Geotechnical Engineering Report

Proposed Arterial Street Improvements

Harvard Avenue from 21st Street to 31st Street

Tulsa, Oklahoma

June 04, 2018

Terracon Project No. 04185089

Prepared for:

Poe & Associates, Inc.
Tulsa, Oklahoma

Prepared by:

Terracon Consultants, Inc.
Tulsa, Oklahoma

June 04, 2018

Poe & Associates, Inc.
4606 South Garnett Road, Suite 600
Tulsa, Oklahoma 74146

Attn: Mr. Jim Hemphill, P.E.
Jim.Hemphill@poeandassociates.com

Re: Geotechnical Engineering Report
Proposed Arterial Street Improvements
Harvard Avenue from 21st Street to 31st Street
Tulsa, Oklahoma
Terracon Project No. 04185089

Dear Mr. Hemphill:

Terracon Consultants, Inc. (Terracon) has completed the geotechnical engineering services for the above referenced project. This study was performed in general accordance with Terracon Proposal No. P04175273 dated October 19, 2017. This report presents the findings of the subsurface exploration and provides geotechnical recommendations for pavement subgrade preparation and pavement section thickness for the proposed project.

We appreciate the opportunity to be of service to you on this project. If you have any questions concerning this report, or if we may be of further service, please contact us.

Sincerely,
Terracon Consultants, Inc.
Cert. of Auth. #CA-4531 exp. 6/30/19

Saba M. Gebretsadik, P.E. (TX)
Staff Engineer

Michael H. Homan, P.E.
Oklahoma No. 15777

REGISTERED PROFESSIONAL ENGINEER
MICHAEL H. HOMAN
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OKLAHOMA

SMG:MHH:cj

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GEOTECHNICAL ENGINEERING REPORT
PROPOSED ARTERIAL STREET IMPROVEMENTS
HARVARD AVENUE FROM 21ST STREET TO 31ST STREET
TULSA, OKLAHOMA

Terracon Project No. 04185089
June 04, 2018

1.0 INTRODUCTION

This geotechnical engineering report has been completed for the Proposed Street Improvements on Harvard Avenue from 21st Street to 31st Street in Tulsa, Oklahoma. Eight borings, designated as B-1 thru B-8, were performed to depths of approximately 5 to 6 feet below the existing pavement surface. Pavement core photo logs, along with a site location map and a boring location plan are included in Appendix A of this report.

The purpose of these services is to provide information and geotechnical engineering recommendations relative to:

- subsurface soil conditions
- groundwater conditions
- pavement thickness and subgrade preparation recommendations
- excavatibility of soils

2.0 PROJECT INFORMATION

2.1 Project Description

Item	Description
Site layout	See Appendix A, Exhibit A-2, Boring Location Plan.
Proposed Development	Street rehabilitation. The project also includes replacement of 12” and 24” water lines that will likely be constructed in the outside northbound and southbound lanes. The rehabilitation will include milling and overlaying. Full-depth asphalt reconstruction with patching will be performed where water lines are replaced; and where the pavement is severely distressed, or where mill and overlay may not be feasible owing to the relatively thin existing full-depth asphalt.

2.2 Site Location and Description

Item	Description
Location	Harvard Avenue from 21st Street to 31st Street in Tulsa, Oklahoma.

Item	Description
Traffic loading	Traffic data ■ 2017 AADT: 29,500 (obtained from the City of Tulsa website) ■ Traffic growth rate: 2% (assumed) ■ Truck traffic: 2% (assumed)
Current ground cover	Asphalt over Portland cement concrete, and asphalt pavement.

3.0 SUBSURFACE CONDITIONS

3.1 Typical Profile

Based on the results of the borings, pavement and subsurface conditions, the project pavement and soil conditions can be generalized as follows:

Description	Approximate Depth to Bottom of Stratum	Material Encountered	Consistency/Density
Surface [1]	2 ¾ to 5 ¾ inches Asphalt 7 to 10 inches of PC Concrete at B-1 thru B-3 and B-6 thru B-8	Asphalt over Portland cement concrete	N/A
Surface [1]	5 ¾ to 8 inches Asphalt at B-4 and B-5	Asphalt	N/A
Stratum 1 [2]	4.5 feet	Fill: Silty gravel with sand	N/A
Stratum 2 [3]	1.3 to 6 feet	Lean clay and silty clay with varying amounts of sand and sandstone fragments; sandy silt	Clay: Medium stiff to hard Sandy silt: Dense to very dense
Stratum 3	Encountered to the termination depths of 4.8 to 5.3 feet in borings B-1, B-3, B-6, and B-7	Weathered sandstone	Cemented to well cemented

1. 1½ to 7½ inches of aggregate base was encountered underneath the pavement in borings B-4, B-5, B-7, and B-8.
2. Encountered in boring B-8.
3. Borings B-2, B-4, B-5, and B-8 terminated in this stratum at a depth of approximately 6 feet.

In the laboratory, collected samples were tested for moisture content, Atterberg limits, and sieve analysis.

Laboratory test results are included on the pavement core logs in Appendix A and grain size distribution curves in Appendix B. A brief description of the AASHTO and USCS classification systems is included in Appendix C.

3.2 Groundwater

The boreholes were observed while drilling and immediately after completion for the presence and level of groundwater. Groundwater was not encountered in the borings at these times.

The groundwater level observations made during our exploration provide an indication of the groundwater conditions at the time the borings were drilled. Longer monitoring in piezometers or cased holes, sealed from the influence of surface water, would be required to evaluate long-term groundwater conditions. During some periods of the year, perched water could be present at various depths. Fluctuations in groundwater levels should be expected throughout the year depending upon variations in the amount of rainfall, runoff, evaporation, and other hydrological factors not apparent at the time the borings were performed.

Based on our experience, soft wet soils are found beneath pavements after demolition.

3.3 Existing Pavement Thickness

The thicknesses of the existing Asphalt over Portland Cement Concrete (APC) and Asphalt Concrete (AC) pavements encountered at the core locations are summarized below.

Boring Number	AC (inches)	PCC (inches)
B-1	2 ¾	9 ¼
B-2	3 ½	8 ¾
B-3	3 ¼	10
B-4	5 ¾	NE [1]
B-5	8	NE
B-6	3	7
B-7	5 ¾	8
B-8	4	8 ½

1. NE = Not Encountered

4.0 RECOMMENDATIONS FOR DESIGN AND CONSTRUCTION

4.1 Geotechnical Considerations

We understand that the project will consist of improving the existing Harvard Avenue between 31st Street (project begins immediately north of East 30th Place) and 21st Street. The project also includes replacement of 12" and 24" water lines that will likely be constructed in the outside northbound and southbound lanes. Based on the information provided by Poe & Associates, The rehabilitation will include milling and overlaying. Full-depth pavement reconstruction to include concrete with asphalt overlay or full depth asphalt will be performed where water lines are replaced; where pavement is severely distressed; and where mill and overlay may not be feasible owing to the relatively thin existing full-depth asphalt.

We cored the existing pavement at eight locations and drilled into the subgrade soils to approximate depths of 5 to 6 feet below the pavement surface. Most of the core locations encountered approximately 2 ¾ to 5 ¾ inches of asphalt pavement underlain by 7 to 10 inches of Portland cement concrete pavement. Asphalt pavement having a thickness of 5 ¾ and 8 inches was encountered at B-4 and B-5, respectively. In addition, aggregate base with thicknesses ranging from 1½ to 7½ inches was encountered beneath the pavement at four core locations.

Existing fill consisting of silty gravel with sand was encountered beneath the pavement at core location B-8 to a depth of about 4.5 feet.

Relatively shallow cemented to well-cemented weathered sandstone was encountered in four of the borings below depths of about 1.5 to 3 feet.

We recommend that full-depth pavement sections incorporate a layer of aggregate base beneath the pavement to improve long-term pavement support. Recommendations for a mill and overlay procedure and full-depth replacement are provided in sections **4.3 Pavements**.

The recommendations contained in this report are based upon the results of field and laboratory testing, engineering analyses, and our current understanding of the proposed project.

4.2 Earthwork

4.2.1 Site Preparation

Areas within the limits of full-depth replacement construction should be stripped and cleared of existing pavement and any other deleterious material.

After stripping and completing any cuts, the subgrade should be proofrolled to aid in locating soft, unstable or otherwise unsuitable soils. Proofrolling should be performed with a loaded tandem axle dump truck weighing at least 25 tons. If it is not possible to proofroll the area, an engineer should evaluate the subgrade. Soft, unstable soils should be removed and replaced full-depth, if they cannot be adequately stabilized in-place. Based on our experience, unstable soils with high moisture content will be encountered directly beneath existing pavements.

After completing the proofrolling, and before placing any fill, the exposed subgrade should be scarified to a minimum depth of 8 inches, moisture conditioned, and compacted as recommended in section **4.2.3 Compaction Requirements**.

4.2.2 Fill Material Types

Engineered fill (if required to raise the subgrade elevation or to replace unsuitable soils) should meet the following material property requirements.

Fill Type [1]	USCS Classification	Acceptable Location for Placement
Imported Low Volume Change (LVC) Material [2]	CL or SC (PI ≤ 20)	All locations and elevations
On-Site Soils	CL (PI ≤ 20)	All locations and elevations [3]
	ML (Non-plastic)	Should not be placed within pavement subgrade
ODOT Type A Aggregate Base [4]	GC-GW, GM-GW	All locations and elevations

1. Controlled, compacted fill should consist of approved materials that are free of organic matter and debris and contain maximum rock size of 3 inches. Frozen material should not be used, and fill should not be placed on a frozen subgrade. A sample of each material type should be submitted to the geotechnical engineer for evaluation.
2. Low plasticity cohesive soil or granular soil having a plasticity index (PI) of 20 or less and at least 15% fines.
3. On-site clay soils with a plasticity index of 20 or less can be used as Low Volume Change fill material.
4. Conforming to section 703.01 of the Oklahoma Department of Transportation (ODOT), Standard Specifications for Highway Construction.

