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SUBGRADE INVESTIGATION AND PAVEMENT DESIGN

SOLACE COLORADO SPRINGS
PAONIA STREET NORTH OF GALLEY ROAD
EL PASO COUNTY, COLORADO

Prepared for:

SUB4 DEVELOPMENT CORPORATION
2301 West Bradley Avenue, Suite 2
Champaign, Illinois 61821

Attention: Jennifer Lowe

Project No. CS19163.001-135

January 9, 2025

TABLE OF CONTENTS

SCOPE

This report presents the results of our Subgrade Investigation and Pavement Design for the extension of Paonia Street, north of Galley Road, as part of the Solace Colorado Springs apartment complex located in Colorado Springs, Colorado. We were asked to develop asphalt pavement thickness recommendations for the roadway improvements, based on the current El Paso County requirements. Paonia Street was paved with asphalt without a subgrade investigation and associated pavement structural section recommendations. The purpose of our investigation was to evaluate the type and support characteristics of the asphalt, aggregate base coarse, and subgrade materials present at the site after construction of the roadway.

This report was prepared from data developed during our field exploration and observations, results of laboratory testing, engineering analysis, and our experience with similar conditions. It includes a description of the subgrade materials found in our exploratory borings, laboratory test results, alternative design pavement sections, and our recommendations for pavement construction based on the subgrade conditions found. The design pavement sections presented in this report were developed based on El Paso County design criteria for asphalt pavement.

SITE CONDITIONS

The site is bounded to the east and west by partially developed land, and existing commercial development to the north and south. The new Solace Colorado Springs apartment complex is located west of the north end of the Paonia Street extension, approximately 600 feet north of Galley Road. The site is located in El Paso County, Colorado. The general vicinity of the project is shown on Fig. 1. At the time of our field investigation, the Paonia Street has been paved with asphalt, and the underground utilities had been installed.

EXISTING ASPHALT CONDITIONS

Based on our records, extension for Paonia Street was paved on October 25, 2023 in two lifts. The extension for Paonia Street does not show any distress. The existing pavement section for the roadway, based on the core data, is presented in Table I.

TABLE I
EXISTING ASPHALT AND AGGREGATE BASE COARSE THICKNESS

Approximate Location	Asphalt Thickness (in)	Asphalt Relative Compaction (percentage)	Aggregate Base Course Thickness (in)
S-1 (Sta. 24+90 West Side)	Top Lift – 1-7/8 Bottom Lift – 2	Top Lift – 95.3 Bottom Lift – 92.0	8-1/2
S-2 (Sta. 23+90 West Side)	Top Lift – 2-1/2 Bottom Lift –2-3/16	Total – 93.5	8
S-3 (Sta. 19+10 East Side)	Top Lift – 2-5/16 Bottom Lift –2-5/16	Top Lift – 93.2 Bottom Lift – 94.3	8
S-4 (Sta. 16+10 West Side)	Top Lift – 2-1/4 Bottom Lift –2-5/16	Top Lift – 95.9 Bottom Lift – 94.3	8
S-5 (Sta. 13+50 East Side)	Top Lift – 2-5/16 Bottom Lift – 2-5/16	Total – 95.0	8

SUBGRADE INVESTIGATION

Subgrade conditions were evaluated by drilling five (5) borings at the approximate locations shown in Fig. 1. Two of the borings were extended to a depth of 11 feet with the remaining borings extending to a depth of 6 feet (below top of pavement). Bulk samples were collected to a depth of 5 feet below grade. The borings were backfilled upon completion of drilling due to safety concerns. Logs of conditions found in the holes are presented in Appendix A.

Laboratory testing (gradation analysis and Atterberg Limits) was performed to provide index properties for the bulk samples collected. The majority of the subgrade materials encountered in the upper 5 feet classify under the AASHTO system as A-2-4, with an isolated sample of A-1-b at test hole S-1.

Swell/consolidation testing was performed in general conformance with ASTM D 4546 on samples collected at 2 feet below the existing grade (top of pavement). Two samples at 2 feet swelled from 0.0 percent to 0.4 percent, and two samples at 2 feet consolidated 0.6 and 1.2 percent, when wetted under a confining pressure of 200 psf. Swell test results are shown in Appendix A and summarized on Table B-I. Water-soluble sulfates were measured from two of the bulk samples at concentrations of less than 0.1 percent.

DESIGN PAVEMENT SECTION

Based on the plans provided by J.R. Engineering, dated January 25, 2020, Paonia Street is classified as an Urban Residential Collector. Paonia Street has a right-of-way width between 80 and 90 feet, with edge of pavement to edge of pavement width between 36 and 45 feet. EL Paso County provides a default, 20-year, 18-kip, equivalent, single-axle load (ESAL) of 821,000 for Urban Residential Collector streets.

The El Paso County pavement design manual provides a formula to convert an "R" value to a Resilient Modulus (M_r). For design proposes, we combined the A-2-4 soils encountered in our borings. We measured an "R" value of 72 to calculate an M_r of 27,027 for the A-2-4 soil subgrade materials using the following equation:

$$M_r = 10^{(S+18.72)/6.24}$$

Where:

$$S = [(R\text{-}value - 5)/11.29] + 3$$

The 1993 AASHTO design method was used to calculate a required structural number of 1.94 utilizing the 20-year ESAL of 821,000 and an M_r of 27,027. Pavement section alternatives were calculated, and the results summarized below in Table II. Paonia Street was recently paved, using the minimum section of asphalt over aggregate base course. Design calculations are presented in Appendix D.

TABLE II
DESIGN PAVEMENT THICKNESS ALTERNATIVES

Street Classification	Asphalt (AC) + Aggregate Base Course (ABC)
Urban Residential Collector Streets (Public) ESAL = 821,000 "R" = 72	4" AC + 8" ABC (Minimum Required Section)

SWELL MITIGATION

The materials encountered in the upper 5 feet of the site consist primarily of clayey sand with varying amounts of gravel and silty-clayey sand, with test hole S-1 containing poorly graded sand and silty sand. The materials were in a in a slightly moist to moist condition and classify as A-2-4, with an isolated area of A-1-b at test hole S-1. El Paso County requires swell testing on

existing soils with Plasticity Indices greater than 10. Based on the Plasticity Indices and swell results obtained for the project, mitigation is not anticipated.

PAVEMENT CONSTRUCTION DETAILS

The design of a pavement system is as much a function of the quality of the paving materials and construction as the support characteristics of the subgrade. The construction process should follow procedures and specifications accepted by the El Paso County for subgrade preparation and compaction, and follow the Pikes Peak Region, Asphalt Paving Specifications (PPRAPS) for asphalt concrete mixes and material specifications. Construction materials meeting the PPRAPS criteria are considered to meet the pavement section design assumptions. Careful attention should be paid to compaction at utility crossings, manholes, valve boxes, and grading fill placement. Documentation of field testing performed has previously been submitted. Asphalt material testing performed on the core samples is provided in Appendix C

The Pikes Peak Region Asphalt Pavement Specifications criteria require the use of PG 58-28 or PG 64-22 as the asphalt binder for moderate volume roadways (between 300,000 and 2,500,000 ESAL's). The mix design should utilize a Design Gyrations value (N_{des}) of 75.

MAINTENANCE

We recommend a preventive maintenance program be developed and followed for all pavement systems to assure the design life can be realized. Choosing to defer maintenance usually results in accelerated deterioration, leading to higher future maintenance costs and/or repair. Guideline maintenance recommendations are provided in Appendix D.

LIMITATIONS

The pavement sections and construction recommendations are based on our field observations and laboratory testing and the El Paso County design criteria. The design procedures were formulated to provide pavement sections with adequate structural strength. Routine maintenance, such as sealing and repair of cracks, is necessary to achieve the long-term life of a pavement system. If the design and construction recommendations cannot be followed, or anticipated traffic loads change considerably, we should be contacted to review our recommendations.

We believe this investigation was conducted in a manner consistent with that level of skill and care normally used by geotechnical engineers practicing under similar conditions. No warranty, express or implied, is made.

If we can be of further service in discussing the contents of this report, please call.

Respectfully submitted,

CTL|THOMPSON, INC.

