Geotechnical Engineering Report

Proposed Arterial Street Improvements

South Utica Avenue:

East 11th Street to East 14th Place

Tulsa, Oklahoma

January 13, 2017

Terracon Project No. 04165212

Prepared for:

BKL, Inc.
Tulsa, Oklahoma

Prepared by:

Terracon Consultants, Inc.
Tulsa, Oklahoma

January 13, 2017

BKL, Inc.
1623 E. 6th Street
Tulsa, Oklahoma 74120

Attn: Mr. Travis Small, P.E.
P: [918] 835-9588
E: small@bklinc.com

Re: Geotechnical Engineering Report
Proposed Arterial Street Improvements
South Utica Avenue: East 11th Street to East 14th Place
Tulsa, Oklahoma
Terracon Project No. 04165212

Dear Mr. Small:

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. P04165212 dated July 27, 2016. 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. 6/30/17

Fernando L. Aponte-Rivera, E.I.T.
Senior Staff Geotechnical Engineer

REGISTERED PROFESSIONAL ENGINEER
MICHAEL H. HOMAN
1/13/2017
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OKLAHOMA

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

FAR:MHH:tm
Enclosures
Addressee (1 via US Mail and 1 via email)

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PROPOSED ARTERIAL STREET IMPROVEMENTS
SOUTH UTICA AVENUE: EAST 11TH STREET TO EAST 14TH PLACE
TULSA, OKLAHOMA

Terracon Project No. 04165212
January 13, 2017

1.0 INTRODUCTION

This geotechnical engineering report has been completed for the Proposed Arterial Street Improvements to South Utica Avenue from East 11th Street to East 14th Place in Tulsa, Oklahoma. Five borings, designated P-1 through P-5, were performed to depths of approximately 2.5 to 5 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
- earthwork
- pavement thickness and subgrade preparation recommendations

2.0 PROJECT INFORMATION

2.1 Project Description

ITEM	DESCRIPTION
Site layout	See Appendix A, Exhibit A-2, Boring Location Plan.
Proposed Development	Based on the information provided by BKL, we understand that the project will consist of rehabilitation of the existing road. The rehabilitation will include patching with milling and overlay in the asphalt section. A full-depth reconstruction will be performed near the intersection of South Utica Avenue and East 11th Street. Patches could be performed for the concrete section south of East 13th Street.

2.2 Site Location and Description

ITEM	DESCRIPTION
Location	South Utica Avenue from East 11th Street to East 14th Place in Tulsa, Oklahoma.

ITEM	DESCRIPTION
Traffic loading	Traffic volume: 19,400 AADT (given) Traffic growth rate: 2% (assumed) Truck Traffic: 2% (assumed)
Current ground cover	Asphalt pavement from East 11th Street to immediately north of 13th Street. Concrete pavement to 13th Place.

3.0 SUBSURFACE CONDITIONS

3.1 Typical Profile

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

Description	Approximate Depth to Bottom of Stratum	Material Encountered	Consistency/Density
Surface 1[1]	7 ¾ inches	Asphalt pavement	N/A
Surface 2[2]	12 ¾ inches	Asphalt pavement overlaying Portland cement concrete pavement	N/A
Surface 3[3]	12 ¼ to 14 ¼ inches	Portland cement concrete pavement overlaying asphalt pavement	N/A
Stratum 1[4]	2.5 to 3.5 feet	Lean clay, lean clay with sand, silty sand (potential fill)	Clay: Medium stiff to stiff Sand: Loose
Stratum 2[5]	5 feet	Lean clay, lean clay with sand, sandy lean clay	Medium stiff to stiff

1. Encountered in boring P-1.
2. Encountered in borings P-2 and P-3.
3. Encountered in borings P-4 and P-5.
4. Boring P-2 terminated in silty sand (potential fill) at approximately 2.5 feet upon encountering apparent metal in borehole.
5. All borings, except P-2, terminated in this stratum at approximately 5 feet.

The subgrade soils in all borings except P-2 were classified as moderate plasticity clays. The samples tested had the following measured liquid limits, plastic limits, plasticity indices and percent passing No. 200 sieve:

Sample Location, Depth	Liquid Limit, (%)	Plastic Limit, (%)	Plasticity Index, (%)	Percent Passing No. 200 Sieve
Boring P-1, 3.5 – 5.0 ft.	43	16	27	86

Sample Location, Depth	Liquid Limit, (%)	Plastic Limit, (%)	Plasticity Index, (%)	Percent Passing No. 200 Sieve
Boring P-2, 1.1 – 2.6 ft.	NP	NP	NP	39
Boring P-3, 1.1 – 2.6 ft.	35	22	13	95
Boring P-4, 3.5 – 5.0 ft.	34	16	18	67
Boring P-5, 1.2 – 2.7 ft.	35	18	17	93
Boring P-6, 0.8 – 2.3 ft.	39	17	22	93
Boring P-7, 2.3 – 3.8 ft.	34	17	17	87
Boring P-8, 0.9 – 2.4 ft.	31	20	11	89

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 boreholes 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.

3.3 Existing Pavement Thickness

The thicknesses of asphalt and concrete pavement encountered at the core locations are summarized below.

Boring Number	Type S4 Asphalt Thickness (inches)	Portland Cement Concrete Thickness (inches)
P-1	7 ¾	--
P-2	5 (surface)	7 ¾
P-3	7 ¾ (surface)	5
P-4	3 ½	8 ¾ (surface)
P-5	4	10 ¼ (surface)

4.0 RECOMMENDATIONS FOR DESIGN AND CONSTRUCTION

4.1 Geotechnical Considerations

We understand that this project is budgeted as a mill and overlay project within the asphalt section. We also understand that some full-depth repair patches will be necessary within the concrete section. In addition, we have learned that full-depth reconstruction will be performed near the intersection of South Utica Avenue and East 11th Street.