4.2.3 Compaction Requirements

The scarified and compacted subgrade and fill (if required) should be moisture conditioned and compacted using the recommendations in the following table:

ITEM	DESCRIPTION
Subgrade Scarification Depth	8 inches
Fill Lift Thickness	8 inches or less in loose thickness
Compaction Requirements [1]	At least 95% of the material's maximum standard Proctor dry density (AASHTO T-99).
Moisture Content	Imported LVC Material and On-Site Lean Clay: A level within -2 to +2% of the material's optimum moisture content, determined in accordance with AASHTO T-99, the standard Proctor procedure. ODOT Type A Aggregate Base: Workable moisture content.[2]

1. We recommend that engineered fill (including scarified compacted subgrade) be tested for moisture content and compaction during placement. Should the results of the in-place density tests indicate the specified moisture or compaction limits have not been met, the area represented by the test should be reworked and retested as required until the specified moisture and compaction requirements are achieved.
2. Workable moisture content in the moisture level sufficient to achieve the required compaction without causing pumping when proofrolled.

The recommended moisture content should be maintained in the scarified and compacted subgrade and fills until fills are completed and pavements are constructed.

4.2.4 Construction Considerations for Earthwork

The near-surface lean clays and sandy silt are moisture sensitive and subject to disturbance and instability when wetted. Based on our experience, high moisture content and unstable soils are often found beneath pavements after demolition. If wet conditions occur during construction, the surficial soils will likely be unstable. Unstable soils should be removed and replaced with engineered fill unless they are chemically stabilized in-place.

Upon completion of filling and grading, care should be taken to maintain the subgrade moisture content prior to pavement construction. Construction traffic over the completed subgrade should be avoided to the extent practical. The site should also be graded to prevent ponding of surface water on the prepared subgrades or in excavations. If the subgrade should become frozen, desiccated, saturated, or disturbed, the affected material should be removed or these materials should be scarified, moisture conditioned, and recompacted prior to pavement construction. The geotechnical engineer should be retained during the construction phase of the project to provide observation and testing during subgrade preparation and earthwork.

The geotechnical engineer should be retained during the construction phase of the project to provide observation and testing during subgrade preparation and earthwork.

4.2.5 Water Line Trench Excavation Considerations

Based on the results of our borings, excavations for the planned water lines should generally encounter aggregate base, gravel, native clays and cemented to well-cemented weathered sandstone.

Excavation of the aggregate base, gravel, and native clays can be made using normal excavation equipment. Based on our experience, bedrock formations that can be penetrated by the flight augers used in our drilling operation can sometimes be excavated using heavy-duty track mounted excavation equipment fitted with rock excavation attachments. However, excavation of the well cemented weathered sandstone, represented by standard penetration blow counts (N values) of 50 blows for 3 inches or less penetration, will be more difficult and could require the use of special rock excavation techniques, such as blasting, pneumatic rock breakers, or other techniques.

4.3 Pavements

Based on information provided by Poe and Associates, we understand that a mill and replacement (overlay) repair sequence is planned for the project, whereas full-depth concrete with asphalt overlay or full depth asphalt construction will be implemented where the new water lines are to be installed.

The following paragraphs provide recommendations for asphalt overlay and full-depth asphalt and Portland cement concrete pavement sections.

4.3.1 Mill and Overlay Sections

We recommend that the full depth of asphalt over the Portland cement concrete (APC) pavement sections be removed and replaced with at least 3 inches of Type S4 asphaltic concrete.

The pavement section consists of only asphaltic concrete underlain by aggregate base at core locations B-4 and B-5. The thickness of the asphalt layer is 5¾ and 8 inches at B-4 and B-5, respectively. A mill and overlay procedure will not be feasible at these locations, as an asphalt layer thicker than that of the milled section will be required. Accordingly, we recommend full-depth reconstruction per section **4.3.3 Full-Depth Concrete with Asphalt Overlay Pavement Recommendations** be implemented where the existing pavement consists only of asphaltic concrete sections. Or if preferred a full-depth asphalt reconstruction can be implemented per section **4.3.2 Full-Depth Asphalt Recommendations.**

Because of the cracks in the existing pavements, there is the potential for reflection cracks to develop in an asphalt overlay. The rate and/or severity of the occurrence of reflection cracking can be reduced by properly sealing the wider cracks, and properly removing and replacing areas with moderate to high severity levels of distress. Also, a geotextile fabric should be used to retard the propagation of reflection cracks in the asphalt overlay.

For full-depth repair patches within the overlay areas, after milling the existing pavement and prior to placement of the overlay, all areas containing moderate or high severity cracking should be removed and patched full depth. After the distressed pavements have been removed, the underlying materials should be overexcavated to a depth of at least 12 inches to expose a firm subgrade surface. We recommend "T" patches, where the existing pavement is removed to a point 12 inches beyond the edge of the excavation. All patched areas should be square or rectangular in shape. Any soft or unstable soils encountered should be removed full depth and replaced with ODOT Type "A" aggregate base. The aggregate base should extend up to the bottom of the concrete pavement section. We recommend construction of the same type and thickness of pavement as at the location of the patch. Concrete patches should be doweled into the existing concrete section.

4.3.2 Full-Depth Asphalt Pavement Recommendations

To improve subgrade support, we recommend constructing a layer of aggregate base beneath the pavement.

Recommended minimum pavement sections are provided below. Our analysis is based on the 1993 AASHTO Guide for Design of Pavement Structures. Other pavement sections could be considered. The pavement sections are based on a 2017 Annual Average Daily Traffic (AADT) volume of 29,500 vehicles taken from publically available City of Tulsa traffic counts.

We used a 2 percent annual growth rate and 2 percent truck traffic. A directional distribution factor of 0.5 and a lane distribution factor of 0.8 have been used. For analysis purposes, the truck traffic was assumed to consist of full concrete trucks with a gross weight of 68,000 pounds or equivalent traffic loading. Our pavement analysis is based on a 20-year design life.

A subgrade resilient modulus value of 5,000 psi was used for the scarified and recompacted subgrade soils. Structural layer coefficients of 0.44 and 0.14 were used for asphaltic concrete and aggregate base material, respectively. Periodic maintenance should be expected to realize the anticipated design life.

Minimum Pavement Recommendations	
Asphalt Pavement Section	
Asphaltic Concrete over Aggregate Base over Compacted Subgrade	2.0” Type “S4” Asphaltic Concrete [1]
	5.0” Type “S3” Asphaltic Concrete [1]
	12.0” Aggregate Base [1]
	Geotextile Filter Fabric
	8.0” Compacted Subgrade

1. ODOT Type “A” aggregate base per section 703.01, ODOT Standard Specifications for Highway Construction.

4.3.3 Full-Depth Concrete with Asphalt Overlay Pavement Recommendations

We understand APC pavement sections will be reconstructed at locations where the water lines are to be installed where the existing pavement consists of APC pavement sections. A minimum recommended pavement section for full-depth APC pavement is presented in the following table.

Minimum Pavement Recommendations	
Asphalt over Concrete Pavement Section	
Portland Cement Concrete – Doweled Joints, Tied Curb (3,500 psi) Over Aggregate Base Over Compacted Subgrade	3.0” Type “S4” Asphaltic Concrete [1]
	Match surrounding Portland Cement Concrete
	12.0” Aggregate Base[1]
	8.0” Compacted Subgrade

1. ODOT Type “A” aggregate base per section 703.01, ODOT Standard Specifications for Highway Construction.

4.3.4 Pavement Drainage

Pavements should be sloped to provide rapid drainage of surface water. Water allowed to pond on or adjacent to the pavements could saturate the subgrade and contribute to premature pavement deterioration.

4.3.5 Pavement Maintenance

The pavement section provided in this report represent minimum recommended thickness and, as such, periodic maintenance should be anticipated. Preventive maintenance should be planned and provided for through an on-going pavement management program. Preventive maintenance activities are intended to slow the rate of pavement deterioration, and to preserve the pavement investment. Preventive maintenance consists of both localized maintenance (e.g. crack and joint sealing and patching) and global maintenance (e.g. surface sealing). Preventive maintenance is usually the first priority when implementing a planned pavement maintenance program and provides the highest return on investment for pavements. Prior to implementing any maintenance, additional engineering observation is recommended to determine the type and extent of preventive maintenance. Even with periodic maintenance, some movements and related cracking may still occur and repairs may be required.

5.0 GENERAL COMMENTS

Terracon should be retained to review the final design plans and specifications so comments can be made regarding interpretation and implementation of our geotechnical recommendations in the design and specifications. Terracon also should be retained to provide observation and testing services during grading, excavation, and other earth-related construction phases of the project.