Dennis Pelham

Dennis E. Pelham, E.I.
Staff Engineer

DEP:TAM:cw

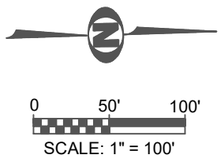
Via e-mail: jen.l@sub4dev.com

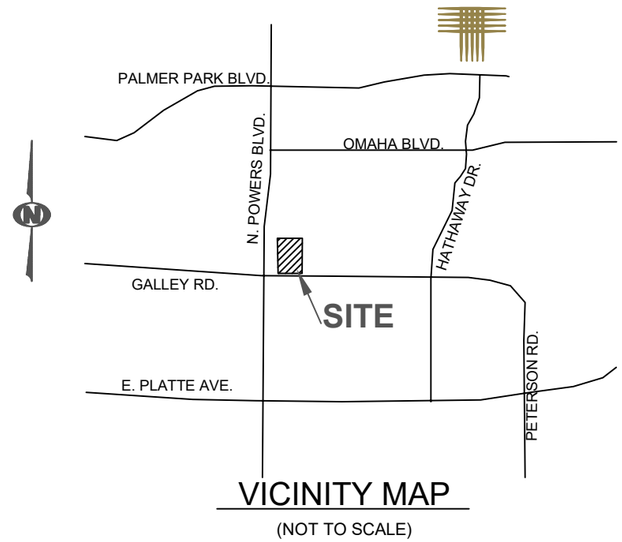
Reviewed By

Timothy A. Mitchell, P.E.
Senior Principal Engineer

LEGEND:

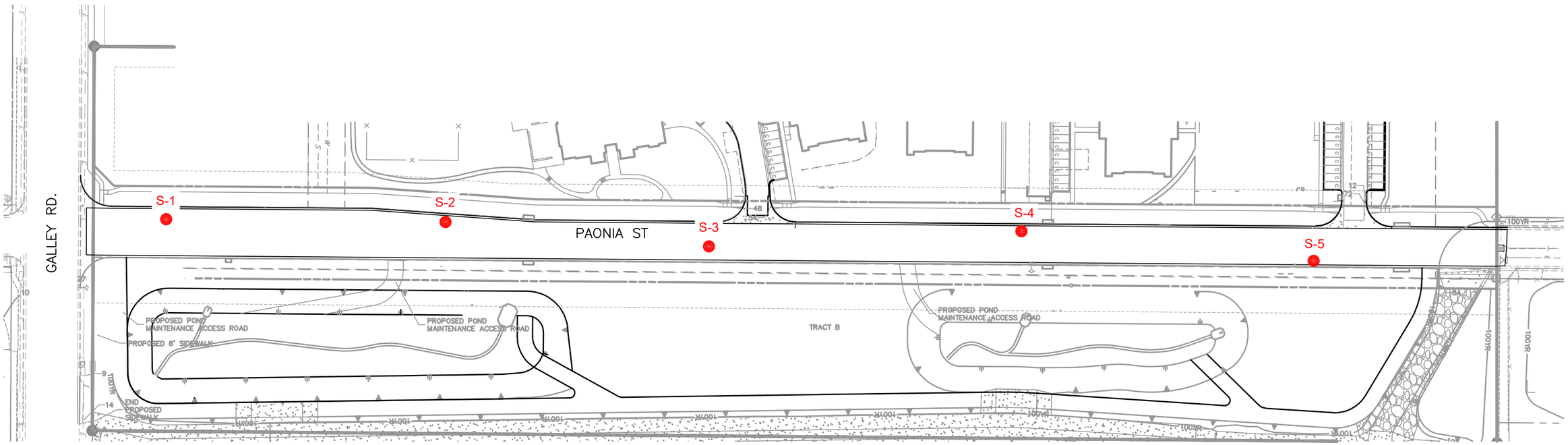
TH-1 — APPROXIMATE LOCATION OF EXPLORATORY BORING.





VICINITY MAP

(NOT TO SCALE)



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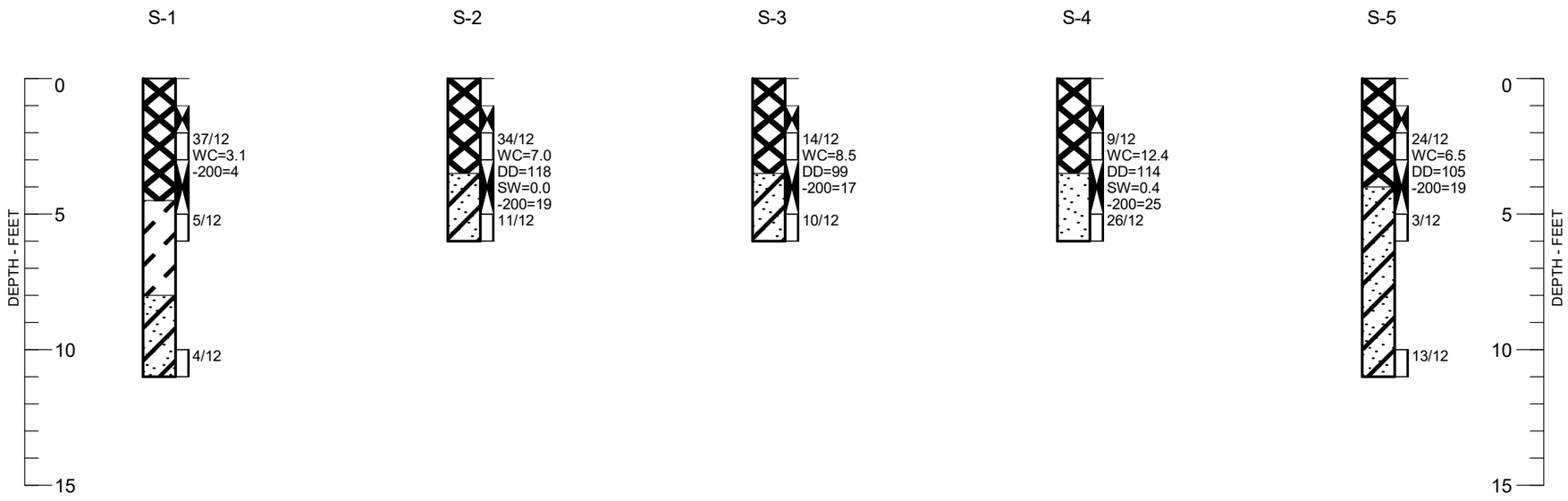
CTL|T PROJECT NO. CS19163.001-135

Location of Exploratory Borings

FIG. 1

APPENDIX A

SUMMARY LOGS OF EXPLORATORY BORINGS



LEGEND:

- FILL SAND, SILTY, DENSE, SLIGHTLY MOIST, LIGHT BROWN.
- CLAY, SANDY, MEDIUM STIFF, MOIST, GRAY, WITH RUST (CL).
- SAND, SILTY, LOOSE, MOIST, GRAY WITH RUST (SM).
- SAND, SLIGHTLY SILTY, MEDIUM DENSE, LIGHT BROWN (SP).
- DRIVE SAMPLE. THE SYMBOL 37/12 INDICATES 37 BLOWS OF A 140-POUND HAMMER FALLING 30 INCHES WERE REQUIRED TO DRIVE A 2.5-INCH O.D. SAMPLER 12 INCHES.
- INDICATES BULK SAMPLE OBTAINED FROM AUGER CUTTINGS.

NOTES:

1. THE BORINGS WERE DRILLED NOVEMBER 15, 2024 USING A 4-INCH DIAMETER, CONTINUOUS-FLIGHT AUGER AND A CME-45, TRUCK-MOUNTED DRILL RIG.

2. GROUNDWATER WAS NOT ENCOUNTERED IN THE EXPLORATORY BORINGS DURING THIS INVESTIGATION.

3. WC - INDICATES MOISTURE CONTENT. (%)
   DD - INDICATES DRY DENSITY. (PCF)
   SW - INDICATES SWELL WHEN WETTED UNDER APPROXIMATE OVERBURDEN PRESSURE. (%)
   LL - INDICATES LIQUID LIMIT. (NV : NO VALUE)
   PI - INDICATES PLASTICITY INDEX. (NP : NON-PLASTIC)
   -200 - INDICATES PASSING NO. 200 SIEVE. (%)
   SS - INDICATES WATER-SOLUBLE SULFATE CONTENT. (%)

4. THESE LOGS ARE SUBJECT TO THE EXPLANATIONS, LIMITATIONS, AND CONCLUSIONS AS CONTAINED IN THIS REPORT.

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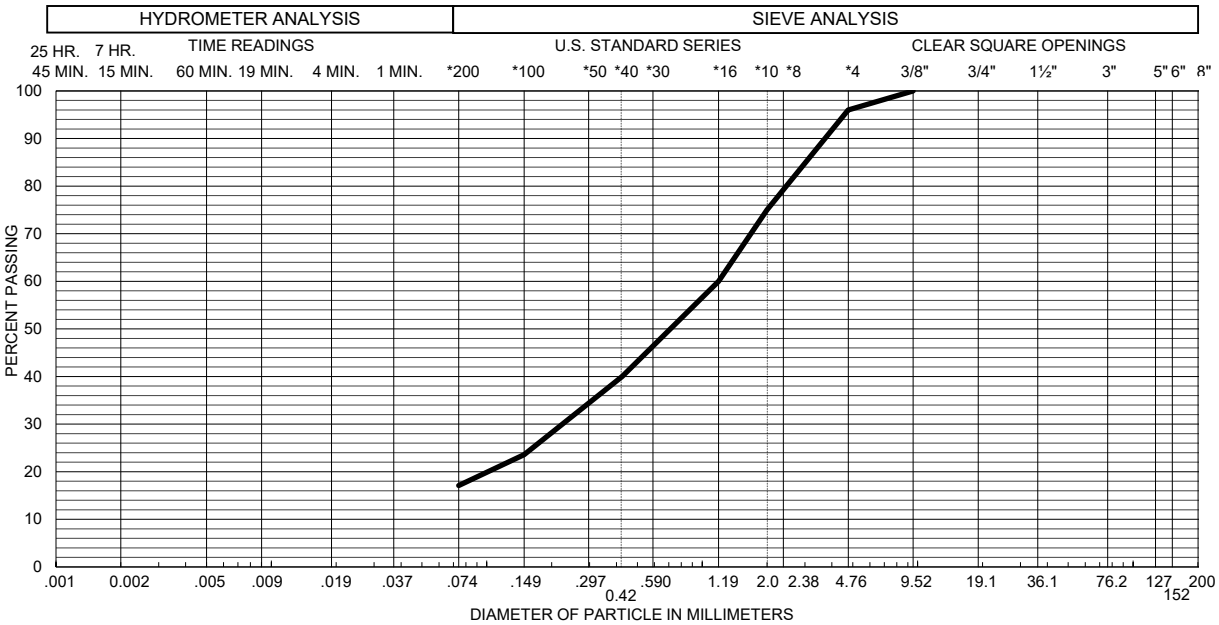
CTL|T PROJECT NO. CS19163.001

