ENTECH
ENGINEERING, INC.

505 ELKTON DRIVE
COLORADO SPRINGS, CO 80907
PHONE (719) 531-5599

PAVEMENT DESIGN REPORT
LEWIS-PALMER MIDDLE SCHOOL
MONUMENT, COLORADO

Prepared for:

Felsburg, Holt, and Ullevig, Inc.
3 South Tejon Street, Suite 300
Colorado Springs, CO 80903

Attn: Steve Bodette

September 12, 2023

Respectfully Submitted,

ENTECH ENGINEERING, INC.

COLORADO LICENSED PROFESSIONAL ENGINEER JOSEPH C GOODE III 52381

Digitally signed by Joseph C Goode III
Date: 2023.09.12 17:16:06 -06'00'

Joseph C. Goode III, P.E.
Project Engineer

Reviewed by:

Joseph C. Goode Jr., P.E.
President

JCG/

Entech Job No. 231321

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1 Introduction

Entech Engineering Inc. (Entech) completed a subsurface investigation for the proposed drive lane and parking lot improvements at Lewis-Palmer Middle School in Monument, Colorado. This report describes the subsurface investigation conducted for the proposed project and provides pavement section alternatives and construction recommendations. Our services were completed for Felsburg, Holt, and Ullevig Inc. (FHU) in accordance with our Agreement for Subconsultant Services dated June 14, 2023. The contents of this report, including the geotechnical evaluation and recommendations, are subject to the limitations and assumptions presented in Section 7.

2 Project Description

The proposed improvements include a new access drive lane and parking lot surfacing at Lewis-Palmer Middle School, located at 1776 Woodmoor Dr in Monument, Colorado. The proposed drive lane will extend southwest from Woodmoor Drive to the existing northeast corner of the existing parking lot. We understand that traffic loading will include school bus traffic and passenger vehicles associated with the school. The current traffic loading of the parking lot does not include school busses.

3 Subsurface Explorations and Laboratory Testing

Subsurface conditions at the project site were explored with six test borings on August 10, 2023. The locations of the test borings are shown on the Test Boring Location Map, Figure 1. TB-1 through TB-3 were drilled in the proposed bus access roadway and TB-4 through TB-6 were drilled in the existing parking lot. Prior to drilling the parking lot borings asphalt cores were recovered and returned to our laboratory for further analysis which is provided in Appendix A. The existing pavement section consisted of 4 to 4-1/2 inches of hot mix asphalt (HMA) over 2 to 4 inches of aggregate base course (ABC). The borings were drilled to depths of 10 feet below the existing ground surface (bgs). The drilling was performed using a truck-mounted, continuous flight auger drill rig supplied and operated by Entech. Descriptive boring logs of the subsurface conditions encountered during drilling are presented in Appendix A. Groundwater levels were measured in each of the open boreholes at the conclusion of drilling.

Soil and bedrock samples were obtained from the borings utilizing the Standard Penetration Test (ASTM D-1586) using a split-barrel California sampler. Results of the Standard Penetration Test (SPT) are included on the boring logs in terms of N-values expressed in blows per foot (bpf). Soil samples recovered from the borings were visually classified and recorded on the boring logs. The soil classifications were later verified utilizing laboratory testing and grouped by soil type. The soil type numbers are included on the boring logs. It should be understood that the soil descriptions shown on the boring logs may vary between boring location and sample depths. It should also be noted that the lines of stratigraphic separation shown on the boring logs represent approximate boundaries between soil types and the actual stratigraphic transitions may be more gradual or variable with location.

Water content testing (ASTM D-2216) was performed on the samples recovered from the borings, and the results are shown on the boring logs. Grain-Size Analysis (ASTM D422) and Atterberg Limits testing (ASTM D4318) were performed on selected samples to assist in classifying the materials encountered in the borings. For pavement design, a modified proctor (ASTM D1557) and California Bearing Ratio (CBR) test (ASTM D1883) were completed. Soluble sulfate testing was performed on select soil samples to evaluate the potential for below grade degradation of concrete due to sulfate attack. The laboratory testing results are presented in Appendix B and summarized in Table B-1.

4 Subgrade Conditions

Two primary soil types were encountered in the test borings drilled for the subsurface investigation. Each soil type was classified in accordance with the Unified Soil Classification System (USCS) and the American Association of State Highway and Transportation Officials (AASHTO) soil classification system using the laboratory testing results and the observations made during drilling.