Asphalt and Portland cement concrete pavements were encountered during our field exploration. We encountered approximately 7 ¾ inches of asphalt in boring P-1, located south of the intersection of South Utica Avenue and East 11th Street. Pavement cores obtained from borings P-2 and P-3, located south of boring P-1, encountered approximately 5 and 7 ¾ inches of asphalt overlaying 7 ¾ and 5 inches of Portland cement concrete pavement, respectively. South of boring P-3, borings P-4 and P-5 encountered approximately 8 ¾ and 10 ¼ inches of Portland cement concrete overlaying 3 ½ and 4 inches of asphalt pavement, respectively.

Loose silty sand was encountered in boring P-2 beneath the existing pavement. We encountered an apparent metal object at about 30 inches in boring P-2. We suspect this is fill material. Silty soils are susceptible to strength loss and instability, particularly when the soils experience increases in moisture content. Therefore, care should be taken during the site grading operation to provide adequate site drainage and to minimize traffic over the exposed soils.

We recommend that full-depth pavement sections, including isolated repair patches for the mill and overlay procedure, incorporate a layer of aggregate base beneath the pavement to improve long-term pavement support. In addition, proper moisture conditioning and compaction of the subgrade materials will be required during construction to develop the pavement subgrade.

Recommendations regarding pavement subgrade preparation, mill and overlay and full-depth pavement thickness are provided below.

4.2 Earthwork

4.2.1 Site Preparation

Site preparation recommendations are appropriate for the full-depth replacement option and isolated full-depth patches on the mill and overlay option.

Areas within the limits of 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 possible given patch size constraints. 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 soft wet 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 Lean Clay Soils	CL (PI ≤ 20)	All locations and elevations[3]
	CL (PI > 20)	Should not be placed within pavement subgrade
On-Site Silty Sand Soils	SM	Should not be placed within pavement subgrade[4]
ODOT Type A Aggregate Base[5]	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 lean clay soils with a plasticity index of 20 or less can be used as Low Volume Change fill material.
4. Silty soils are susceptible to strength loss and instability, particularly when the soils experience increases in moisture content.
5. 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

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.

4.3 Pavements

4.3.1 Mill & Overlay Section

We recommend that the top 2 inches of the asphalt pavement sections be removed and replaced with 2 inches of Type S4 asphaltic concrete in all pavement areas.

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.

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 distressed pavement removal, 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 full depth removal 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.

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 present-day Annual Average Daily Traffic (AADT) volume of 19,400 vehicles. This data was provided by BKL, Inc.

We used a 2 percent annual growth rate and 2 percent truck traffic. 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 and a subgrade resilient modulus value of 5,000 psi for the 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. Additional AASHTO pavement section design parameters used in our analysis include:

- Total Flexible ESAL's = 3.6×10^6
- Directional Distribution Factor = 0.5
- Lane Distribution Factor = 0.8

- Initial Serviceability = 4.2 (Flexible)
- Terminal Serviceability = 2.0 (Flexible)
- Reliability = 85%
- Overall Deviation for Flexible Pavement = 0.45
- Drainage Coefficient = 1.0 for Aggregate Base Material

Minimum Pavement Recommendations	
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. Oklahoma Department of Transportation Standard Specifications

4.3.3 Full-Depth Concrete Pavement Recommendations

We understand that full-depth isolated concrete patches could be performed for the existing concrete section. For patches in concrete pavement, removal of the distressed concrete pavement should extend to non-distressed pavement.

Minimum recommended pavement sections for full-depth patches are presented in the following table.

Minimum Pavement Recommendation – Full-Depth Pavement Patch	
Pavement Section	
3,500 psi Air Entrained Portland Cement Concrete Over Aggregate Base Over Approved Subgrade	9.0" Concrete[2]
	12.0" Aggregate Base[1]
	Approved Subgrade

1. Oklahoma Department of Transportation Specifications.
2. Doweled into existing concrete pavement with No. 3 reinforcing bars spaced 18 inches apart, placed at mid-depth of concrete.

In addition to patching distressed pavements, it is important the cracks be routed and filled. Crack filling is critical maintenance item and should also be carried out on a yearly basis after making the initial repairs. Crack filling will help reduce moisture infiltration into the subgrade and reduce the rate of further pavement deterioration adjacent to the cracks.

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 sections provided in this report represent minimum recommended thicknesses 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.