Summary Logs of Exploratory Borings

FIG. A-1

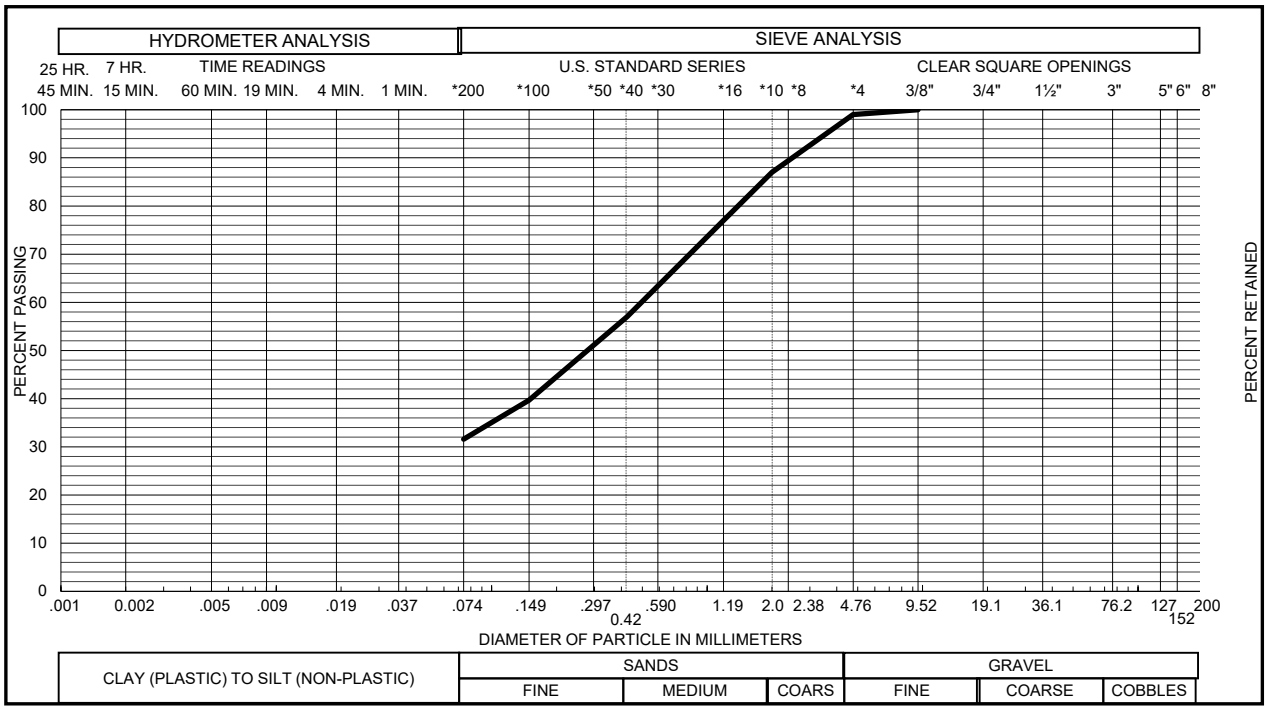
APPENDIX B

LABORATORY TEST RESULTS
TABLE B-I - SUMMARY OF LABORATORY TESTING



Sample of FILL, SAND, SILTY (SM) (A-1-b)
From S - 1 AT 1-5 FEET

GRAVEL 4 % SAND 79 %
SILT & CLAY 17 % LIQUID LIMIT NV
PLASTICITY INDEX NP



Sample of FILL, SANDY, SILTY-CLAYEY (SC-SM) (A-2-4)
From S - 2 AT 1-5 FEET

GRAVEL 1 % SAND 67 %
SILT & CLAY 32 % LIQUID LIMIT 25
PLASTICITY INDEX 7

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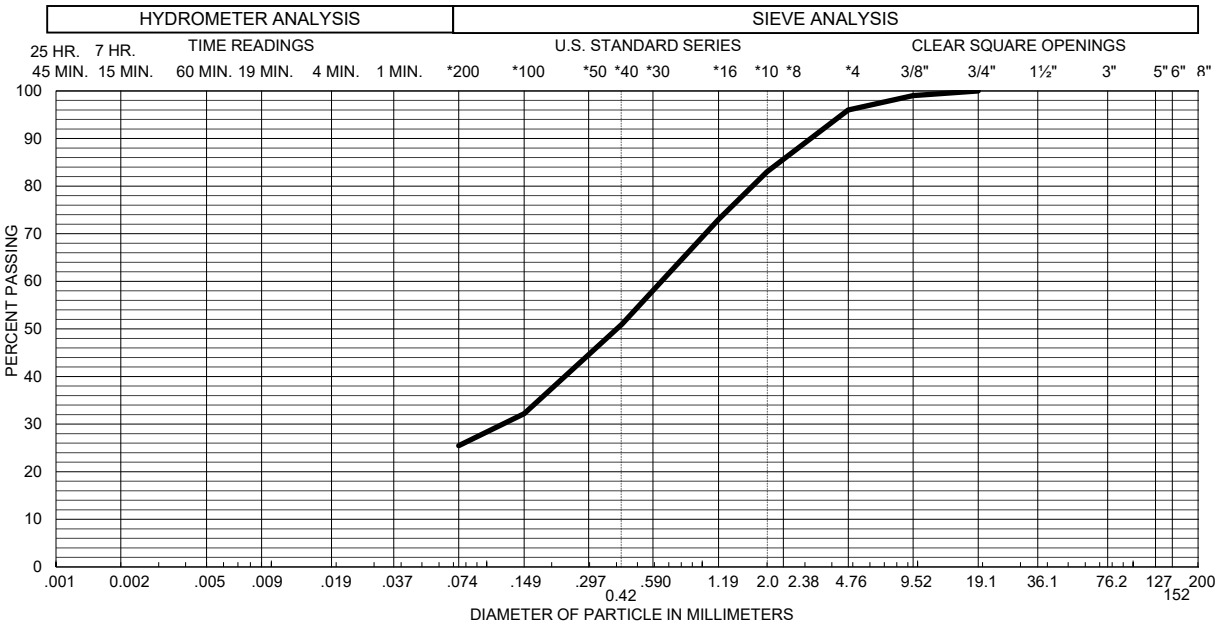
CTL|T PROJECT NO. CS19163.001-135