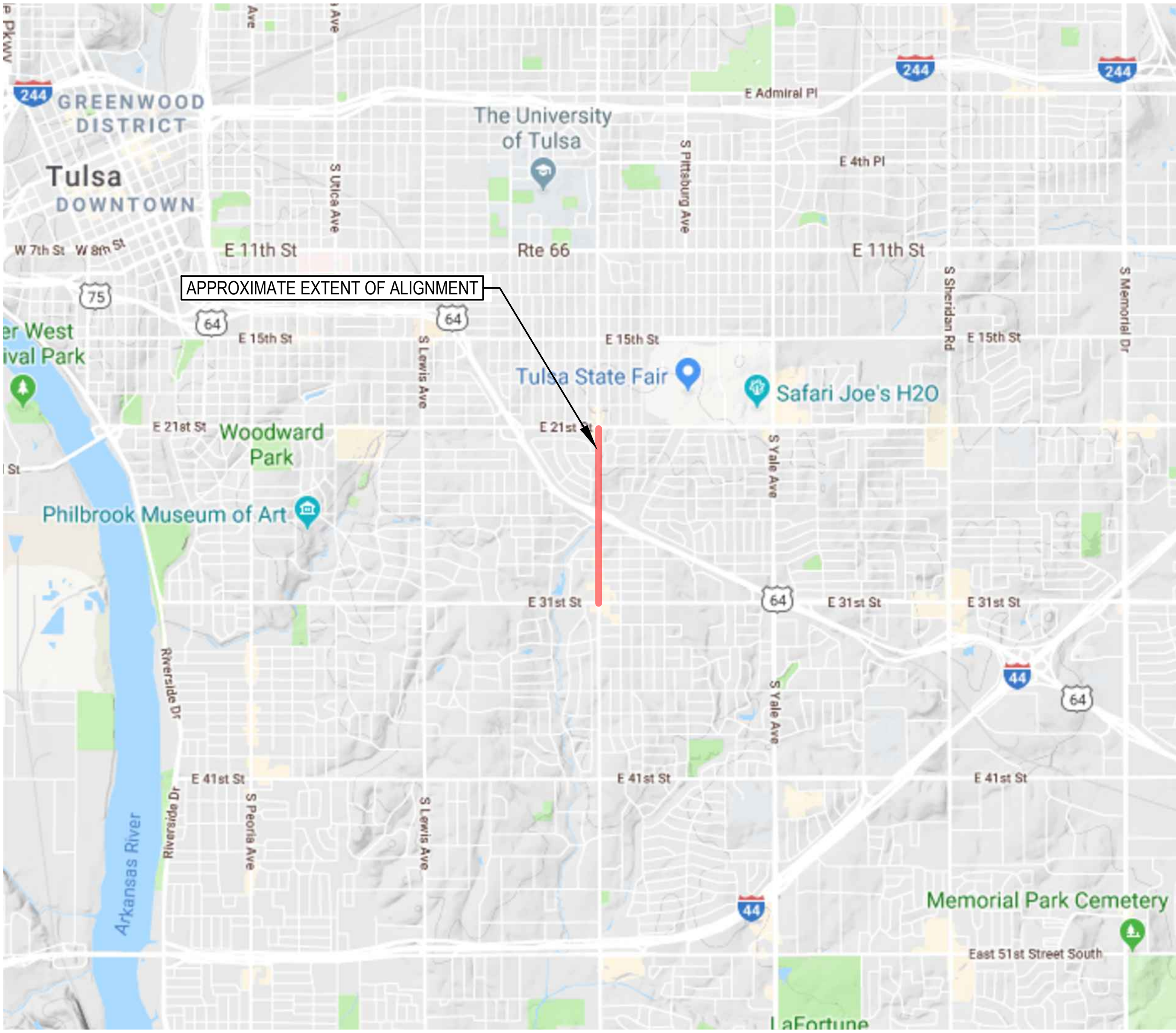
The analysis and recommendations presented in this report are based upon the data obtained from the borings and pavement cores performed at the indicated locations and from other information discussed in this report. This report does not reflect variations that may occur between borings, across the site, or due to the modifying effects of construction or weather. The nature and extent of such variations may not become evident until during or after construction. If variations appear, we should be immediately notified so that further evaluation and supplemental recommendations can be provided.

The scope of services for this project does not include either specifically or by implication any environmental assessment of the site or identification or prevention of pollutants, hazardous materials or conditions. If the owner is concerned about the potential for such contamination or pollution, other studies should be undertaken.

This report has been prepared for the exclusive use of our client for specific application to the project discussed and has been prepared in accordance with generally accepted geotechnical engineering practices. No warranties, either express or implied, are intended or made. Site safety, excavation support, and dewatering requirements are the responsibility of others. In the event that changes in the nature, design, or location of the project as outlined in this report are planned, the conclusions and recommendations contained in this report shall not be considered valid unless Terracon reviews the changes and either verifies or modifies the conclusions of this report in writing.

APPENDIX A

FIELD EXPLORATION



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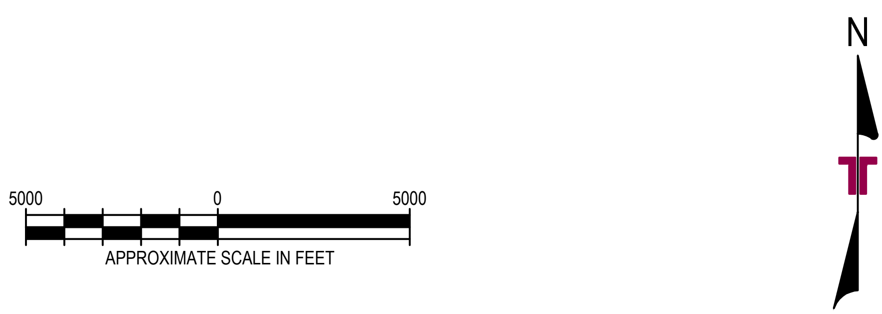

Project Mngr:	ANS
Drawn By:	MM
Checked By:	ANS
Approved By:	MHH

Project No.	04185089
Scale:	SEE BAR SCALE
File No.	04185089
Date:	JUNE 2018

Terracon
Consulting Engineers and Scientists
9522 EAST 47TH PLACE, UNIT D TULSA, OKLAHOMA 74145
PH. (918) 250-0461 FAX. (918) 250-4570

SITE LOCATION MAP
GEOTECHNICAL EXPLORATION
ARTERIAL STREET IMPROVEMENTS
HARVARD AVENUE FROM 21ST STREET TO 31ST STREET
TULSA, OKLAHOMA

EXHIBIT NO.
A-2

BORING	LANE DIRECTION
B-1	NORTHBOUND
B-2	SOUTHBOUND
B-3	NORTHBOUND
B-4	SOUTHBOUND

100 0 100

APPROXIMATE SCALE IN FEET

LEGEND

◐ PAVEMENT CORE LOCATION

DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

Project Mngr:	ANS	Project No.	04185089
Drawn By:	MM	Scale:	SEE BAR SCALE
Checked By:	ANS	File No.	04185089
Approved By:	MHH	Date:	JUNE 2018

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PAVEMENT CORE LOCATION PLAN

GEOTECHNICAL EXPLORATION

ARTERIAL STREET IMPROVEMENTS

HARVARD AVENUE FROM 21ST STREET TO 31ST STREET

TULSA, OKLAHOMA

PAGE 1 OF 2

EXHIBIT NO.

A-3

BORING	LANE DIRECTION
B-5	NORTHBOUND
B-6	SOUTHBOUND
B-7	NORTHBOUND
B-8	SOUTHBOUND

100 0 100

APPROXIMATE SCALE IN FEET

LEGEND

PAVEMENT CORE LOCATION

DIAGRAM IS FOR GENERAL LOCATION ONLY,
AND IS NOT INTENDED FOR CONSTRUCTION PURPOSES

Project Mngr:	ANS	Project No.	04185089
Drawn By:	MM	Scale:	SEE BAR SCALE
Checked By:	ANS	File No.	04185089
Approved By:	MHH	Date:	JUNE 2018

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PAVEMENT CORE LOCATION PLAN

GEOTECHNICAL EXPLORATION
ARTERIAL STREET IMPROVEMENTS
HARVARD AVENUE FROM 21ST STREET TO 31ST STREET
TULSA, OKLAHOMA

EXHIBIT NO.
A-3

Field Exploration Description

The boring locations were established in the field by Terracon personnel by taping from existing reference features and by the aid of a hand held GPS unit. The boring locations should be considered accurate only to the degree implied by the methods used to define them.

We used a core machine with a diamond-bit core barrel to core the pavement at the boring locations. The borings were drilled after coring through the pavement with an ATV rotary drill rig using continuous flight solid-stem augers to advance the boreholes. Representative samples were obtained by the split-barrel sampling procedure. The split-barrel sampling procedure uses a standard 2-inch, O.D. split-barrel sampling spoon that is driven into the bottom of the boring with a 140-pound drive hammer falling 30 inches. The number of blows required to advance the sampling spoon the last 12 inches, or less, of an 18-inch sampling interval or portion thereof, is recorded as the standard penetration resistance value, N. The N value is used to estimate the in-situ relative density of granular soils and, to a lesser degree of accuracy, the consistency of cohesive soils and the hardness of weathered bedrock. The samples were tagged for identification, sealed to reduce moisture loss and returned to the laboratory for further examination, testing and classification.

An automatic SPT hammer was used to advance the split-barrel sampler in the borings performed on this site. Generally, a greater efficiency is achieved with the automatic hammer compared to the conventional safety hammer operated with a cathead and rope. The effect of the automatic hammer's efficiency has been considered in the interpretation and analysis of the subsurface information for this report.

A field log of each boring was prepared by the drill crew. These logs included visual classifications of the materials encountered during drilling as well as the driller’s interpretation of the subsurface conditions between samples. Final pavement core logs included with this report represent the engineer's interpretation of the field logs and include modifications based on laboratory observation and tests of the samples.

TOP

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CORE LOG

CORE NUMBER	B-1
DATE CORED	5/1/2018
LANE DIRECTION	Northbound
LOCATION	South Harvard Avenue

CORE LAYER DATA (FROM TOP TO BOTTOM):

Sample No	Layer Type	Layer Thickness (in.)	Layer Characteristics*
1	Asphaltic Concrete - Type B	2 3/4	Separation at 2 3/4 inches
	Portland Cement Concrete	9 1/4	

CORE DATA

Surface Material Type: ☑ A.C. ☐ P.C.C. ☐ Continuously Reinforced Concrete

Stripping or Separation in Asphalt: ☐ Stripping ☑ Separation ☐ N/A

Honeycomb or "D" Cracking in PCC: ☐ Honeycomb ☐ "D" Cracking ☑ N/A

Stabilized Subgrade Beneath Pavement or Sub-base? ☐ Yes ☑ No ☐ Unknown

Sample No		Thickness	LL/PL/PI	> #200 (%)	MC (%)	SPT-N (blows/ft)
	Total Core Thickness	**12**				
2	Lean clay with sand (CL/(A-6(8)), brown, dark brown & reddish brown, very stiff	24	29-17-12	82	19	28
3	Weathered sandstone, brown to gray brown, poorly cemented	18			14	50/4"
4	Same as above	3			11	50/3"
	Total Thickness / Depth	**57**				

*** Asphalt type based on visual observation only**

TOP

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CORE LOG

CORE NUMBER	B-2
DATE CORED	5/1/2018
LANE DIRECTION	Southbound
LOCATION	South Harvard Avenue

CORE LAYER DATA (FROM TOP TO BOTTOM):