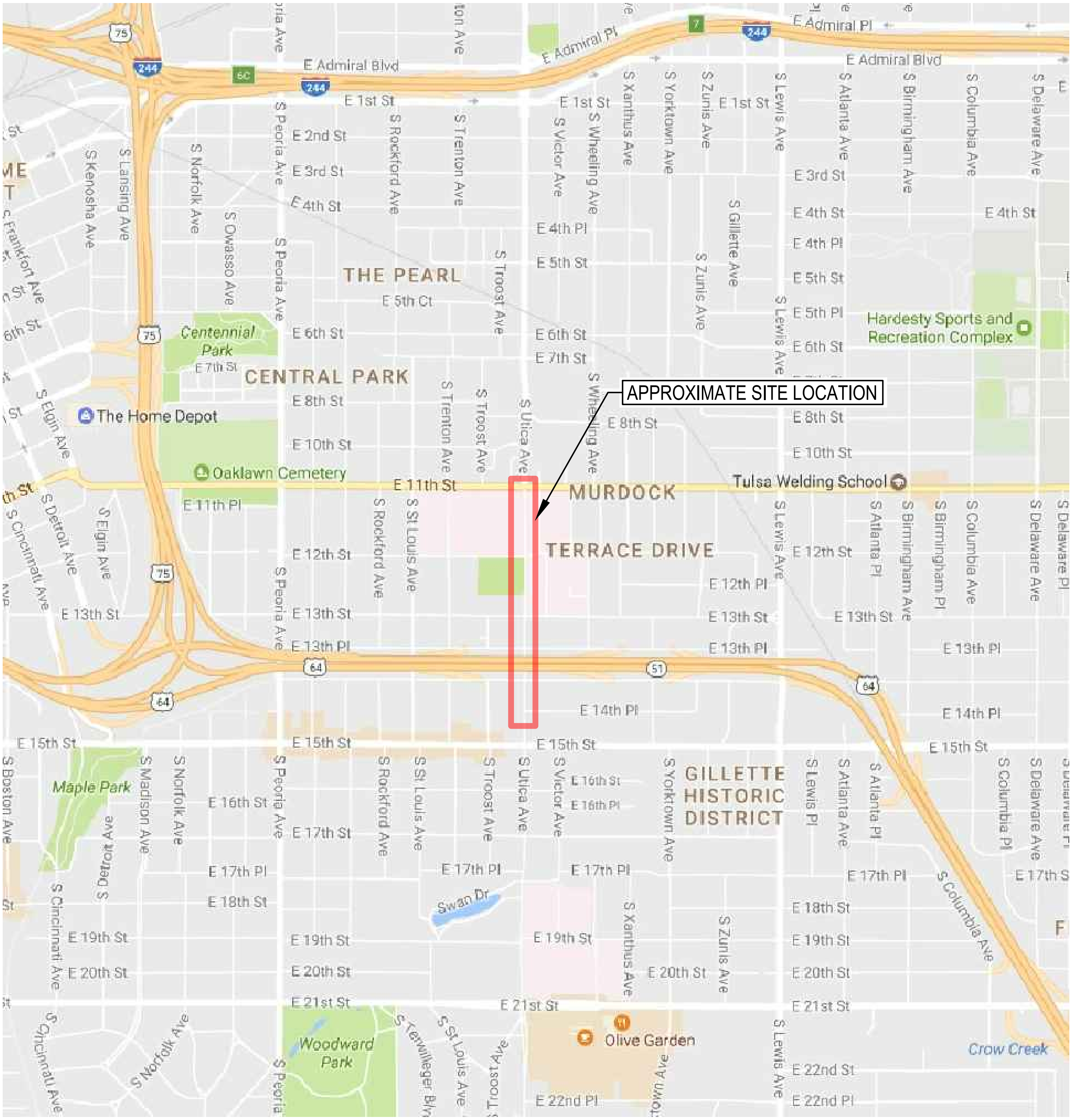
The analysis and recommendations presented in this report are based upon the data obtained from the borings performed at the indicated locations and from other information discussed in this report. This report does not reflect variations that may occur between borings, across the site, or due to the 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



© 2016 GOOGLE

N

1500 0 500 1000 1500

APPROXIMATE SCALE IN FEET

Project Mngr: FAR	Project No. 04165212	Terracon Consulting Engineers and Scientists	SITE LOCATION MAP	EXHIBIT NO.
Drawn By: JM	Scale: SEE BAR SCALE		GEOTECHNICAL EXPLORATION	A-1
Checked By: FAR	File No. 04165212	9522 EAST 47TH PLACE, UNIT D TULSA, OKLAHOMA 74145	PROPOSED ARTERIAL STREET IMPROVEMENTS	
Approved By: MHH	Date: JANUARY 2017	PH. (918) 250-0461 FAX. (918) 250-4570	TULSA, OKLAHOMA	

LEGEND
● BORING LOCATION

150 0 50 100 150

APPROXIMATE SCALE IN FEET

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

Project Mngr: FAR	Project No. 04165212		
Drawn By: JM	Scale: SEE BAR SCALE		
Checked By: FAR	File No. 04165212		
Approved By: MHH	Date: JANUARY 2017		

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

BORING LOCATION PLAN

GEOTECHNICAL EXPLORATION

PROPOSED ARTERIAL STREET IMPROVEMENTS

TULSA, OKLAHOMA

EXHIBIT NO.

A-2

Field Exploration Description

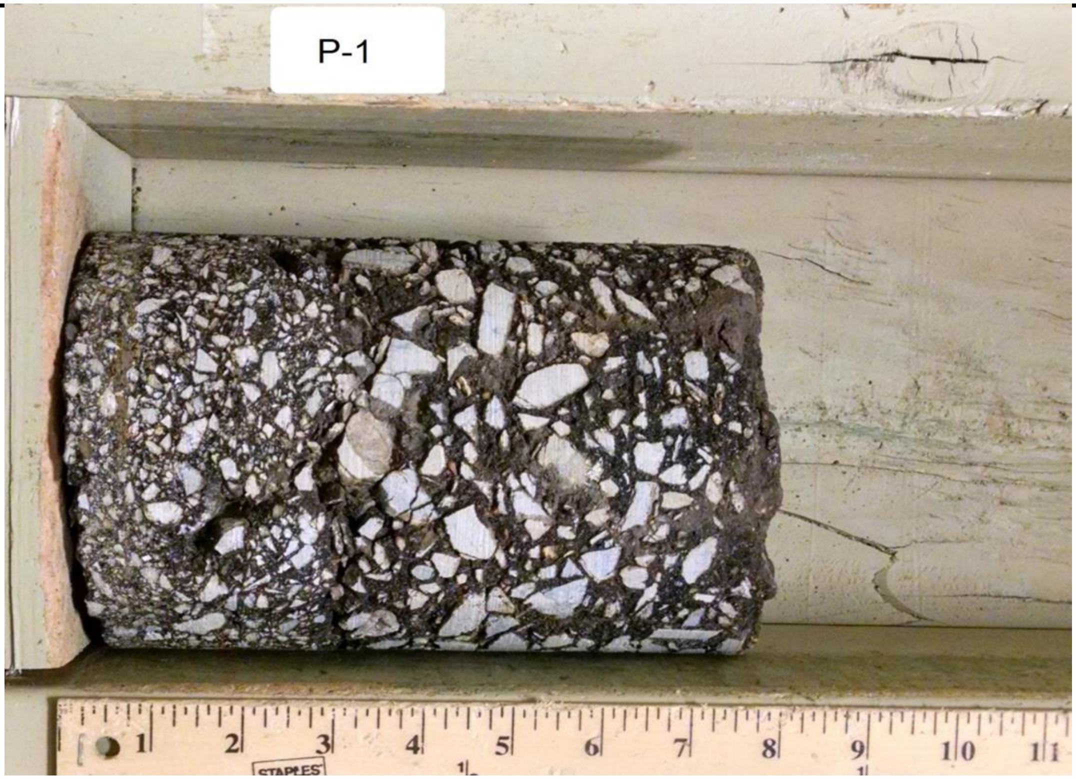
The boring locations were established in the field by Terracon personnel by taping from existing reference features and by the aid of a hand held GPS unit. The boring locations should be considered accurate only to the degree implied by the methods used to define them.