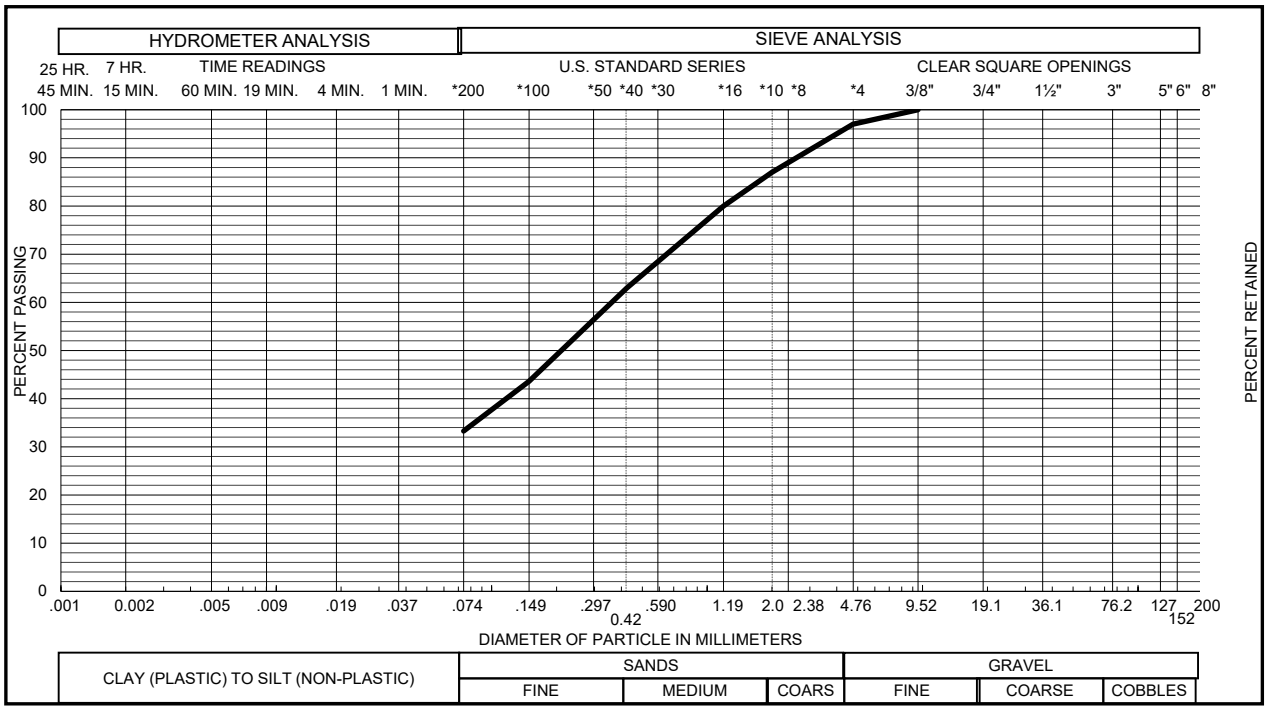
Gradation Test Results

FIG. B-1



Sample of FILL, SANDY, SILTY-CLAYEY (SC-SM) (A-2-4)
From S - 3 AT 1-5 FEET

GRAVEL 4 % SAND 70 %
SILT & CLAY 26 % LIQUID LIMIT 25
PLASTICITY INDEX 4



Sample of FILL, SAND, CLAYEY (SC) (A-2-4)
From S - 4 AT 1-5 FEET

GRAVEL 3 % SAND 64 %
SILT & CLAY 33 % LIQUID LIMIT 29
PLASTICITY INDEX 10

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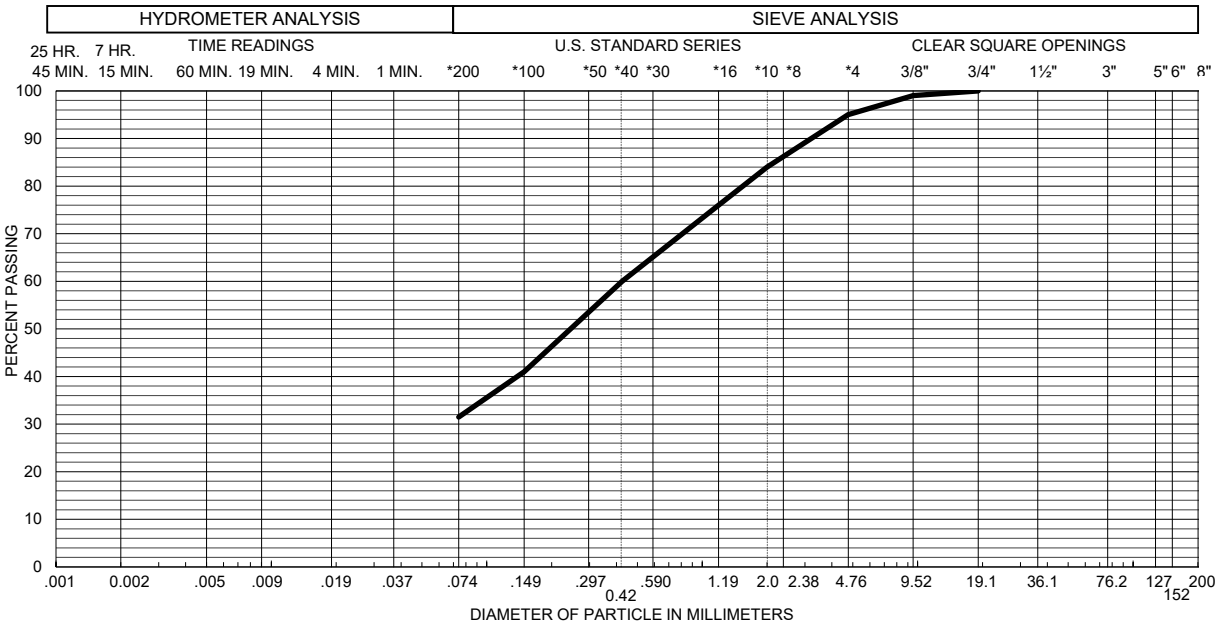
CTL|T PROJECT NO. CS19163.001-135

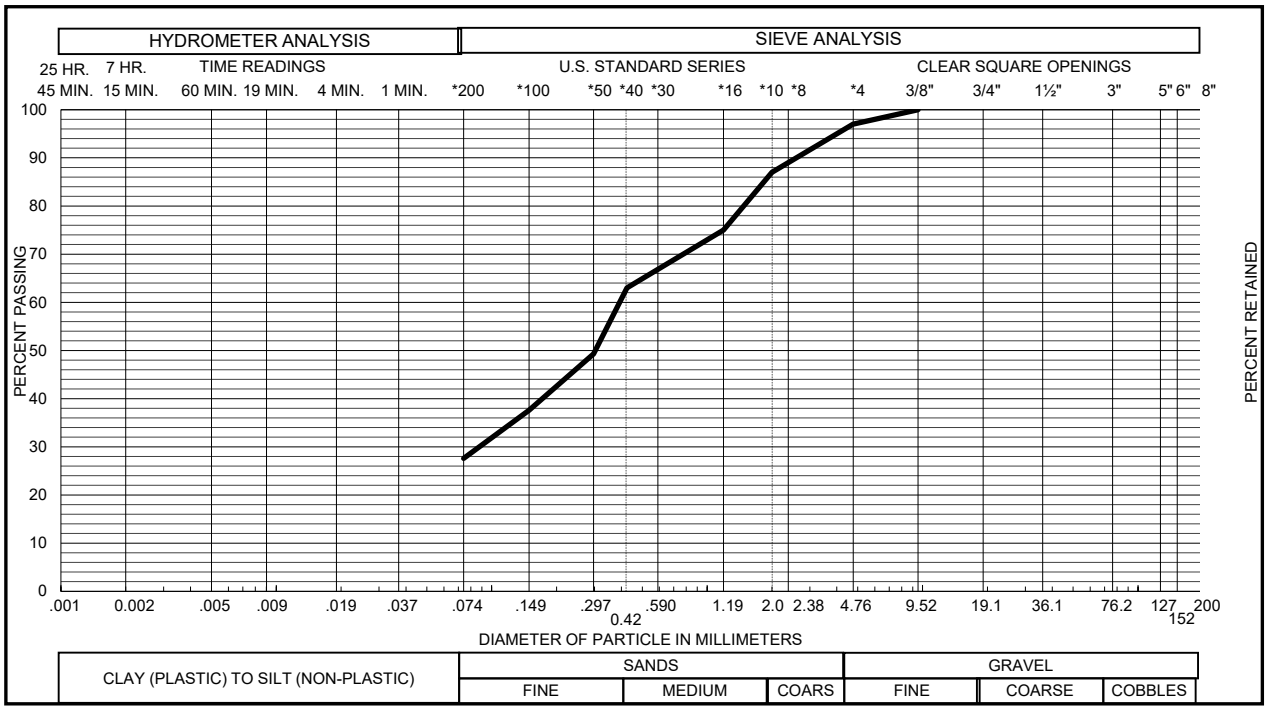
Gradation Test Results

FIG. B-2



Sample of FILL, SAND, CLAYEY, SLIGHTLY GRAVEELY (SC) (A
From S - 5 AT 1-5 FEET

GRAVEL 5 % SAND 63 %
SILT & CLAY 32 % LIQUID LIMIT 31
PLASTICITY INDEX 9



Sample of FILL, SAND, CLAYEY (SC) (A-2-4)
From COMBINED - B AT 1-5 FEET

GRAVEL 3 % SAND 69 %
SILT & CLAY 28 % LIQUID LIMIT 28
PLASTICITY INDEX 8

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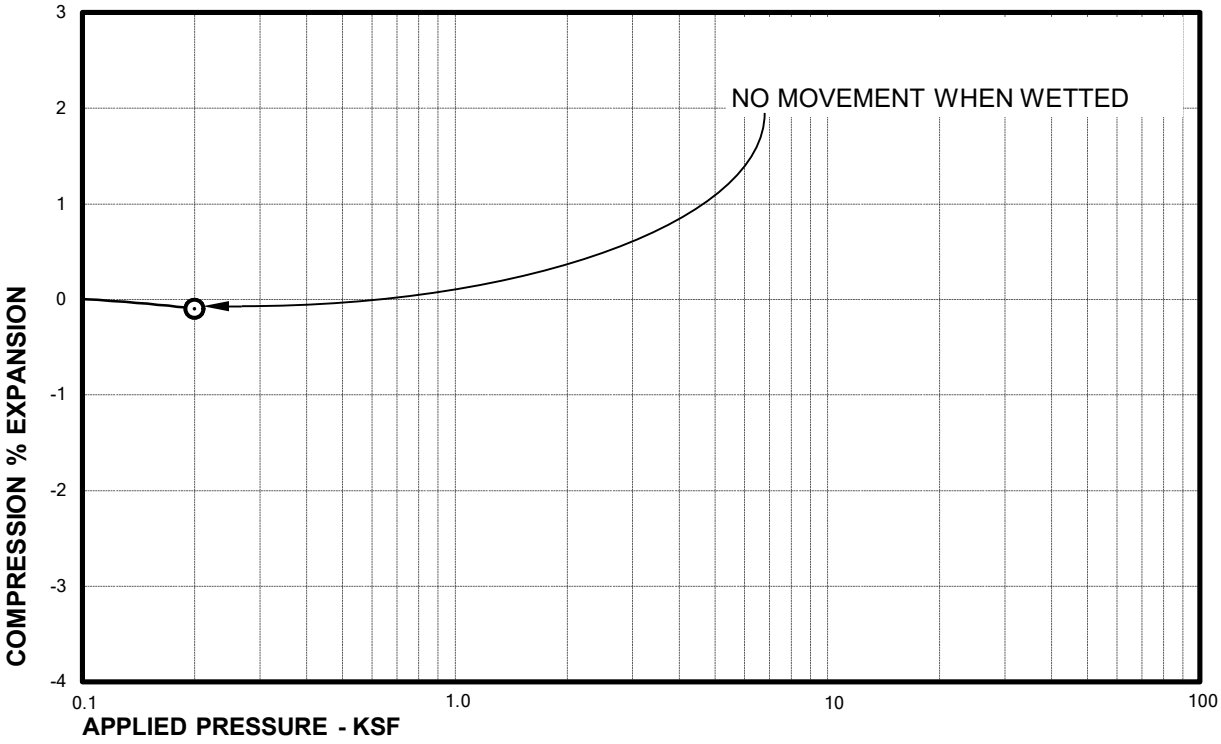
CTL|T PROJECT NO. CS19163.001-135