Sample No	Layer Type	Layer Thickness (in.)	Layer Characteristics*			
1	Asphaltic Concrete - Type B	3 1/2				
	Portland Cement Concrete	8 3/4				
	Total Core Thickness	**12 1/4**				
			LL/PL/PI	> #200 (%)	MC (%)	SPT-N (blows/ft)
2	Lean clay with sand (CL/A-6(10)), dark brown to dark gray, and gray brown, medium stiff to stiff	23 3/4	30-16-14	85	19	6
3	Same as above	18			22	6
4	Same as above	18			22	11
	Total Thickness / Depth	**72**				

*** Asphalt type based on visual observation only**

CORE DATA

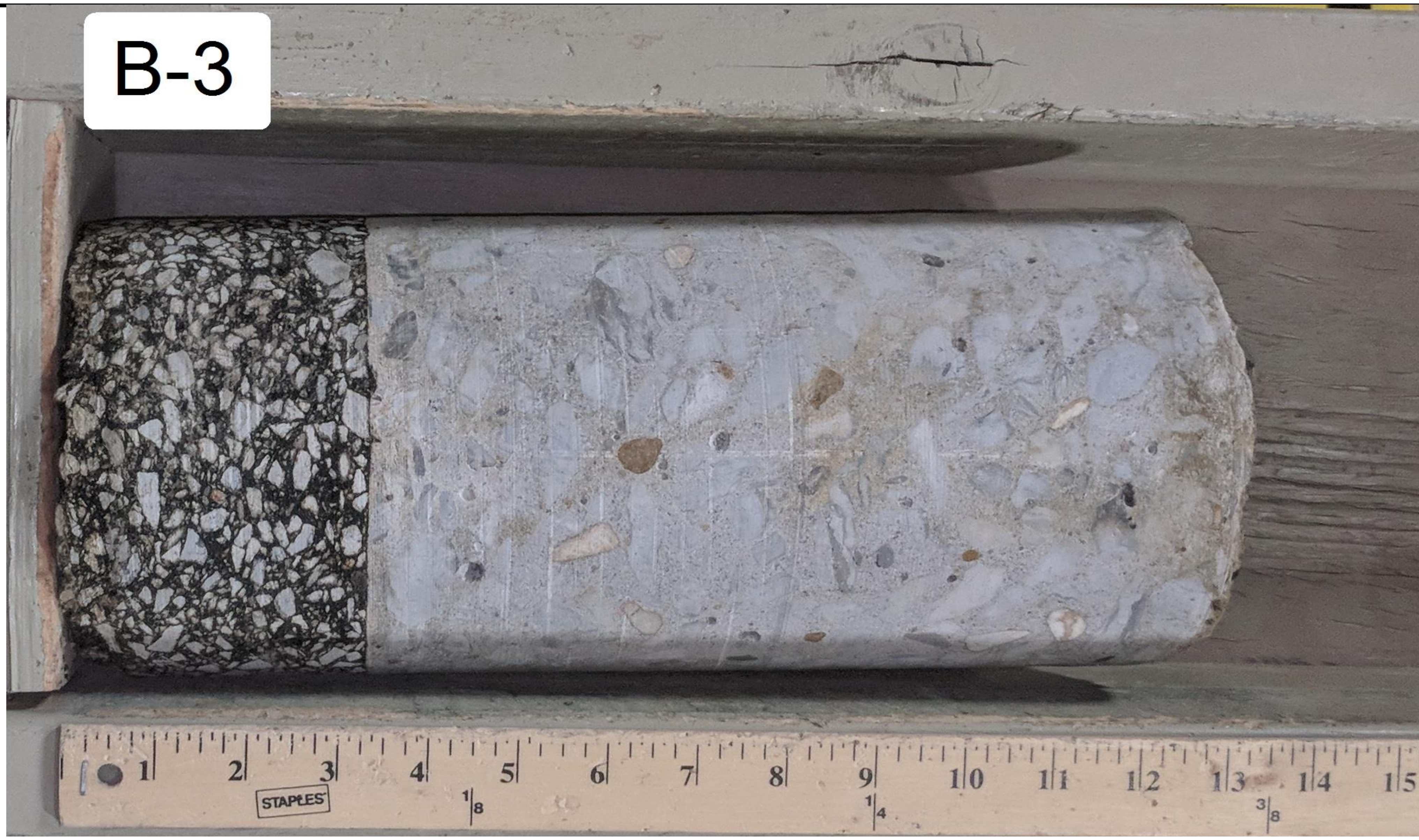
Surface Material Type: ☑ A.C. ☐ P.C.C. ☐ Continuously Reinforced Concrete

Stripping or Separation in Asphalt: ☐ Stripping ☐ Separation ☑ N/A

Honeycomb or "D" Cracking in PCC: ☐ Honeycomb ☐ "D" Cracking ☑ N/A

Stabilized Subgrade Beneath Pavement or Sub-base? ☐ Yes ☑ No ☐ Unknown

TOP



Terracon **CORE LOG**

CORE NUMBER	B-3
DATE CORED	5/1/2018
LANE DIRECTION	Northbound
LOCATION	South Harvard Avenue

CORE LAYER DATA (FROM TOP TO BOTTOM):

Sample No	Layer Type	Layer Thickness (in.)	Layer Characteristics*			
1	Asphaltic Concrete - Type B	3 1/4				
	Portland Cement Concrete	10				
	Total Core Thickness	**13 1/4**				
			LL/PL/PI	> #200 (%)	MC (%)	SPT-N (blows/ft)
2	Sandy lean clay (CL/(A-6(3)), with sandstone seams, dark brown, brown, trace reddish brown, medium stiff	22 3/4	27-16-11	53	20	8
3	Sandy lean clay (CL), with sandstone seams, brown, greenish gray, reddish brown, hard	18			14	46
4	Weathered sandstone, light brown, well-cemented	10			15	34-50/4"
	Total Thickness / Depth	**64**				

CORE DATA

Surface Material Type: ☑ A.C. ☐ P.C.C. ☐ Continuously Reinforced Concrete

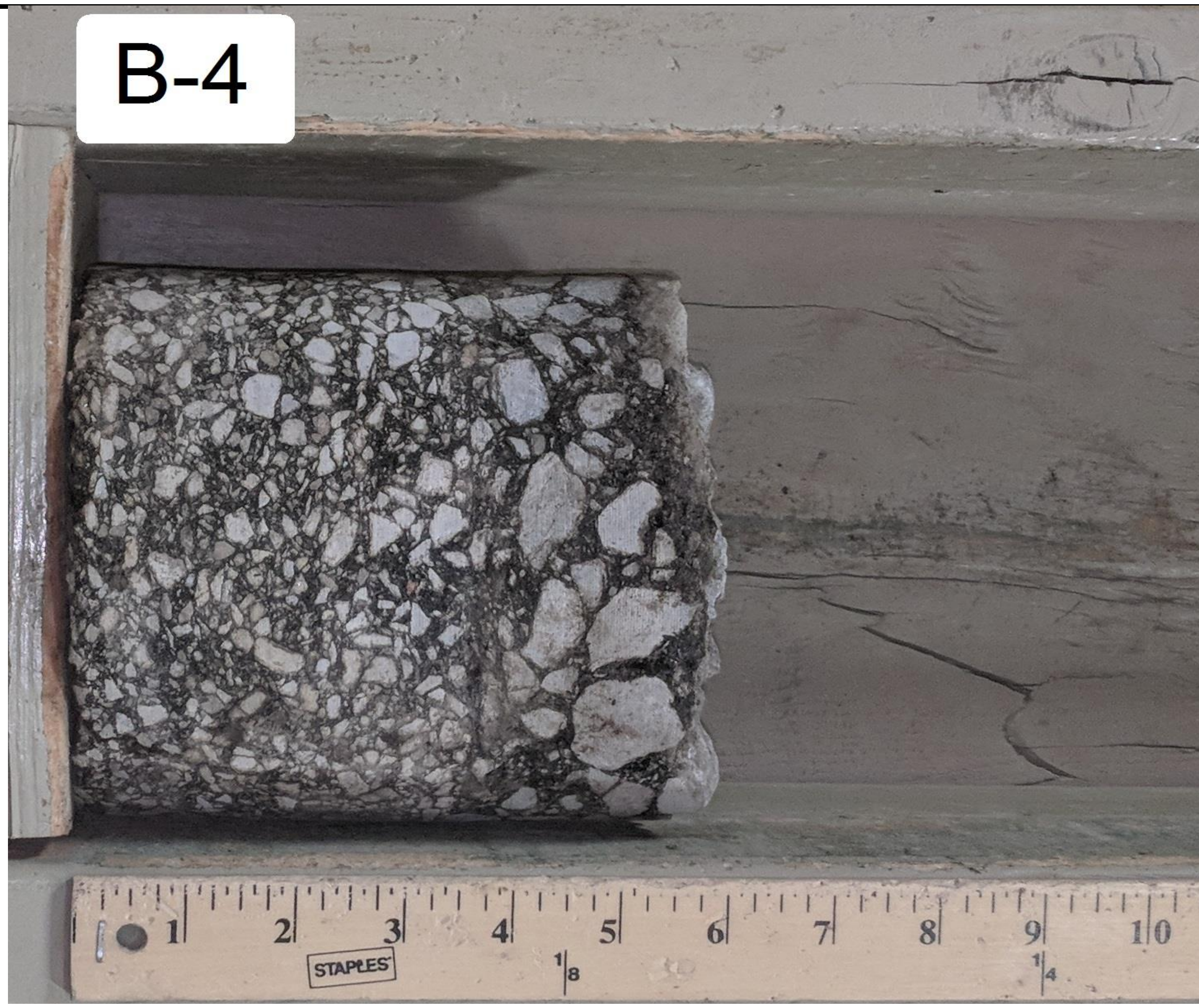
Stripping or Separation in Asphalt: ☐ Stripping ☐ Separation ☑ N/A

Honeycomb or "D" Cracking in PCC: ☐ Honeycomb ☐ "D" Cracking ☑ N/A

Stabilized Subgrade Beneath Pavement or Sub-base? ☐ Yes ☑ No ☐ Unknown

*** Asphalt type based on visual observation only**

TOP



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CORE LOG

CORE NUMBER	B-4
DATE CORED	5/1/2018
LANE DIRECTION	Southbound
LOCATION	South Harvard Avenue