We used a core machine with a diamond-bit core barrel to core the pavement. 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



Terracon **CORE LOG**

CORE NUMBER	P-1
DATE CORED	12/21/2016
LANE DIRECTION	Southbound
LOCATION	South Utica Avenue

LATITUDE	LONGITUDE
36.14761164	-95.96722667

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

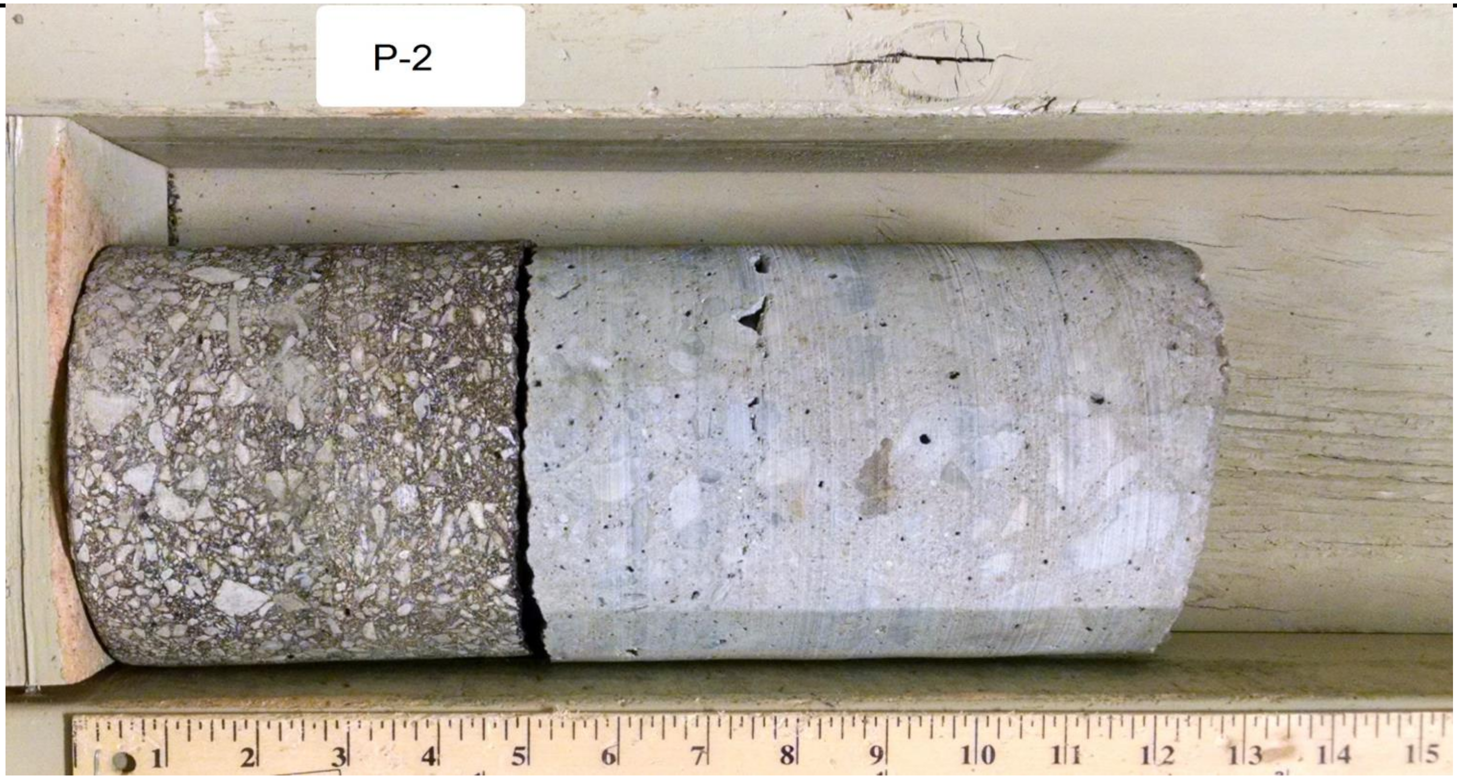
Stabilized Subgrade Beneath Pavement or Sub-base? ☐ Yes ☑ No ☐ Unknown

CORE LAYER DATA (FROM TOP TO BOTTOM):

Sample No	Layer Type	Layer Thickness (in.)	Layer Characteristics*			
1	Asphaltic Concrete	3				
	Asphaltic Concrete	4 3/4				
	Total Core Thickness	**7 3/4**	SPT N (blows/ft)	LL/PL/PI	> #200 (%)	MC (%)
2	LEAN CLAY (CL), with sand, brown and orangish-brown, medium stiff	34 1/4	6			20
3	LEAN CLAY (CL) / A-7-6(23), light brown and light orangish-brown, medium stiff	18	6	43/16/27	86	19
	Total Thickness / Depth	**60**				

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

TOP



Terracon **CORE LOG**

CORE LAYER DATA (FROM TOP TO BOTTOM):

CORE NUMBER: P-2
DATE CORED: 12/21/2016

LANE DIRECTION: Northbound
LOCATION: South Utica Avenue

LATITUDE	LONGITUDE
36.14623347	-95.96701687

Sample No	Layer Type	Layer Thickness (in.)	Layer Characteristics*			
1	Asphaltic Concrete	3				
	Asphaltic Concrete	2				
	Portland Cement Concrete	7 3/4				
	Total Core Thickness	**12 3/4**	SPT			
			N (blows/ft)	LL/PL/PI	> #200 (%)	MC (%)
2	SILTY SAND (SM) / A-4(0), dark brown, loose (potential fill material) - apparent metal encountered at approximately 31 inches. Boring was terminated at this depth.	18	5	NP	39	16
	Total Thickness / Depth	**30 3/4**				