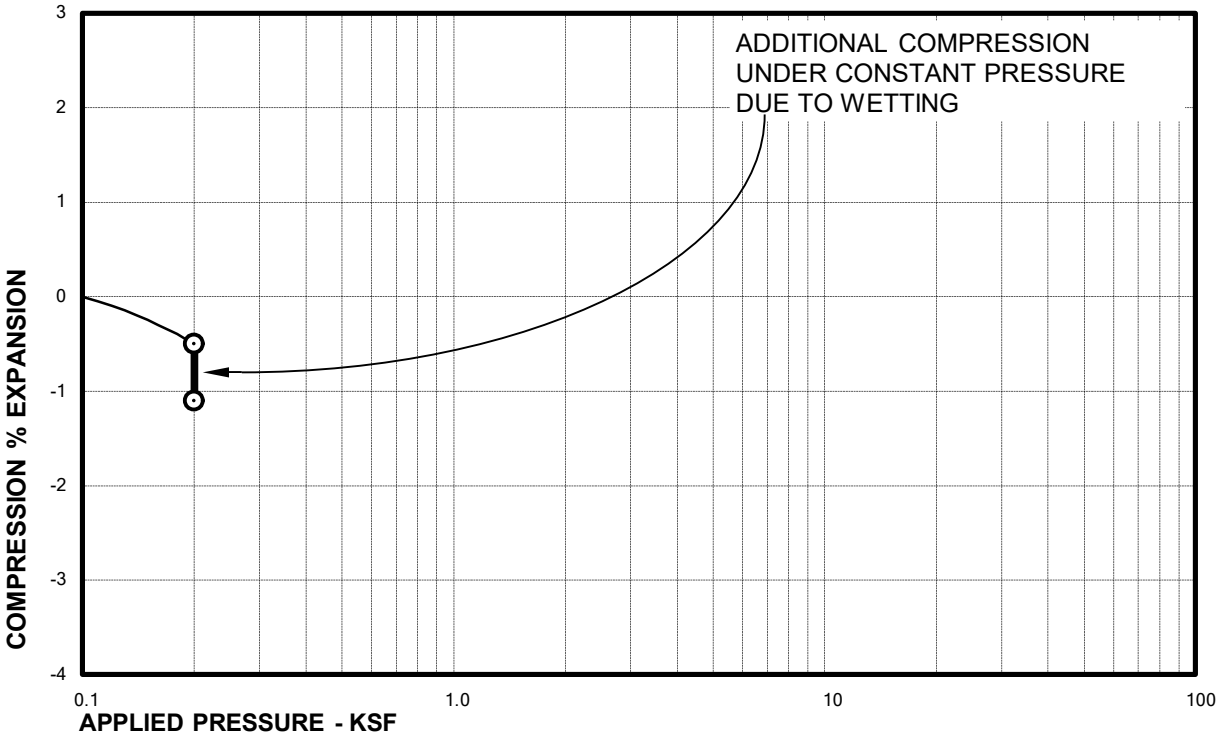
Gradation Test Results

FIG. B-3



Sample of FILL, SAND, SILTY-CLAYEY
From S-2 AT 2 FEET

DRY UNIT WEIGHT= 118 PCF
MOISTURE CONTENT= 7.0 %



Sample of FILL, SAND, SILTY-CLAYEY
From S-3 AT 2 FEET

DRY UNIT WEIGHT= 99 PCF
MOISTURE CONTENT= 8.5 %

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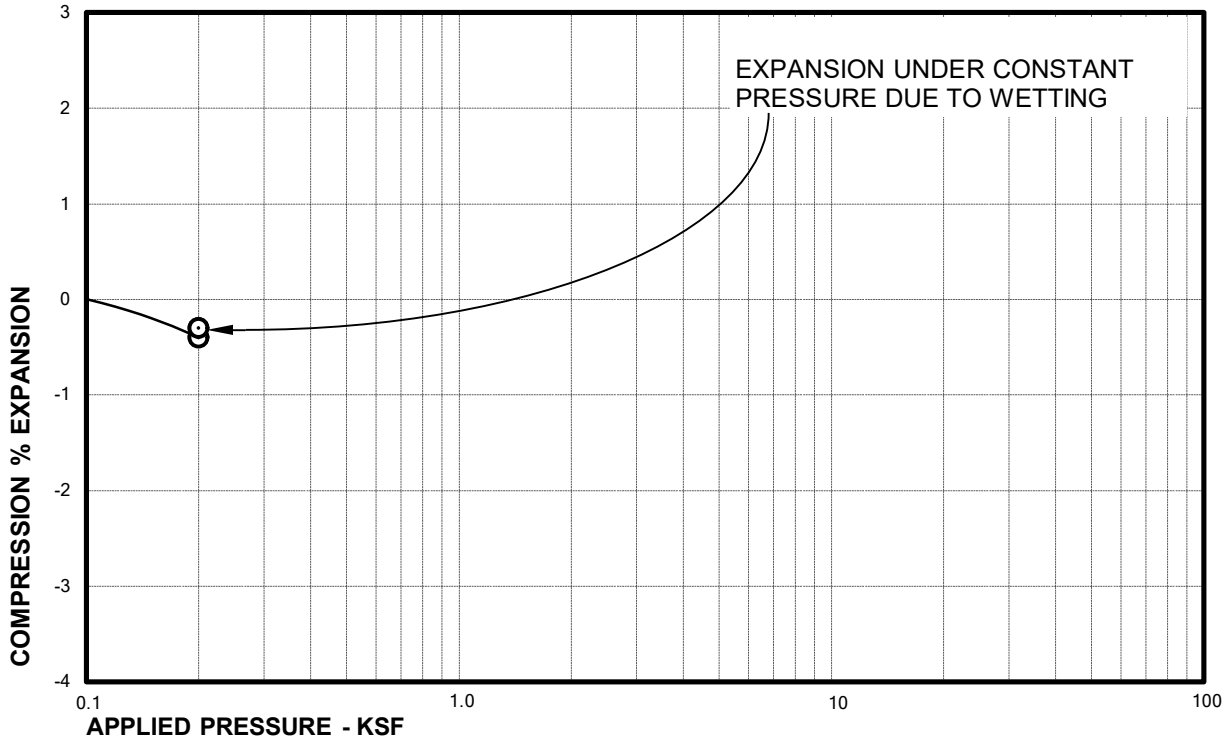
CTL|T PROJECT NO. CS19163.001-135