CORE DATA

Surface Material Type: ☑ A.C. ☐ P.C.C. ☐ Continuously Reinforced Concrete

Stripping or Separation in Asphalt: ☐ Stripping ☐ Separation ☑ N/A

Honeycomb or "D" Cracking in PCC: ☐ Honeycomb ☐ "D" Cracking ☑ N/A

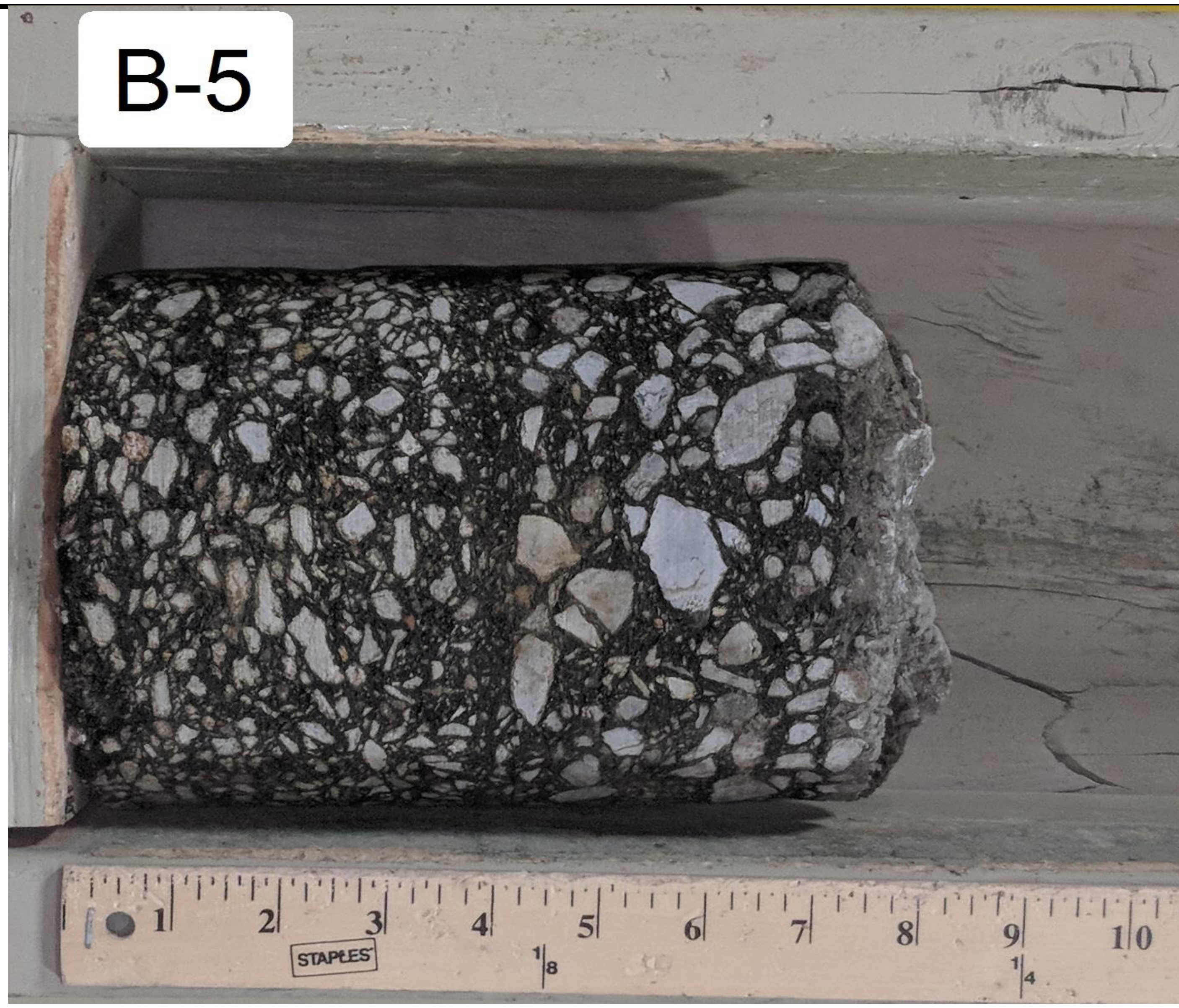
Stabilized Subgrade Beneath Pavement or Sub-base? ☐ Yes ☑ No ☐ Unknown

CORE LAYER DATA (FROM TOP TO BOTTOM):

Sample No	Layer Type	Layer Thickness (in.)	Layer Characteristics*			
1	Asphaltic Concrete - Type B	3 3/4				
	Asphaltic Concrete - Type A	2				
	Total Core Thickness	**5 3/4**				
			LL/PL/PI	> #200 (%)	MC (%)	SPT-N (blows/ft)
2	Aggregate Base Course	7 1/2				
3	Sandy lean clay (CL/(A-4(2)), with sandstone seams, dark brown and reddish brown, stiff	22 3/4	22-14-8	58	24	9
4	Lean clay (CL), with gravel, olive brown and gray, medium stiff	18			12	8
5	Sandy lean clay (CL), with sandstone seams, brown to light brown and gray, hard	18			16	50
	Total Thickness / Depth	**72**				

*** Asphalt type based on visual observation only**

TOP



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CORE LOG

CORE NUMBER	B-5
DATE CORED	5/1/2018
LANE DIRECTION	Northbound
LOCATION	South Harvard Avenue

CORE DATA

Surface Material Type: ☑ A.C. ☐ P.C.C. ☐ Continuously Reinforced Concrete

Stripping or Separation in Asphalt: ☐ Stripping ☐ Separation ☑ N/A

Honeycomb or "D" Cracking in PCC: ☐ Honeycomb ☐ "D" Cracking ☑ N/A

Stabilized Subgrade Beneath Pavement or Sub-base? ☐ Yes ☑ No ☐ Unknown

CORE LAYER DATA (FROM TOP TO BOTTOM):

Sample No	Layer Type	Layer Thickness (in.)	Layer Characteristics*
1	Asphaltic Concrete -Type B	4	
	Asphaltic Concrete - Type A	3 1/4	
	Asphaltic Concrete - Type C	3/4	
	Total Core Thickness	**8**	

Sample No	Layer Type	Layer Thickness (in.)	LL/PL/PI	> #200 (%)	MC (%)	SPT-N (blows/ft)
2	Aggregate Base Course	4 1/2				
3	Sandy lean clay (CL/(A-6(5)), with sandstone seams, olive brown and maroon, very stiff	23 1/2	24-11-13	67	12	16
4	Lean clay (CL), with sand, shaley, olive brown to gray brown, very stiff to hard	18			21	29
5	Same as above	18			20	52
	Total Thickness / Depth	**72**				

*** Asphalt type based on visual observation only**

TOP

Terracon

CORE LOG

CORE NUMBER B-6
DATE CORED 5/1/2018

LANE DIRECTION Southbound
LOCATION South Harvard Avenue

CORE LAYER DATA (FROM TOP TO BOTTOM):

Sample No	Layer Type	Layer Thickness (in.)	Layer Characteristics*			
1	Asphaltic Concrete - Type B	3				
	Portland Cement Concrete	7				
	Total Core Thickness	**10**				
			LL/PL/PI	> #200 (%)	MC (%)	SPT-N (blows/ft)
2	Sandy silt (ML/(A-4(0)), brown to light brown, dense	6	NP	63	20	4-42-50/2"
3	Weathered sandstone, brown to light brown cemented to well-cemented	42			12	50/2"
4	Same as above	2			10	50/2"
	Total Thickness / Depth	**60**				

*** Asphalt type based on visual observation only**

CORE DATA

Surface Material Type: ☑ A.C. ☐ P.C.C. ☐ Continuously Reinforced Concrete

Stripping or Separation in Asphalt: ☐ Stripping ☐ Separation ☑ N/A

Honeycomb or "D" Cracking in PCC: ☐ Honeycomb ☐ "D" Cracking ☑ N/A

Stabilized Subgrade Beneath Pavement or Sub-base? ☐ Yes ☑ No ☐ Unknown

TOP

Terracon **CORE LOG**

CORE NUMBER	B-7
DATE CORED	5/1/2018
LANE DIRECTION	Northbound
LOCATION	South Harvard Avenue

CORE LAYER DATA (FROM TOP TO BOTTOM):

Sample No	Layer Type	Layer Thickness (in.)	Layer Characteristics*
1	Asphaltic Concrete - Type B	4 1/4	
	Asphaltic Concrete - Type B	1 1/2	Separation at 5 3/4 inches
	Portland Cement Concrete	8	
	Total Core Thickness	**13 3/4**	

Sample No	Layer Type	Layer Thickness (in.)	LL/PL/PI	> #200 (%)	MC (%)	SPT-N (blows/ft)
2	Aggregate Base Course	1 1/2				
3	Sandy silt (ML/(A-4(0)), brown to gray brown, trace reddish brown, very dense	18	NP	62	15	41-50/6"
4	Weathered sandstone, brown to gray brown, cemented to well cemented	24 3/4			17	50/4"
5	Same as above	2			13	50/2"
	Total Thickness / Depth	**60**				

CORE DATA

Surface Material Type: ☑ A.C. ☐ P.C.C. ☐ Continuously Reinforced Concrete

Stripping or Separation in Asphalt: ☐ Stripping ☑ Separation ☐ N/A

Honeycomb or "D" Cracking in PCC: ☐ Honeycomb ☐ "D" Cracking ☑ N/A

Stabilized Subgrade Beneath Pavement or Sub-base? ☐ Yes ☑ No ☐ Unknown

*** Asphalt type based on visual observation only**

TOP

CORE LOG

CORE NUMBER B-8
DATE CORED 5/1/2018

LANE DIRECTION Southbound
LOCATION South Harvard Avenue

CORE LAYER DATA (FROM TOP TO BOTTOM):

Sample No	Layer Type	Layer Thickness (in.)	Layer Characteristics*
1	Asphaltic Concrete - Type B	2 1/4	
	Asphaltic Concrete - Type B	1 3/4	Separation at 4 inches
	Portland Cement Concrete	8 1/2	
	Total Core Thickness	**12 1/2**	

			LL/PL/PI	> #200 (%)	MC (%)	SPT-N (blows/ft)
2	Aggregate Base Course	2				
3	Fill: Silty gravel with sand (GM/A-4(0)), brown	21 1/2	NP	42	15	10
4	Same as above	18			14	7
5	Silty clay (CL-ML), dark brown, soft	18			23	4
	Total Thickness / Depth	**72**				

*** Asphalt type based on visual observation only**

CORE DATA

Surface Material Type: ☑ A.C. ☐ P.C.C. ☐ Continuously Reinforced Concrete

Stripping or Separation in Asphalt: ☐ Stripping ☑ Separation ☐ N/A

Honeycomb or "D" Cracking in PCC: ☐ Honeycomb ☐ "D" Cracking ☑ N/A

Stabilized Subgrade Beneath Pavement or Sub-base? ☐ Yes ☑ No ☐ Unknown

APPENDIX B

LABORATORY TESTING

Laboratory Testing

Samples retrieved during the field exploration were taken to the laboratory for further observation by the project geotechnical engineer and were classified in accordance with the Unified Soil Classification System (USCS) and American Association of State Highway and Transportation Officials (AASHTO) classification systems described in Appendix C. Bedrock materials were classified according to the General Notes and described using commonly accepted geotechnical terminology. After the testing was completed, the field descriptions were confirmed or modified as necessary.