CORE DATA

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

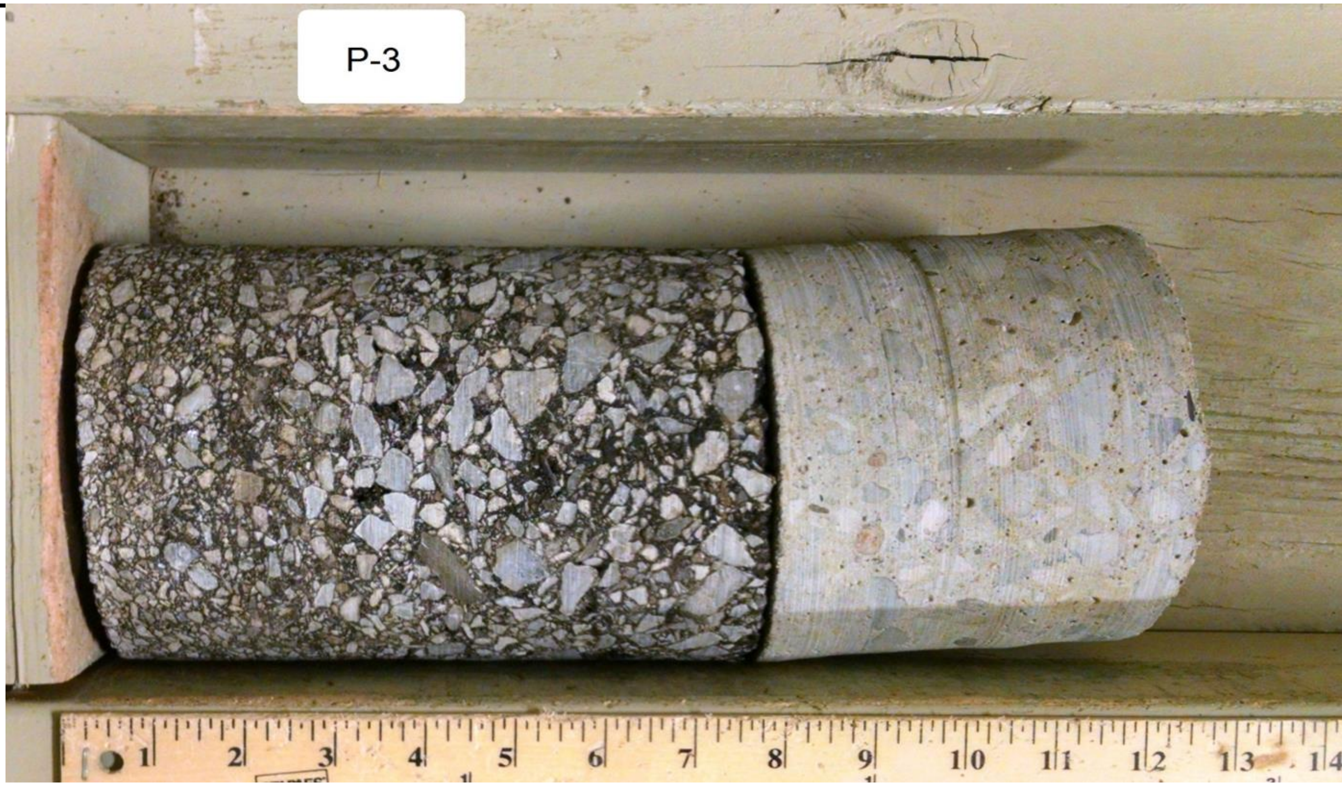
Stripping or Separation in Asphalt: ☐ Stripping ☐ Separation ☑ N/A

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

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

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

TOP



Terracon

CORE LOG

CORE NUMBER	P-3
DATE CORED	12/21/2016
LANE DIRECTION	Southbound
LOCATION	South Utica Avenue

LATITUDE	LONGITUDE
36.14466143	-95.96723638

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	2	
	Asphaltic Concrete	5 3/4	
	Portland Cement Concrete	5	
	Total Core Thickness	**12 3/4**	

Sample No	Layer Type	Layer Thickness (in.)	SPT N (blows/ft)	LL/PL/PI	> #200 (%)	MC (%)
2	LEAN CLAY (CL) / A-6(13), with shale fragments, olive-brown and gray, medium stiff	29 1/4	8	35/22/13	95	17
3	LEAN CLAY (CL), with sand, orangish-brown, medium stiff	18	7			18
	Total Thickness / Depth	**60**				