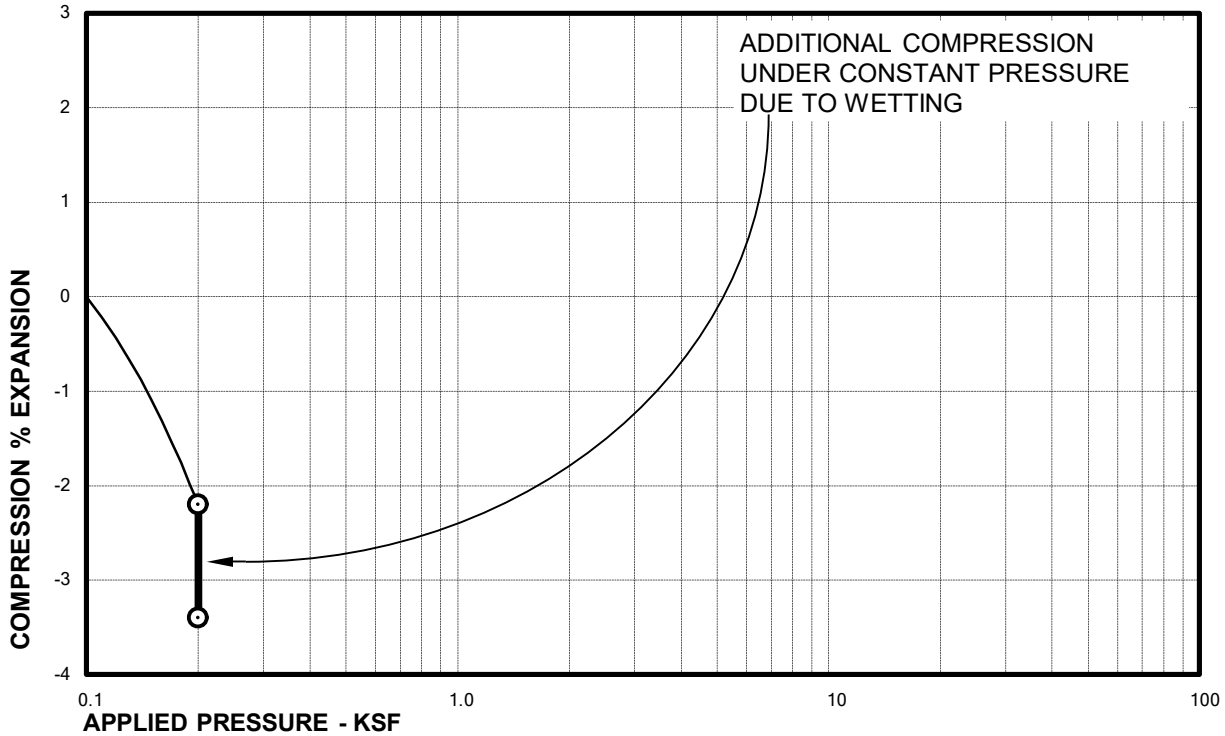
Swell Consolidation Test Results

FIG. B-4



Sample of FILL, SAND, CLAYEY
From S-4 AT 2 FEET

DRY UNIT WEIGHT= 114 PCF
MOISTURE CONTENT= 12.4 %



Sample of FILL, SAND, CLAYEY, SLIGHTLY GRAVELLY
From S-5 AT 2 FEET

DRY UNIT WEIGHT= 105 PCF
MOISTURE CONTENT= 6.5 %

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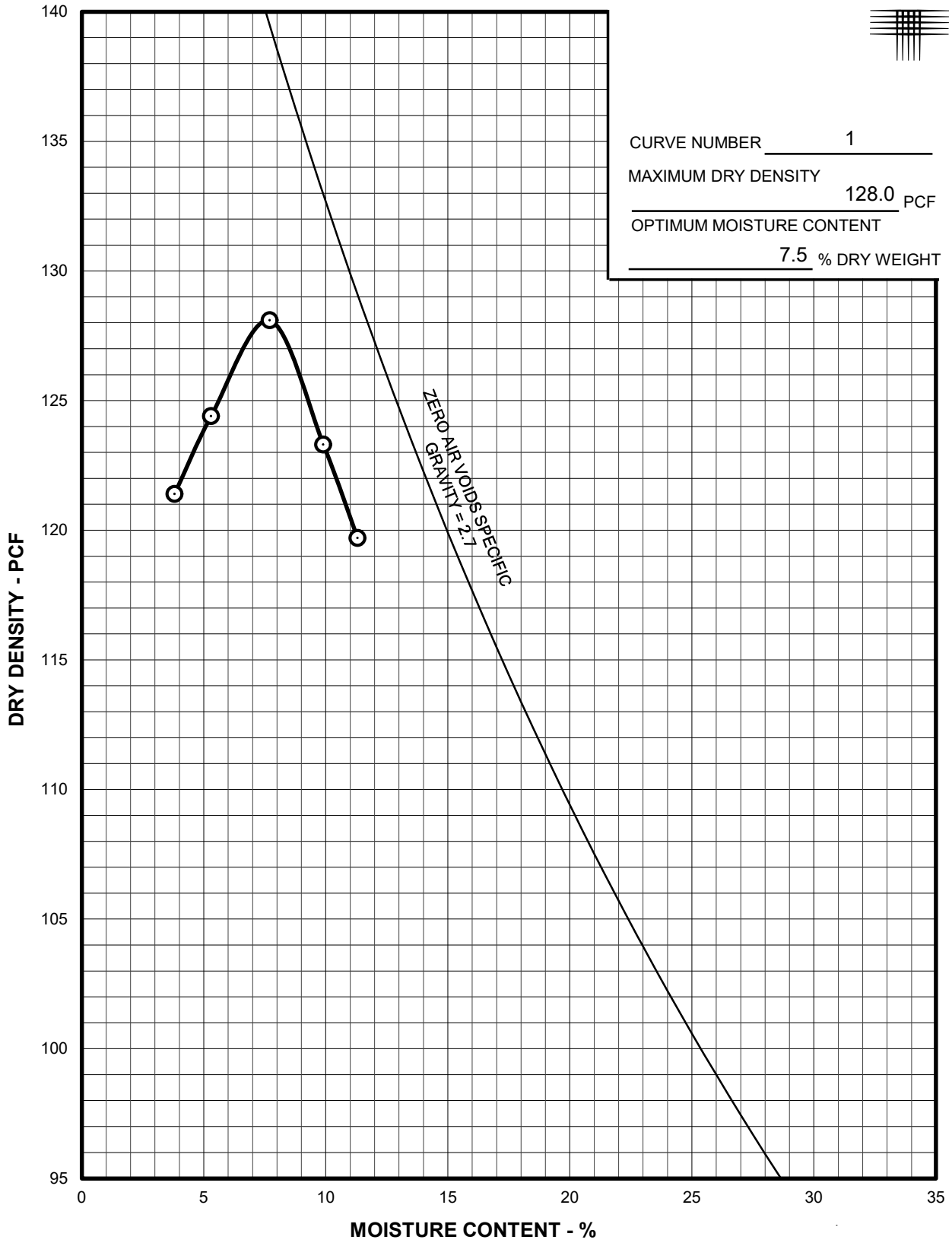
CTL|T PROJECT NO. CS19163.001-135

Swell Consolidation Test Results

FIG. B-5



Sample Description	Clayey sand, medium to dark brown	LIQUID LIMIT	28
		PLASTICITY INDEX	8
Location	Combined bulk samples from S-2, S-3, S-4, S-5	GRAVEL	3 %
		SAND	69 %
Compaction Test Procedure	ASTM D 1557 METHOD B	SILT AND CLAY	28 %
		DATE	11/25/2024

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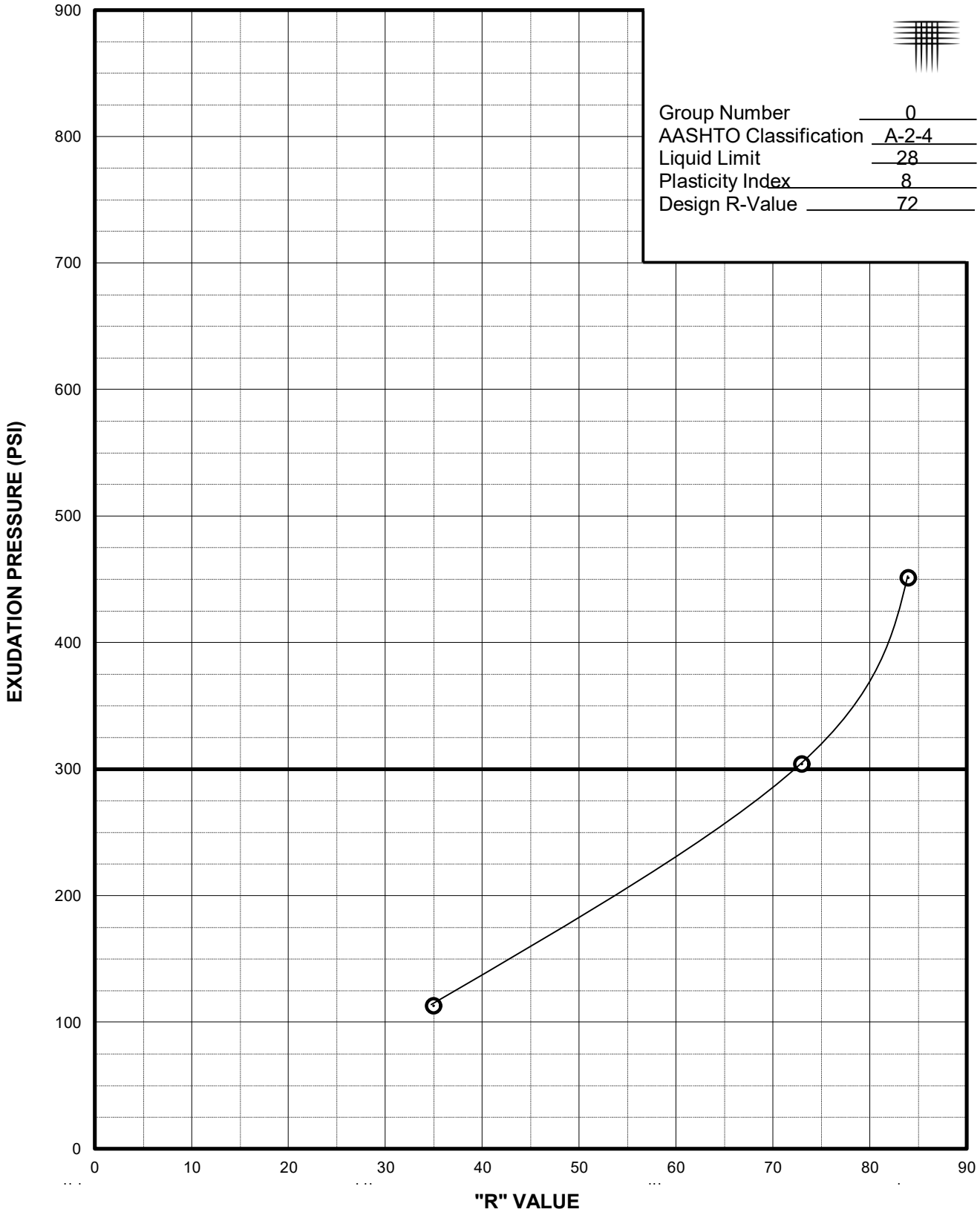
Laboratory Moisture-Density Test Results