Laboratory tests were conducted on selected soil samples. The laboratory test results are presented on the pavement core logs next to the respective samples. Laboratory tests were performed in general accordance with the applicable ASTM, local or other accepted standards.

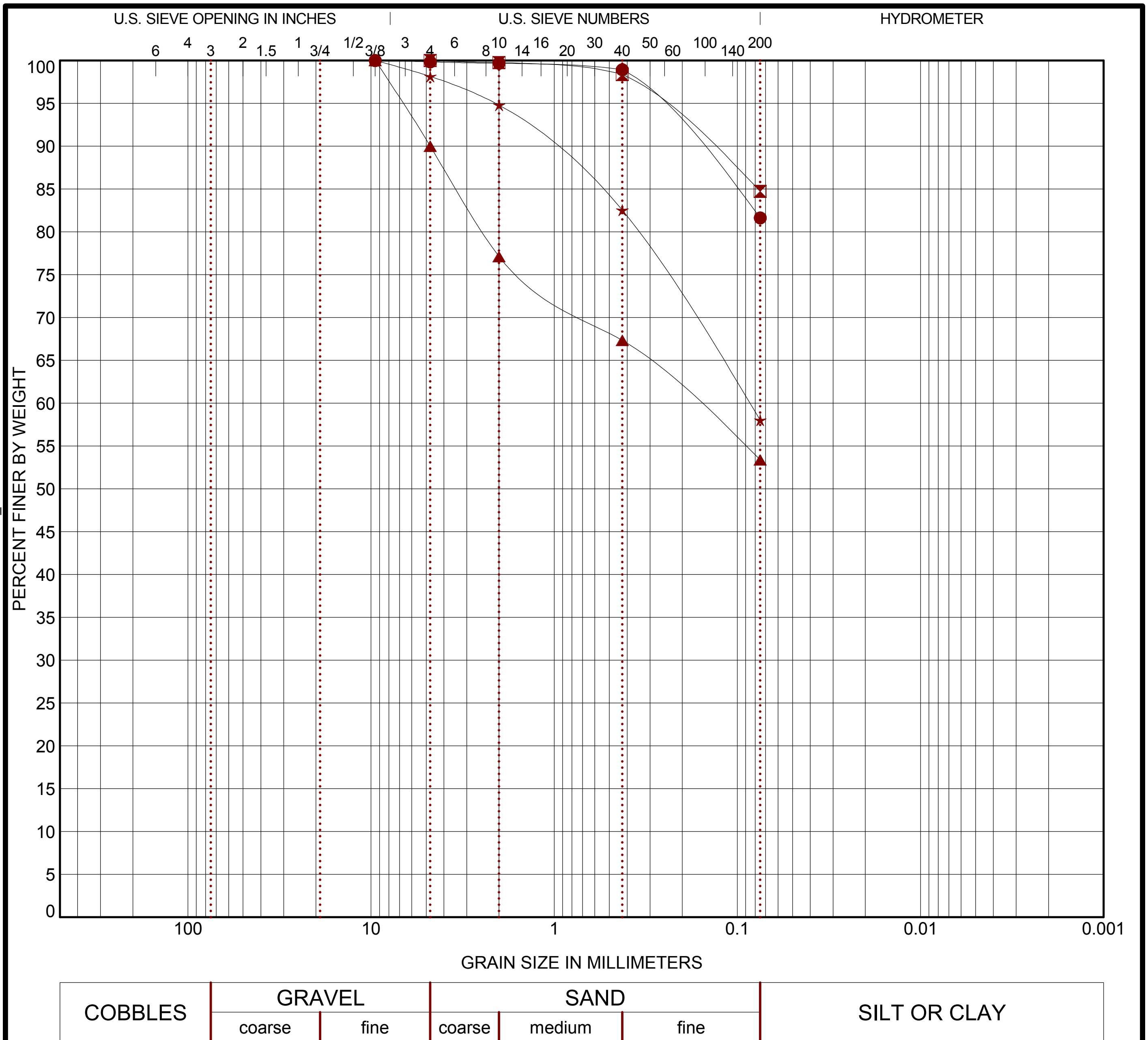
Selected soil samples obtained from the site were tested for the following engineering properties:

- Water content (ASTM D2216)
- Atterberg limits (AASHTO T 90)
- Sieve analysis (AASHTO T 88)

Procedural standards noted above are for reference to methodology in general. In some cases variations to methods are applied as a result of local practice or professional judgment.

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



	Boring ID	Depth	USCS Classification	AASHTO Classification	WC (%)	LL	PL	PI	Cc	Cu
●	B-1	1.1 - 2.6	LEAN CLAY with SAND (CL)	A-6 (8)	19	29	17	12		
⧗	B-2	1.1 - 2.6	LEAN CLAY with SAND (CL)	A-6 (10)	19	30	16	14		
▲	B-3	1.1 - 2.6	SANDY LEAN CLAY (CL)	A-6 (3)	20	27	16	11		
★	B-4	1.1 - 2.6	SANDY LEAN CLAY (CL)	A-4 (2)	24	22	14	8		

	Boring ID	Depth	D_{100}	D_{60}	D_{30}	D_{10}	%Gravel	%Sand	%Silt	%Fines	%Clay
●	B-1	1.1 - 2.6	9.5				0.2	18.2		81.6	
⧗	B-2	1.1 - 2.6	4.75				0.0	15.3		84.7	
▲	B-3	1.1 - 2.6	9.5	0.171			10.0	36.6		53.4	
★	B-4	1.1 - 2.6	9.5	0.086			1.9	40.1		58.0	