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

TOP

Terracon

CORE LOG

CORE NUMBER P-4
DATE CORED 12/21/2016

LANE DIRECTION Northbound
LOCATION South Utica Avenue

LATITUDE	LONGITUDE
36.14358532	-95.96709021

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

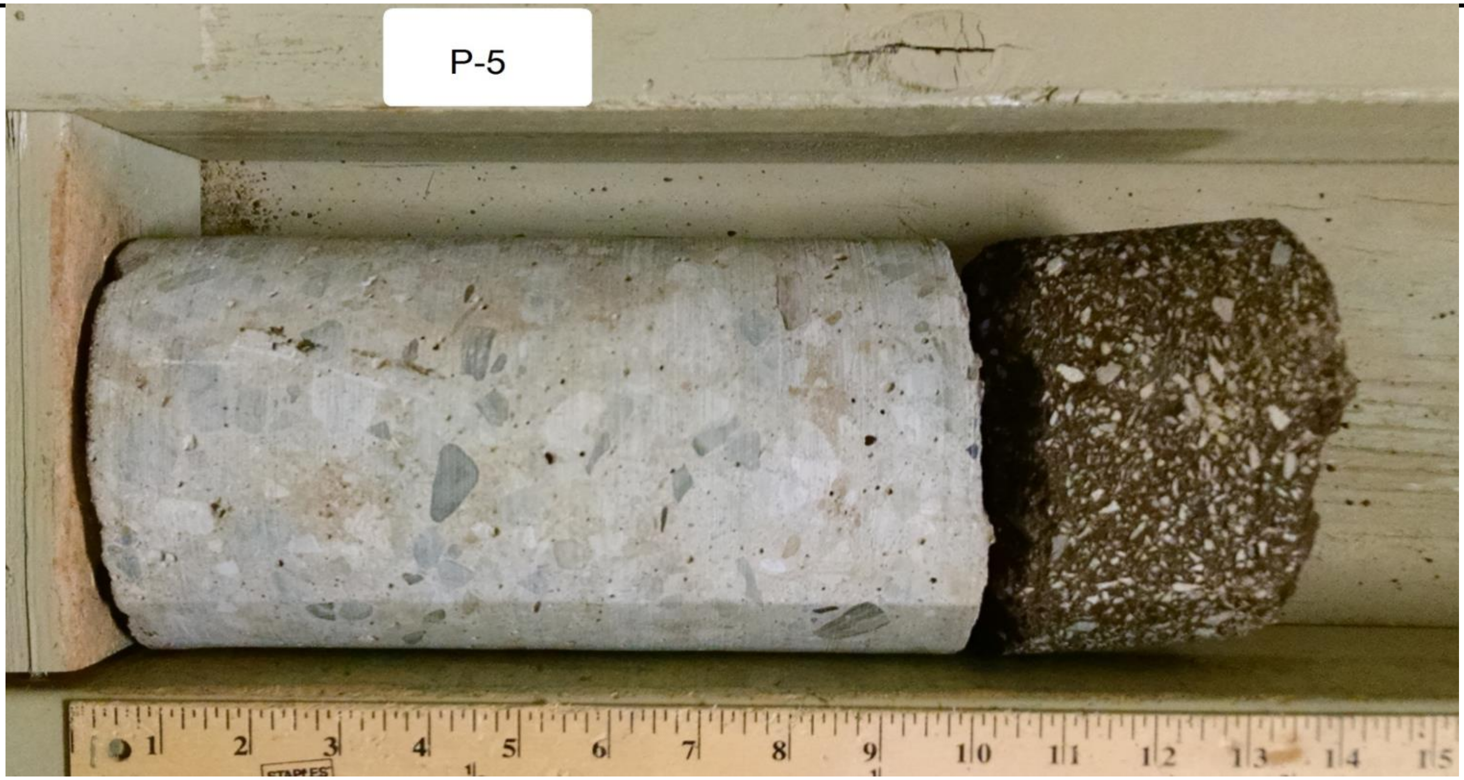
Stabilized Subgrade Beneath Pavement or Sub-base? ☐ Yes ☑ No ☐ Unknown

CORE LAYER DATA (FROM TOP TO BOTTOM):

Sample No	Layer Type	Layer Thickness (in.)	Layer Characteristics*			
1	Portland Cement Concrete	8 3/4				
	Asphaltic Concrete	1/2	Separation at 9 1/4 inches			
	Asphaltic Concrete	3				
	Total Core Thickness	**12 1/4**	SPT			
			N (blows/ft)	LL/PL/PI	> #200 (%)	MC (%)
2	LEAN CLAY (CL), with sand, trace shale fragments, dark orangish-brown and gray, medium stiff to stiff	29 3/4	8			16
3	SANDY LEAN CLAY (CL) / A-6(10), orangish-brown, medium stiff	18	5	34/16/18	67	15
	Total Thickness / Depth	**60**				

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

TOP



Terracon

CORE LOG

CORE NUMBER P-5
DATE CORED 12/21/2016

LANE DIRECTION Southbound
LOCATION South Utica Avenue

LATITUDE 36.14191966
LONGITUDE -95.9672435

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	Portland Cement Concrete	10 1/4	Separation at 10 1/4"			
	Asphaltic Concrete	4				
	Total Core Thickness	**14 1/4**	SPT N (blows/ft)	LL/PL/PI	> #200 (%)	MC (%)
2	LEAN CLAY (CL) / A-6(16), orangish-brown, stiff	27 3/4	9	35/18/17	93	20
3	LEAN CLAY (CL) / A-6(16), orangish-brown, stiff	18	8			21
	Total Thickness / Depth	**60**				

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

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) described in Appendix C. The field descriptions were modified as necessary and an applicable laboratory testing program was formulated to determine engineering properties of the subsurface materials.