FIG. B-6



Sample Location: COMBINED B

Sample Description: Fill, Sand, Clayey, Brown

Hveem Stabilometer

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PROJECT NO. CS19163.001-135

Fig. B-7

TABLE B-I

SUMMARY OF LABORATORY TESTING
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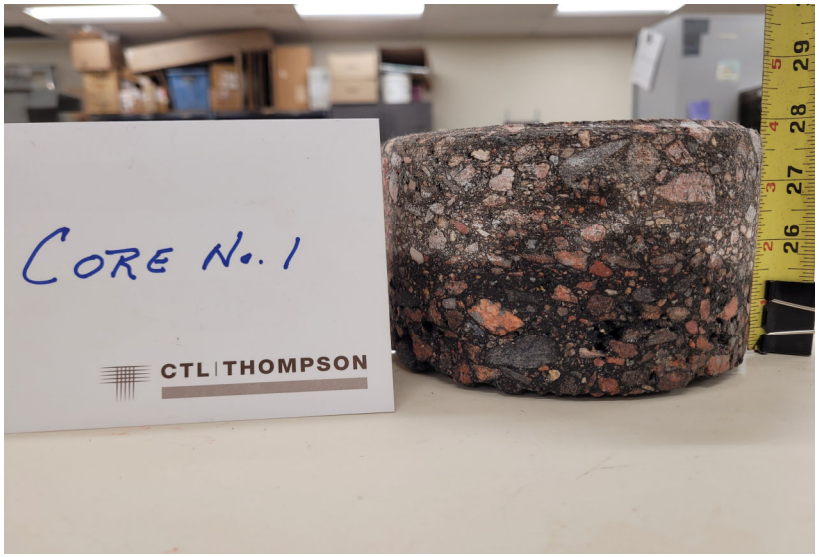
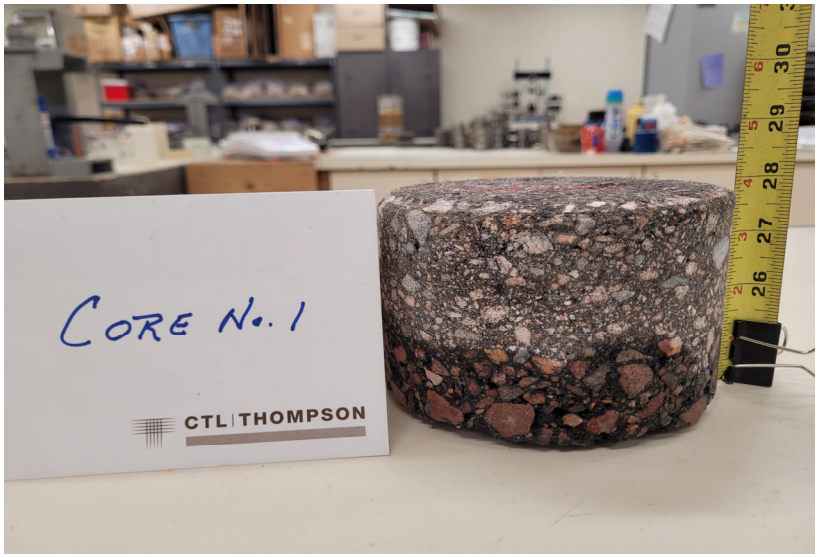
SUBGRADE SAMPLE	DEPTH (FEET)	GROUP NAME	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	ATTERBERG LIMITS		SWELL* (%)	PASSING NO. 200 SIEVE (%)	WATER SOLUBLE SULFATES (%)	GROUP INDEX	CLASSIFICATION		DESCRIPTION
					LIQUID LIMIT	PLASTICITY INDEX					AASHTO	UNIFIED	
S-1	1-5	A	4.7		NV	NP		17		0	A-1-b	SM	FILL, SAND, SILTY
S-2	1-5	B	8.4		25	7		32		0	A-2-4	SC-SM	FILL, SAND, SILTY-CLAYEY
S-3	1-5	B	8.2		25	4		26	<0.1	0	A-2-4	SC-SM	FILL, SAND, SILTY-CLAYEY
S-4	1-5	B	11.2		29	10		33	<0.1	0	A-2-4	SC	FILL, SAND, CLAYEY
S-5	1-5	B	9.7		31	9		32		0	A-2-4	SC	FILL, SAND, CLAYEY, SLIGHTLY GRAVELLY
S-1	2		3.1					4				SP	FILL, SAND
S-2	2		7.0	118			0.0	19				SC-SM	FILL, SAND, SILTY-CLAYEY
S-3	2		8.5	99			-0.6	17				SC-SM	FILL, SAND, SILTY-CLAYEY
S-4	2		12.4	114			0.4	25				SC	FILL, SAND, CLAYEY
S-5	2		6.5	105			-1.2	19				SC	FILL, SAND, CLAYEY, SLIGHTLY GRAVELLY
COMBINED	B		8.9		28	8		28		0	A-2-4	SC	FILL, SAND, CLAYEY

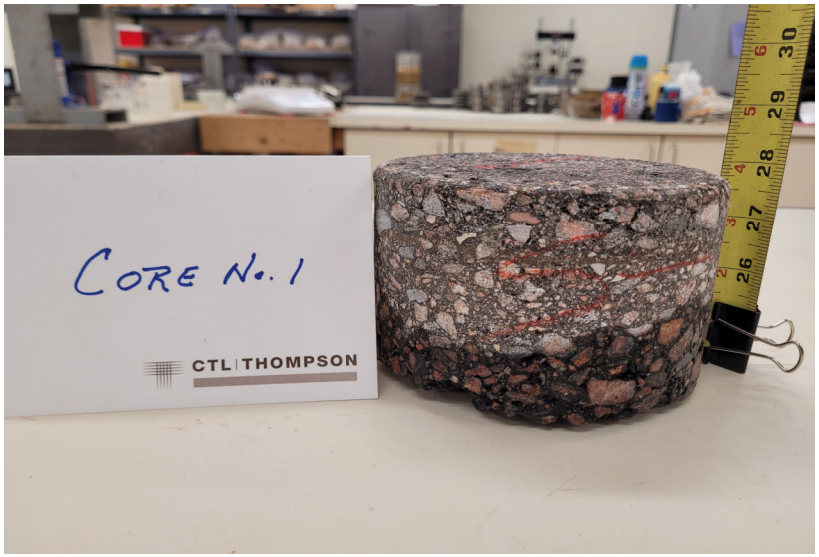
* SWELL MEASURED WITH 200 PSF APPLIED PRESSURE.

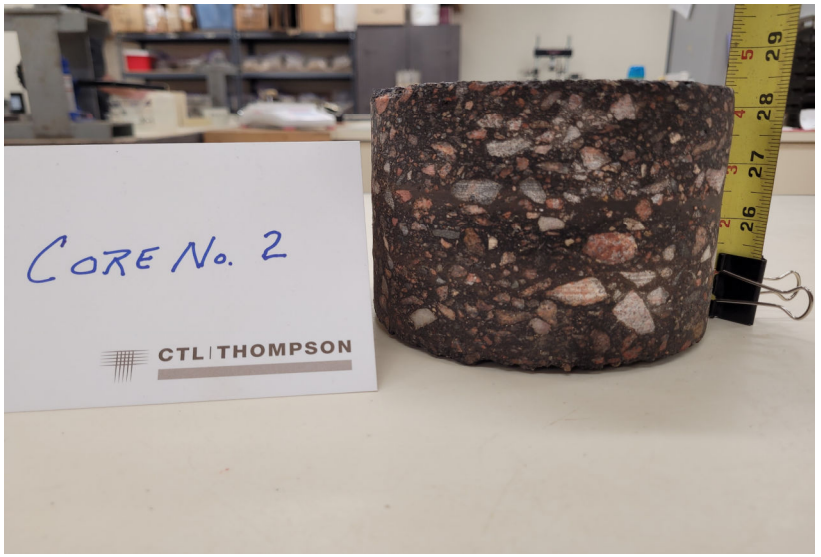
APPENDIX C

ASPHALT LABORATORY TEST RESULTS AND CORE PICTURES









SUB4 DEVELOPMENT CORPORATION
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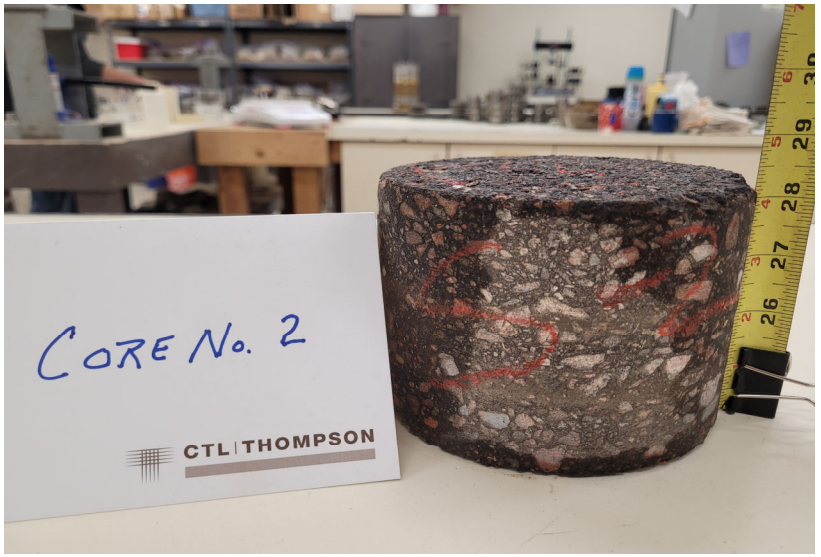
CTL|T PROJECT NO. CS19163.001-135
C:\USERS\DPELHAM\APPDATA\LOCAL\BOX\BOX EDIT\DOCUMENTS\B9PPNPFNUK6ARSCZJC13AQ==\CS19163.001-135 AC PICTURES.XLS

