author of several books on trenchless technology and asset management. As Director of the Center for Underground Infrastructure Research and Education (CUIRE) at the University of Texas at Arlington, Dr. Najafi has led many research projects with more than $3M of funding secured competitively from funding agencies such as WaterRF, WERF, and TRB. Dr. Najafi is a renowned international expert in pipeline engineering and trenchless technology and has been a frequent invited keynote speaker at national and international conferences. Under his direction, a new Master of Construction Management (MCM) was instituted at the University of Texas at Arlington. Dr. Najafi has also extensive administrative and management experience of research activities gained through his position as Director of CUIRE. Dr. Najafi is an active member of ASCE, ASTM, AWWA, and NASTT. He has served as the Chair of ASCE Pipeline Division Executive Committee and was the Chair of ASCE Pipelines 2013 conference. He is also the Chief-Editor of ASCE Journal of Pipeline Systems Engineering and Practice. Dr. Najafi is a registered Professional Engineer in Texas.

2. Books Published through McGraw Hill

- Pipeline Renewal and Asset Management (2016).
- Trenchless Technology Piping – Installation and Inspection (2010).
SAHAR HABIBZADEH

Center for Underground Infrastructure Research and Education (CUIRE)
The University of Texas at Arlington
Phone: 817-272-9177, Email: sahar.habibzadeh@mavs.uta.edu

(a) Professional Preparation

Shiraz University, Iran, BS, Architectural Engineering  2014
The University of Texas at Arlington, MS, Civil Engineering 2016 – Present

(b) Appointments

Program Manager  May 2017 – Present
Center for Underground Infrastructure Research and Education,
The University of Texas at Arlington, TX

(c) Synergistic activities

Program Coordinator, The Second Trenchless Technology
and Pipe Conference, The University of Texas at Arlington, TX  June 2017

(d) Awards

CMAA North Texas Chapter Construction Management  May 2017
Association of America Scholarship  August 2015
TIMOTHY KRZUZIC

Lab Tech for UTA Department of Civil Engineering/CUIRE
Feb 2015 – Current

Intern at UTA environmental engineering lab
June 2014 – Current
Assisted in analysis of Halo-acetic acid, Tri-halomethane, and NDMA for the development of a new method for the treatment of city water

Arlington ISD, Arlington TX

Substitute Teacher
March 2010-June 2011
Instructed upon basic principles with Chemistry and Biology
Introduced students about standard practices in laboratory.

University of Texas at Arlington, Arlington, TX

Chemistry Tutor
August 2008-December 2010
Assisted with principles in all areas of Chemistry

University of Texas at Arlington, Arlington, TX

UTA Undergrad Research
December 2008- December 2010
Used UV Vis and built laser apparatus under Dr. Roshan Perera with the goal of identifying the mechanism of cytochrome P450.

Armstrong Forensic Lab, Arlington, TX

Assistant Lab Tech
May 2008- August 2008
Assisted in forensic tests and management of evidence for arson cases.

(a) EDUCATION

University of Texas at Arlington
Bachelor of Science in Chemistry, December 2010

(b) EQUIPMENT AND INSTRUMENT EXPERIENCE

- Colorimeters
- Ultraviolet-visible spectrophotometers
- Gas chromatography–mass spectrometer (GC-MS)
Appendix C

Additional Equipment
Figure C.1. -- CCTV Testing Equipment

Figure C.2. -- Hydraulics Facilities

Figure C.3. -- Trenchless Technology Testing Site