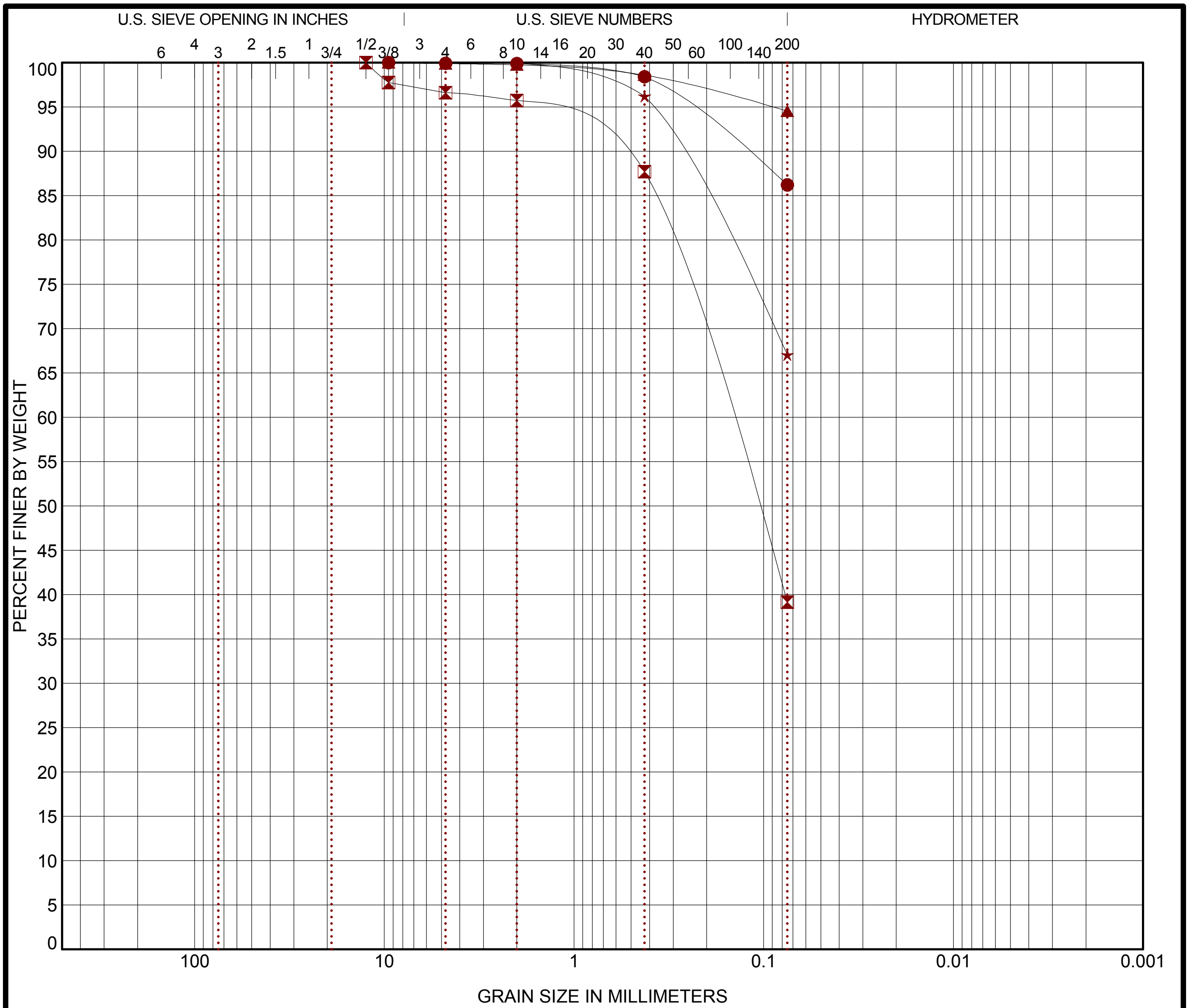
Laboratory tests were conducted on selected soil samples. The laboratory test results are presented on the pavement core logs next to the respective samples. Laboratory tests were performed in general accordance with the applicable ASTM, local or other accepted standards.

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

- Water content
- Atterberg limits
- Gradation size distribution

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Boring ID	Depth	USCS Classification	AASHTO Classification	WC (%)	LL	PL	PI	Cc	Cu
● P-1	3.5 - 5	LEAN CLAY (CL)	A-7-6 (23)	20	43	16	27		
⊠ P-2	1.1 - 2.6	SILTY SAND (SM)	A-4 (0)	16	NP	NP	NP		
▲ P-3	1.1 - 2.6	LEAN CLAY (CL)	A-6 (13)	17	35	22	13		
★ P-4	3.5 - 5	SANDY LEAN CLAY (CL)	A-6 (10)	15	34	16	18		

Boring ID	Depth	D_{100}	D_{60}	D_{30}	D_{10}	%Gravel	%Sand	%Silt	%Fines	%Clay
● P-1	3.5 - 5	9.5				0.1	13.7		86.2	
⊠ P-2	1.1 - 2.6	12.5	0.158			3.4	57.5		39.2	
▲ P-3	1.1 - 2.6	9.5				0.1	5.3		94.5	
★ P-4	3.5 - 5	4.75				0.0	32.9		67.1	