PROJECT: Harvard Avenue from 21st Street to 31st Street

SITE: 21st Street to 31st Street
Tulsa, Oklahoma

Terracon
9522 E 47th Pl Ste D
Tulsa, OK

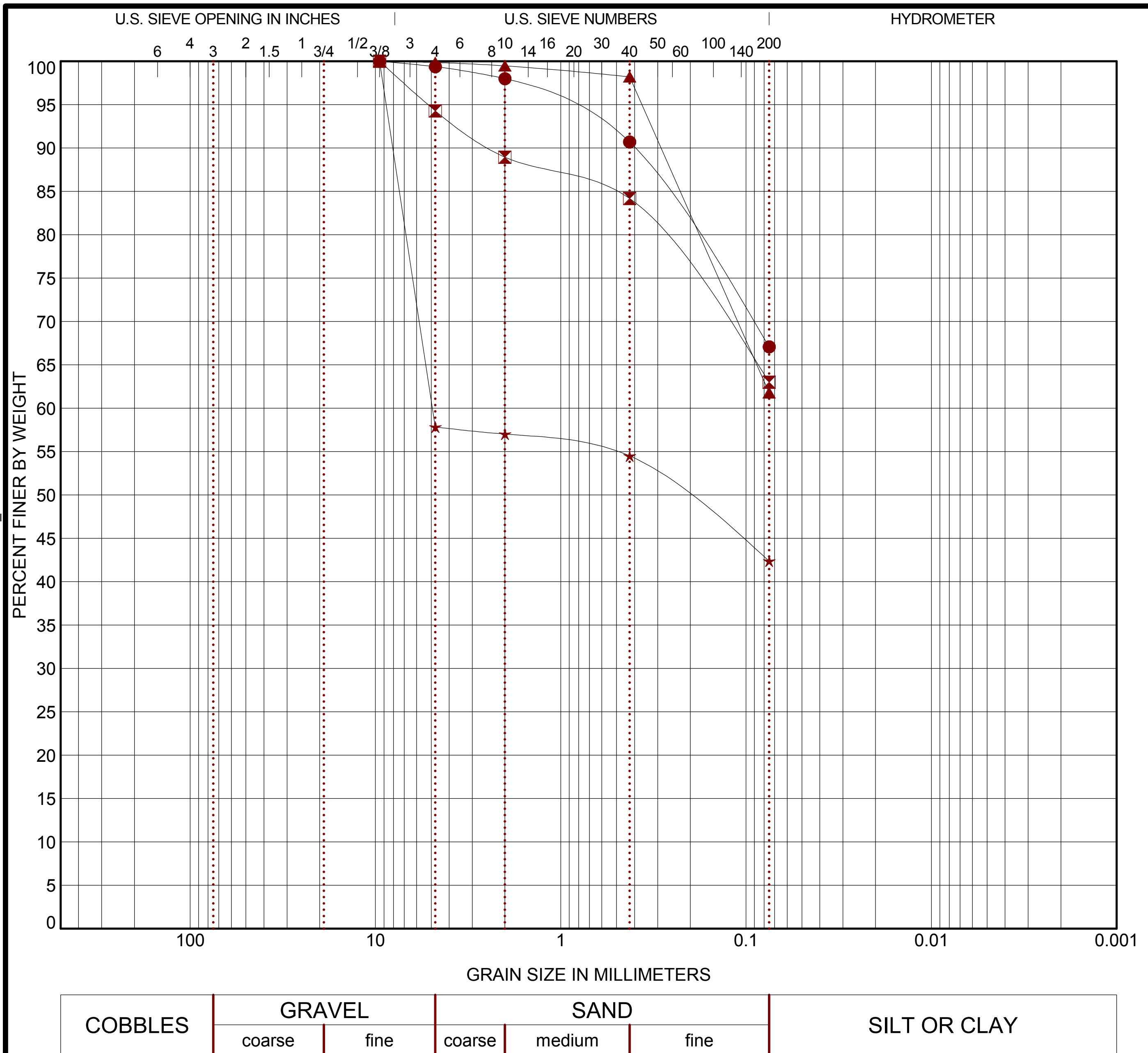
PROJECT NUMBER: 04185089

CLIENT: Poe & Associates, Inc
Tulsa, Oklahoma

EXHIBIT: B-2

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



	Boring ID	Depth	USCS Classification	AASHTO Classification	WC (%)	LL	PL	PI	Cc	Cu
●	B-5	1.1 - 2.6	SANDY LEAN CLAY (CL)	A-6 (5)	12	24	11	13		
⊠	B-6	1 - 2.2	SANDY SILT (ML)	A-4 (0)	20	NP	NP	NP		
▲	B-7	1.3 - 2.8	SANDY SILT (ML)	A-4 (0)	15	NP	NP	NP		
★	B-8	1.3 - 2.8	SILTY GRAVEL with SAND (GM)	A-4 (0)	15	NP	NP	NP		

	Boring ID	Depth	D_{100}	D_{60}	D_{30}	D_{10}	%Gravel	%Sand	%Silt	%Fines	%Clay
●	B-5	1.1 - 2.6	9.5				0.6	32.3		67.1	
⊠	B-6	1 - 2.2	9.5				5.7	31.3		63.0	
▲	B-7	1.3 - 2.8	9.5				0.1	38.1		61.8	
★	B-8	1.3 - 2.8	9.5	4.922			42.2	15.5		42.4	

PROJECT: Harvard Avenue from 21st Street to 31st Street

SITE: 21st Street to 31st Street
Tulsa, Oklahoma

Terracon
9522 E 47th Pl Ste D
Tulsa, OK

PROJECT NUMBER: 04185089

CLIENT: Poe & Associates, Inc
Tulsa, Oklahoma

EXHIBIT: B-3

APPENDIX C

SUPPORTING DOCUMENTS

GENERAL NOTES

DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

SAMPLING		
	Auger	Split Spoon
	Shelby Tube	Macro Core
	Ring Sampler	Rock Core
	Grab Sample	No Recovery

WATER LEVEL

- Water Initially Encountered
- Water Level After a Specified Period of Time
- Water Level After a Specified Period of Time

Water levels indicated on the soil boring logs are the levels measured in the borehole at the times indicated. Groundwater level variations will occur over time. In low permeability soils, accurate determination of groundwater levels is not possible with short term water level observations.

FIELD TESTS

(HP)	Hand Penetrometer
(T)	Torvane
(b/f)	Standard Penetration Test (blows per foot)
(PID)	Photo-Ionization Detector
(OVA)	Organic Vapor Analyzer

DESCRIPTIVE SOIL CLASSIFICATION

Soil classification is based on the Unified Soil Classification System. Coarse Grained Soils have more than 50% of their dry weight retained on a #200 sieve; their principal descriptors are: boulders, cobbles, gravel or sand. Fine Grained Soils have less than 50% of their dry weight retained on a #200 sieve; they are principally described as clays if they are plastic, and silts if they are slightly plastic or non-plastic. Major constituents may be added as modifiers and minor constituents may be added according to the relative proportions based on grain size. In addition to gradation, coarse-grained soils are defined on the basis of their in-place relative density and fine-grained soils on the basis of their consistency.

LOCATION AND ELEVATION NOTES

Unless otherwise noted, Latitude and Longitude are approximately determined using a hand-held GPS device. The accuracy of such devices is variable. Surface elevation data annotated with +/- indicates that no actual topographical survey was conducted to confirm the surface elevation. Instead, the surface elevation was approximately determined from topographic maps of the area.

STRENGTH TERMS

RELATIVE DENSITY OF COARSE-GRAINED SOILS (More than 50% retained on No. 200 sieve.) Density determined by Standard Penetration Resistance Includes gravels, sands and silts.			**CONSISTENCY OF FINE-GRAINED SOILS** (50% or more passing the No. 200 sieve.) Consistency determined by laboratory shear strength testing, field visual-manual procedures or standard penetration resistance			
Descriptive Term (Density)	**Standard Penetration or N-Value Blows/Ft.**	**Ring Sampler Blows/Ft.**	**Descriptive Term (Consistency)**	**Unconfined Compressive Strength, Qu, psf**	**Standard Penetration or N-Value Blows/Ft.**	**Ring Sampler Blows/Ft.**
Very Loose	0 - 3	0 - 6	Very Soft	less than 500	0 - 1	< 3
Loose	4 - 9	7 - 18	Soft	500 to 1,000	2 - 4	3 - 4
Medium Dense	10 - 29	19 - 58	Medium-Stiff	1,000 to 2,000	4 - 8	5 - 9
Dense	30 - 50	59 - 98	Stiff	2,000 to 4,000	8 - 15	10 - 18
Very Dense	> 50	$\geq$ 99	Very Stiff	4,000 to 8,000	15 - 30	19 - 42
			Hard	> 8,000	> 30	> 42

RELATIVE PROPORTIONS OF SAND AND GRAVEL

Descriptive Term(s) of other constituents	Percent of Dry Weight
Trace	< 15
With	15 - 29
Modifier	> 30

GRAIN SIZE TERMINOLOGY

Major Component of Sample	Particle Size
Boulders	Over 12 in. (300 mm)
Cobbles	12 in. to 3 in. (300mm to 75mm)
Gravel	3 in. to #4 sieve (75mm to 4.75 mm)
Sand	#4 to #200 sieve (4.75mm to 0.075mm
Silt or Clay	Passing #200 sieve (0.075mm)

RELATIVE PROPORTIONS OF FINES

Descriptive Term(s) of other constituents	Percent of Dry Weight
Trace	< 5
With	5 - 12
Modifier	> 12

PLASTICITY DESCRIPTION

Term	Plasticity Index
Non-plastic	0
Low	1 - 10
Medium	11 - 30
High	> 30

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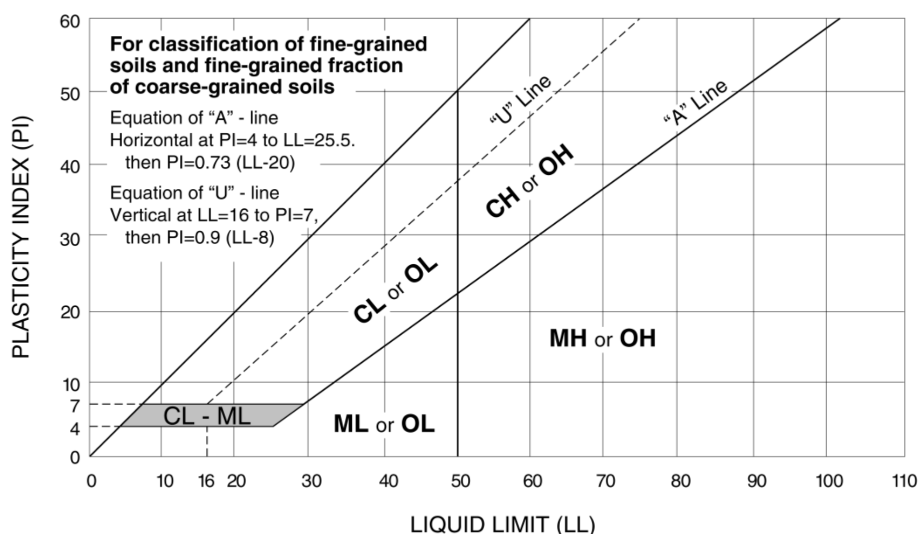
UNIFIED SOIL CLASSIFICATION SYSTEM

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests [A]				Soil Classification	
				Group Symbol	Group Name [B]
Coarse Grained Soils: More than 50% retained on No. 200 sieve	**Gravels:** More than 50% of coarse fraction retained on No. 4 sieve	**Clean Gravels:** Less than 5% fines [C]	$Cu \geq 4$ and $1 \leq Cc \leq 3$ [E]	GW	Well-graded gravel [F]
			$Cu < 4$ and/or $1 > Cc > 3$ [E]	GP	Poorly graded gravel [F]
		Gravels with Fines: More than 12% fines [C]	Fines classify as ML or MH	GM	Silty gravel [F,G, H]
			Fines classify as CL or CH	GC	Clayey gravel [F,G,H]
	Sands: 50% or more of coarse fraction passes No. 4 sieve	**Clean Sands:** Less than 5% fines [D]	$Cu \geq 6$ and $1 \leq Cc \leq 3$ [E]	SW	Well-graded sand [I]
			$Cu < 6$ and/or $1 > Cc > 3$ [E]	SP	Poorly graded sand [I]
		Sands with Fines: More than 12% fines [D]	Fines classify as ML or MH	SM	Silty sand [G,H,I]
			Fines Classify as CL or CH	SC	Clayey sand [G,H,I]
Fine-Grained Soils: 50% or more passes the No. 200 sieve	**Silts and Clays:** Liquid limit less than 50	**Inorganic:**	$PI > 7$ and plots on or above "A" line [J]	CL	Lean clay [K,L,M]
			$PI < 4$ or plots below "A" line [J]	ML	Silt [K,L,M]
		Organic:	Liquid limit - oven dried / Liquid limit - not dried < 0.75	OL	Organic clay [K,L,M,N]
					Organic silt [K,L,M,O]
	Silts and Clays: Liquid limit 50 or more	**Inorganic:**	PI plots on or above "A" line	CH	Fat clay [K,L,M]
			PI plots below "A" line	MH	Elastic Silt [K,L,M]
		Organic:	Liquid limit - oven dried / Liquid limit - not dried < 0.75	OH	Organic clay [K,L,M,P]
					Organic silt [K,L,M,Q]
Highly organic soils:	Primarily organic matter, dark in color, and organic odor			PT	Peat