FIG. C-1



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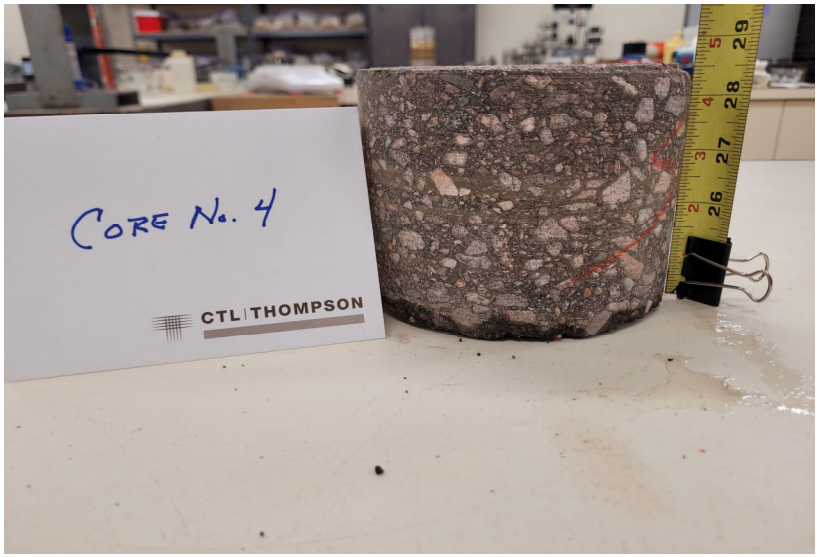
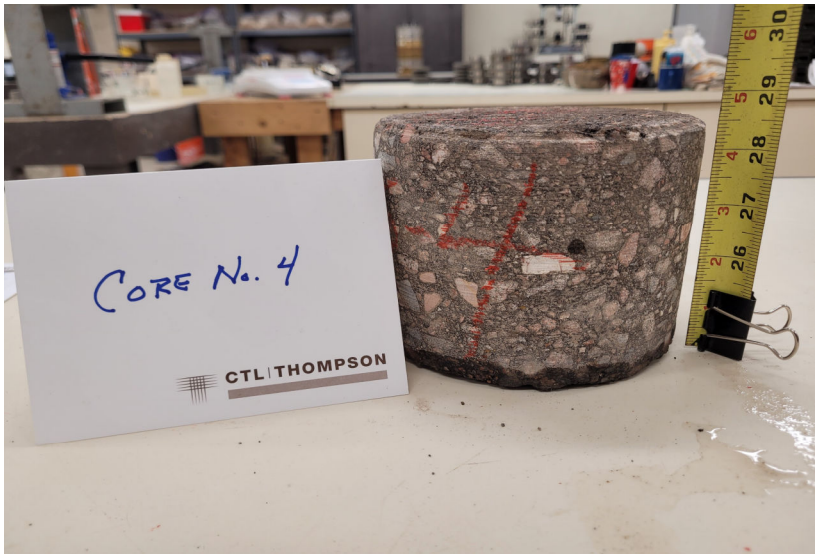
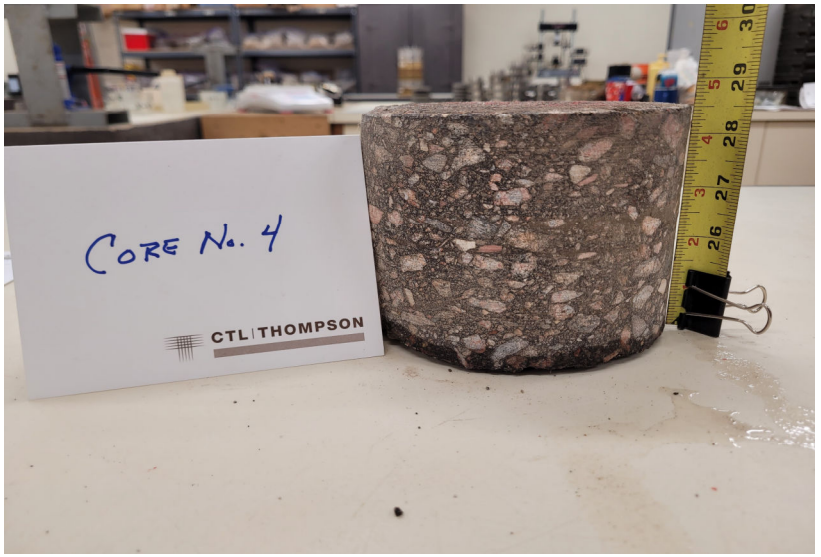
SOLACE COLORADO SPRINGS
CTL|T PROJECT NO. CS19163.001-135
C:\USERS\DPELHAM\APPDATA\LOCAL\BOX\BOX EDIT\DOCUMENTS\B9PPNPFNUK6ARSCZJC13AQ==\CS19163.001-135 AC PICTURES.XLS

FIG. C-2







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CTL|T PROJECT NO. CS19163.001-135
C:\USERS\DPELHAM\APPDATA\LOCAL\BOX\BOX EDIT\DOCUMENTS\B9PPNPFNUK6ARSCZJC13AQ==\CS19163.001-135 AC PICTURES.XLS

FIG. C-3

SUB4 DEVELOPMENT CORPORATION
SOLACE COLORADO SPRINGS
CTL|T PROJECT NO. CS19163.001-135
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Asphalt Concrete Material Analysis

CTL | THOMPSON INCORPORATED

CLIENT: Sub4 Development Corporation
PROJECT: Solace Colorado Springs
PROJECT NO: CS19163.001-135
SAMPLE DATE: 11/15/2024

SIEVE SIZE	5462- CS MARTIN MARIETTA SX-75		PERCENT PASSING	
	MIX DESIGN	PROJECT TOLERANCE		
2 INCH	-	-		
1-1/2 INCH	100	100		
1 INCH	100	100		
3/4 INCH	100	100	100	
1/2 INCH	94	88 - 100	94.3	
3/8 INCH	87	81 - 93	84.6	
NO. 4	66	61 - 71	64.3	
NO. 8	48	43 - 53	49	
NO. 16	36	-	37.6	
NO. 30	26	22 - 30	27.3	
NO. 50	17	-	18.9	
NO. 100	10	-	12.3	
NO. 200	6.3	4.3 - 8.3	8.3	
ASPHALT CONTENT [1]	5.5	5.1 - 5.9	5.8	
FIELD MIX TEMP (°F)				
UNIT WEIGHT	153.0	-	152.4	
% AIR VOIDS	3.5	-		
VMA	15.0	-		
LOTTMAN	-	-		

[1] WEIGHT OF AGGREGATE AND OIL USED TO DETERMINE ASPHALT CONTENT

SUB4 DEVELOPMENT CORPORATION
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REVIEWED BY: Dennis E. Pelham
FIG. C-5

APPENDIX D

DESIGN CALCULATIONS

Flexible Structural Design

Roadway(s): Paonia Street - Urban Residential Collector

Soil Type(s): Clayey Sand (SC) (A-2-4)

Reliability	85	%
Standard Deviation	0.44	
Initial Serviceability	4.5	
Terminal Serviceability	2.5	
Resilient Modulus	27,027	psi
Design ESALs	821,000	

Design Structural Number
1.94

Layers	Structural Coefficient	Drainage	Thickness	SN
HMA	0.44	1	4	1.76
ABC	0.11	1	8	0.88
			SUM	2.64

APPENDIX E

GUIDELINE MAINTENANCE RECOMMENDATIONS
FOR FLEXIBLE AND RIGID PAVEMENTS

MAINTENANCE RECOMMENDATIONS FOR FLEXIBLE PAVEMENTS

A primary cause for deterioration of pavements is oxidative aging resulting in brittle pavements. Tire loads from traffic are necessary to "work" or knead the asphalt concrete to keep it flexible and rejuvenated. Preventive maintenance treatments will typically preserve the original or existing pavement by providing a protective seal or rejuvenating the asphalt binder to extend pavement life.

1. Annual Preventive Maintenance

    a. Visual pavement evaluations should be performed each spring or fall.
    b. Reports documenting the progress of distress should be kept current to provide information on effective times to apply preventive maintenance treatments.
    c. Crack sealing should be performed annually as new cracks appear.

2. 3 to 5 Year Preventive Maintenance

    a. The owner should budget for a preventive treatment at approximate intervals of 3 to 5 years to reduce oxidative embrittlement problems.
    b. Typical preventive maintenance treatments include chip seals, fog seals, slurry seals and crack sealing.

3. 5 to 10 Year Corrective Maintenance

    a. Corrective maintenance may be necessary, as dictated by the pavement condition, to correct rutting, cracking and structurally failed areas.
    b. Corrective maintenance may include full-depth patching, milling and overlays.
    c. In order for the pavement to provide a 20-year service life, at least one major corrective overlay should be expected.

MAINTENANCE RECOMMENDATIONS FOR RIGID PAVEMENTS

High traffic volumes create pavement rutting and smooth, polished surfaces. Preventive maintenance treatments will typically preserve the original or existing pavement by providing a protective seal and improving skid resistance through a new wearing course.

1. Annual Preventive Maintenance

    a. Visual pavement evaluations should be performed each spring or fall.
    b. Reports documenting the progress of distress should be kept current to provide information of effective times to apply preventive maintenance.
    c. Crack sealing should be performed annually as new cracks appear.

2. 4 to 8 Year Preventive Maintenance

    a. The owner should budget for a preventive treatment at approximate intervals of 4 to 8 years to reduce joint deterioration.
    b. Typical preventive maintenance for rigid pavements include patching, crack sealing and joint cleaning and sealing.
    c. Where joint sealants are missing or distressed, resealing is mandatory.

3. 15 to 20 Year Corrective Maintenance

    a. Corrective maintenance for rigid pavements includes patching and slab replacement to correct subgrade failures, edge damage and material failure.
    b. Asphalt concrete overlays may be required at 15 to 20 year intervals to improve the structural capacity of the pavement.