PROJECT: South Utica Avenue from East 11th Street to East 14th Place

SITE: Tulsa, Oklahoma

Terracon
9522 E 47th Pl Ste D
Tulsa, OK

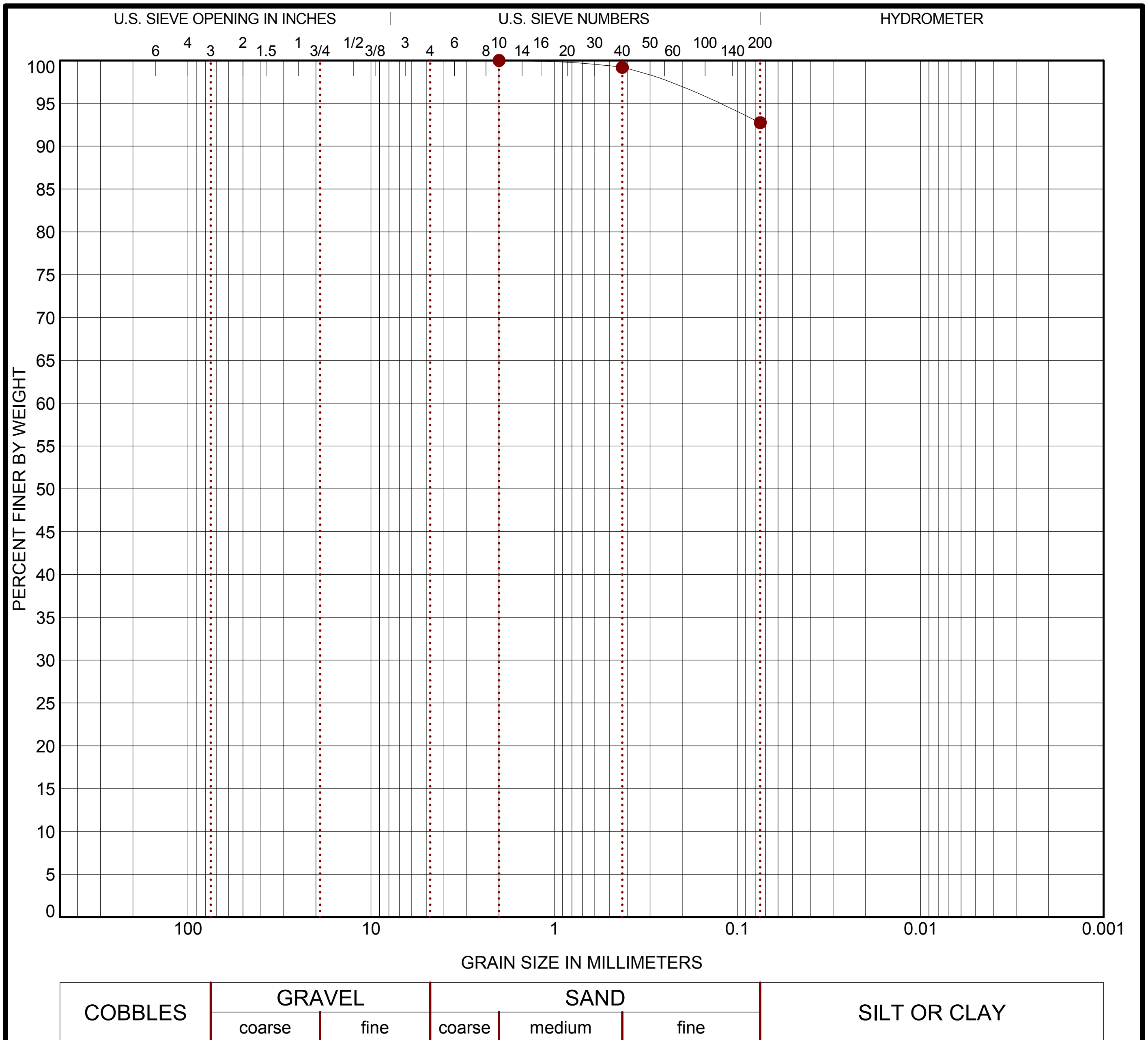
PROJECT NUMBER: 04165212

CLIENT: BKL, Inc.

EXHIBIT: B-2

GRAIN SIZE DISTRIBUTION

ASTM D422 / ASTM C136



	Boring ID	Depth	USCS Classification	AASHTO Classification	WC (%)	LL	PL	PI	Cc	Cu
●	P-5	1.2 - 2.7	LEAN CLAY (CL)	A-6 (16)	20	35	18	17		

	Boring ID	Depth	D_{100}	D_{60}	D_{30}	D_{10}	%Gravel	%Sand	%Silt	%Fines	%Clay
●	P-5	1.2 - 2.7	2				0.0	7.3		92.7	

PROJECT: South Utica Avenue from East 11th Street to East 14th Place

SITE: Tulsa, Oklahoma

Terracon
9522 E 47th Pl Ste D
Tulsa, OK

PROJECT NUMBER: 04165212

CLIENT: BKL, Inc.

EXHIBIT: B-3

LABORATORY TESTS ARE NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GRAIN SIZE: USCS & AASHTO COMBINED 04165212 BORE LOGS.GPJ TERRACON2015.GDT 1/6/17

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	≥ 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

Terracon

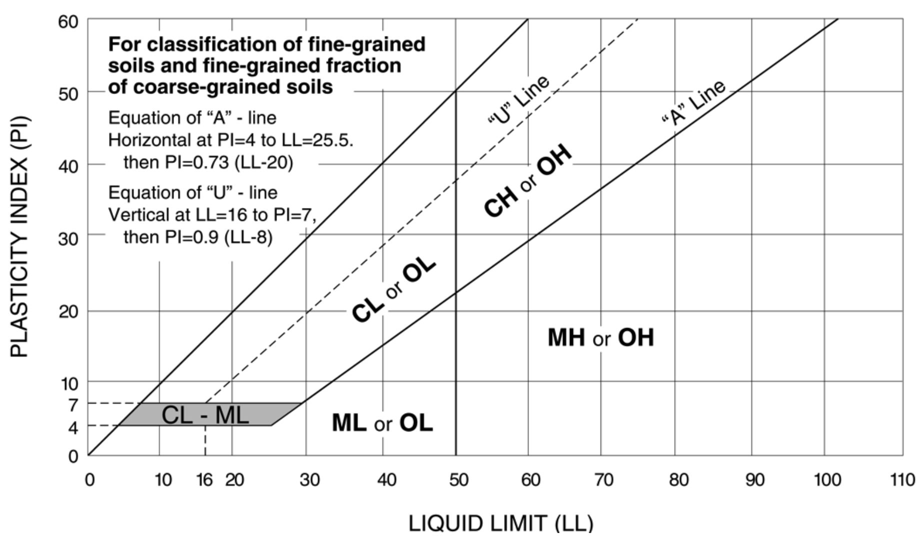
UNIFIED SOIL CLASSIFICATION SYSTEM

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests [A]					Soil Classification: Group Symbol	Soil Classification: 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 ≥ 4 and 1 ≤ Cc ≤ 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 ≥ 6 and 1 ≤ Cc ≤ 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	< 0.75	OL	Organic clay [K,L,M,N]
			Liquid limit - not dried			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	< 0.75	OH	Organic clay [K,L,M,P]
			Liquid limit - not dried			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 ≥ 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 ≥ 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 ≥ 30% plus No. 200 predominantly sand, add "sandy" to group name.
[M] If soil contains ≥ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.
[N] PI ≥ 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)	≤ 50	–	–	–	–	–	–	–	–	–	–
0.425 mm (No. 40)	≤ 30	≤ 50	≥ 51	–	–	–	–	–	–	–	–
0.075 mm (No. 200)	≤ 15	≤ 25	≤ 10	≤ 35	≤ 35	≤ 35	≤ 35	≥ 36	≥ 36	≥ 36	≥ 36
CHARACTERISTICS OF FRACTION PASSING 0.425 SIEVE (No. 40):											
LIQUID LIMIT	–		–	≤ 40	≥ 41	≤ 40	≥ 41	≤ 40	≥ 41	≤ 40	≥ 41
PLASTICITY INDEX *	6 max		NP	≤ 10	≤ 10	≥ 11	≥ 11	≤ 10	≤ 10	≥ 11	≥ 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.