[A] Based on the material passing the 3-in. (75-mm) sieve
[B] If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.
[C] Gravels with 5 to 12% fines require dual symbols: GW-GM well-graded gravel with silt, GW-GC well-graded gravel with clay, GP-GM poorly graded gravel with silt, GP-GC poorly graded gravel with clay.
[D] Sands with 5 to 12% fines require dual symbols: SW-SM well-graded sand with silt, SW-SC well-graded sand with clay, SP-SM poorly graded sand with silt, SP-SC poorly graded sand with clay
[E] $Cu = D_{60}/D_{10} \quad Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$
[F] If soil contains $\geq$ 15% sand, add "with sand" to group name.
[G] If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.
[H] If fines are organic, add "with organic fines" to group name.
[I] If soil contains $\geq$ 15% gravel, add "with gravel" to group name.
[J] If Atterberg limits plot in shaded area, soil is a CL-ML, silty clay.
[K] If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel," whichever is predominant.
[L] If soil contains $\geq$ 30% plus No. 200 predominantly sand, add "sandy" to group name.
[M] If soil contains $\geq$ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.
[N] $PI \geq 4$ and plots on or above "A" line.
[O] $PI < 4$ or plots below "A" line.
[P] PI plots on or above "A" line.
[Q] PI plots below "A" line.



AASHTO SOIL CLASSIFICATION SYSTEM

GENERAL CLASSIFICATION	GRANULAR MATERIALS (35% OR LESS PASSING 0.075 SIEVE)							SILT-CLAY MATERIALS (MORE THAN 35% PASSING 0.075 SIEVE)			
GROUP CLASSIFICATION	A–1		A–3	A–2				A–4	A–5	A–6	A–7–5 A–7–6
	A–1–a	A–1–b		A-2-4	A-2-5	A-2-6	A-2-7				
SIEVE ANALYSIS, PERCENT PASSING: 2.00 mm (No. 10) 0.425 mm (No. 40) 0.075 mm (No. 200)	 ≤ 50 ≤ 30 ≤ 15	 – ≤ 50 ≤ 25	 – ≥ 51 ≤ 10	 – – ≤ 35	 – – ≤ 35	 – – ≤ 35	 – – ≤ 35	 – – ≥ 36	 – – ≥ 36	 – – ≥ 36	 – – ≥ 36
CHARACTERISTICS OF FRACTION PASSING 0.425 SIEVE (No. 40): LIQUID LIMIT PLASTICITY INDEX *	– 6 max		– NP	≤ 40 ≤ 10	≥ 41 ≤ 10	≤ 40 ≥ 11	≥ 41 ≥ 11	≤ 40 ≤ 10	≥ 41 ≤ 10	≤ 40 ≥ 11	≥ 41 ≥ 11
USUAL TYPES OF CONSTITUENT MATERIALS	STONE FRAGM'TS, GRAVEL, SAND		FINE SAND	SILTY OR CLAYEY GRAVEL AND SAND				SILTY SOILS		CLAYEY SOILS	
GENERAL RATING AS A SUBGRADE	EXCELLENT TO GOOD							FAIR TO POOR			

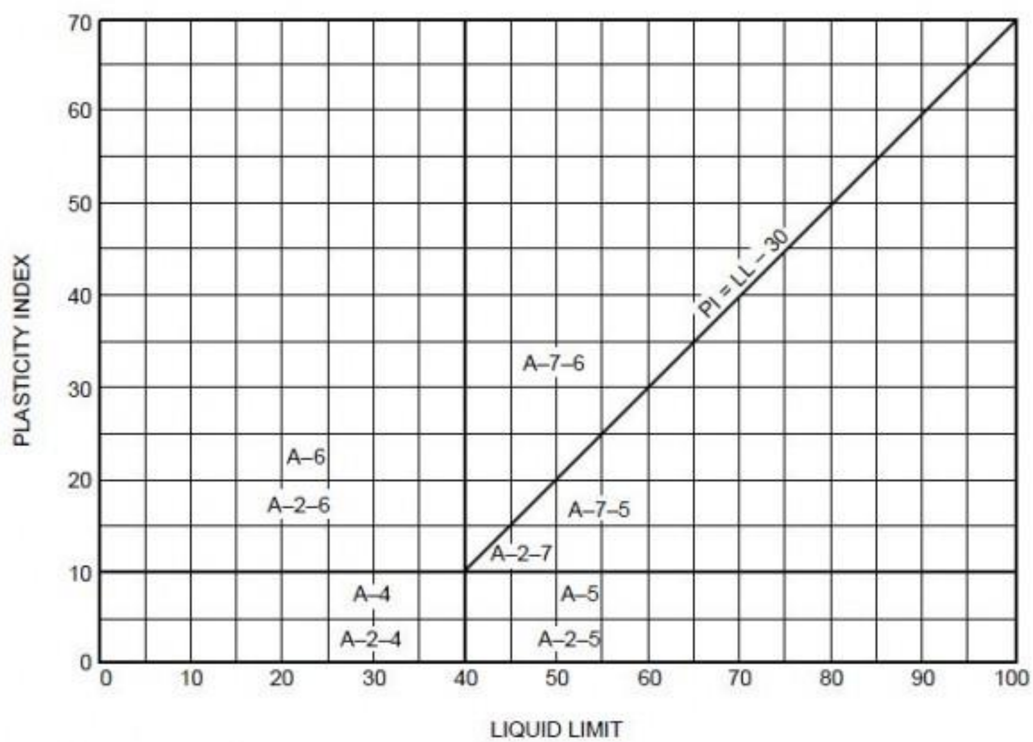
*Plasticity index of A-7-5 subgroup is equal to or less than LL-30. Plasticity index of A-7-6 subgroup is greater than LL-30.
NP = Non-plastic (use "0"). Symbol "–" means that the particular sieve analysis is not considered for that classification.

If the soil classification is A4-A7, then calculate the group index (GI) as shown below and report with classification. The higher the GI, the less suitable the soil. Example: A-6 with GI = 15 is less suitable than A-6 with GI = 10.

$$GI = (F - 35)[0.2 + 0.005(LL - 40)] + 0.01(F - 15)(PI - 10)$$

where: F = Percent passing No. 200 sieve, expressed as a whole number. This percentage is based only on the material passing the No. 200 sieve.
LL = Liquid limit
PI = Plasticity index

If the computed value of GI < 0, then use GI = 0.



GENERAL NOTES

Sedimentary Rock Classification

DESCRIPTIVE ROCK CLASSIFICATION:

Sedimentary rocks are composed of cemented clay, silt and sand sized particles. The most common minerals are clay, quartz and calcite. Rock composed primarily of calcite is called limestone; rock of sand size grains is called sandstone, and rock of clay and silt size grains is called mudstone or claystone, siltstone, or shale. Modifiers such as shaly, sandy, dolomitic, calcareous, carbonaceous, etc. are used to describe various constituents. Examples: sandy shale; calcareous sandstone.

LIMESTONE	Light to dark colored, crystalline to fine-grained texture, composed of $CaCo_3$, reacts readily with HCl.
DOLOMITE	Light to dark colored, crystalline to fine-grained texture, composed of $CaMg(CO_3)_2$, harder than limestone, reacts with HCl when powdered.
CHERT	Light to dark colored, very fine-grained texture, composed of micro-crystalline quartz ($Si0_2$), brittle, breaks into angular fragments, will scratch glass.
SHALE	Very fine-grained texture, composed of consolidated silt or clay, bedded in thin layers. The unlaminated equivalent is frequently referred to as siltstone, claystone or mudstone.
SANDSTONE	Usually light colored, coarse to fine texture, composed of cemented sand size grains of quartz, feldspar, etc. Cement usually is silica but may be such minerals as calcite, iron-oxide, or some other carbonate.
CONGLOMERATE	Rounded rock fragments of variable mineralogy varying in size from near sand to boulder size but usually pebble to cobble size (½ inch to 6 inches). Cemented together with various cementing agents. Breccia is similar but composed of angular, fractured rock particles cemented together.

PHYSICAL PROPERTIES:

DEGREE OF WEATHERING

Slight	Slight decomposition of parent material on joints. May be color change.
Moderate	Some decomposition and color change throughout.
High	Rock highly decomposed, may be extremely broken.

HARDNESS AND DEGREE OF CEMENTATION

Limestone and Dolomite:

Hard	Difficult to scratch with knife.
Moderately Hard	Can be scratched easily with knife, cannot be scratched with fingernail.
Soft	Can be scratched with fingernail.

Shale, Siltstone and Claystone

Hard	Can be scratched easily with knife, cannot be scratched with fingernail.
Moderately Hard	Can be scratched with fingernail.
Soft	Can be easily dented but not molded with fingers.

Sandstone and Conglomerate

Well Cemented	Capable of scratching a knife blade.
Cemented	Can be scratched with knife.
Poorly Cemented	Can be broken apart easily with fingers.

BEDDING AND JOINT CHARACTERISTICS

Bed Thickness	Joint Spacing	Dimensions
Very Thick	Very Wide	>10′
Thick	Wide	3′ - 10′
Medium	Moderately Close	1′ - 3′
Thin	Close	2″ - 1′
Very Thin	Very Close	.4″ - 2″
Laminated	—	.1″ - .4″

Bedding Plane	A plane dividing sedimentary rocks of the same or different lithology.
Joint	Fracture in rock, generally more or less vertical or transverse to bedding, along which no appreciable movement has occurred.
Seam	Generally applies to bedding plane with an unspecified degree of weathering.

SOLUTION AND VOID CONDITIONS

Solid	Contains no voids.
Vuggy (Pitted)	Rock having small solution pits or cavities up to ½ inch diameter, frequently with a mineral lining.
Porous	Containing numerous voids, pores, or other openings, which may or may not interconnect.
Cavernous	Containing cavities or caverns, sometimes quite large.

Exhibit C-4

Terracon