4.1 Subsurface Conditions

Subsurface conditions along the proposed access drive and the parking lot subgrade consisted of silty sand fill to sand with silt fill (Soil Type 1), native silty sand and sand with silt and gravel (Soil Type 2), and sandstone bedrock, or very dense silty sand when classified as a soil (Soil Type 3). (Soil Types 2 and 3) were located below the zone of subgrade influence. The Type 1 and Type 2 subgrade soils classify as A-1-b soils using the AASHTO classification system. Groundwater was not encountered in the test borings. Water soluble sulfate tests results indicated that the soils exhibit a negligible potential for sulfate attack

4.2 Groundwater

Groundwater was not encountered in the test borings. Groundwater fluctuations are likely and will depend on seasonal variations, local precipitation, runoff, and other factors. We do not anticipate groundwater to affect the proposed construction.

5 Pavement Design Recommendations

Pavement design recommendations were made in accordance with the City of Colorado Springs Pavement Design Criteria Manual.

5.1 Subgrade Conditions

California Bearing Ratio (CBR) testing was performed on a representative sample of the subgrade silty sand (Soil Type 1) from TB-5 to determine the support characteristic of the subgrade soils for the roadway sections. The results of the CBR testing are presented in Appendix B and summarized in Exhibit 1.

Exhibit 1: Subsurface Laboratory Testing Summary

Design Parameter	Value
Soil Type	1 – Silty Sand Fill
CBR at 95%	19.5
Design CBR	10
Liquid Limit	NV
Plasticity Index	NP
Percent Passing 200	17.7
AASHTO Classification	A-1-b
Group Index	0
Unified Soils Classification	SM

5.2 Swell Mitigation

Based on the A-1-b soils encountered on site, mitigation of expansive soils is not required on this site. Laboratory test results are presented in Appendix B and are summarized in Table B-1.

5.3 Traffic Loading

Based on discussions with FHU, bus loading for the drive lane and parking areas will consist of approximately 20 busses per day. To determine the design 18-kip equivalent single axle loading (ESAL), we assumed 2 passes per bus per day, for 5 days a week for a maximum of 40 weeks per year. Using these inputs, we calculated a design ESAL of 450,000 for a twenty-year design life.

5.4 Pavement Design

The recommended pavement sections were determined utilizing the Colorado Springs Pavement Design Manual (which is used by the Town of Monument), the CBR testing, and calculated ESAL value. Design parameters used in the pavement analysis are presented in Exhibit 2.

Exhibit 2: Pavement Design Parameters

Design Parameter	Value
Reliability	85%
Standard Deviation	0.44
Serviceability Loss (Δ psi)	2.5
Design CBR	10
Resilient Modulus	15,000 psi
Structural Coefficients	
HMA	0.44
Existing HMA	0.24
ABC	0.12
Existing ABC	0.10

ABC = aggregate base course; HMA = hot mix asphalt; psi = pounds per square inch

The existing asphalt is in good condition with occasional cracking noted in the parking lot and drive aisles. The age of the existing asphalt is unknown, however appears to have been overlayed after May, 2020 based on aerial imagery. If heavier bus traffic is routed through the existing parking lot a design life of less than 4 years would be expected, depending on when the last overlay was completed. As shown in Exhibit 2, when completing HMA overlays, the structural coefficient for existing HMA and existing ABC is reduced. The reduction in structural layer coefficients creates the need for thicker total pavement sections when compared with a new pavement section. The overlay and new construction pavement sections recommended for the drive lane and parking area are summarized in Exhibit 3. The pavement design calculations are presented in Appendix C.

Exhibit 3: Recommended Pavement Sections for Parking and Drive Aisles

Construction Type	Design Life	Design ESAL	Alternative
Rehabilitation	4 years	85,000	2.0-inch mill with 2.0 inches HMA overlay [1]
	8 years	180,000	2.0-inch mill with 2.5 inches HMA overlay [1,2]
New Construction	20 years	450,000	4.0 inches HMA over 6.0 inches ABC

ABC = Aggregate Base Course; ESAL = equivalent single axle loads; HMA = Hot Mix Asphalt

Notes:

1. Based on an existing section of 4 inches HMA over 3 inches ABC.
2. Requires a 0.5-inch grade raise.

6 Construction Recommendations

Pavement design recommendations provided herein are contingent on good construction practices, and poor construction techniques may result in poor performance. Our analyses assumed that this project is constructed according to the Colorado Springs Standard Specifications Manual, and the Pikes Peak Region Asphalt Paving Specifications.

6.1 Earthwork Recommendations for Pavement Subgrade

6.1.1 Subgrade Preparation

Proper subgrade preparation is required for adequate pavement performance. Paving areas should be cleared of all deleterious materials including but not limited to; existing pavements, utility poles, vegetation, tree roots, and fence poles. Existing asphalt should be removed or reclaimed in place by pulverizing and integrating into the subgrade materials. Surface vegetation should be removed by stripping, with the depth to be field determined.

The final subgrade surface should be scarified to a depth of 12 inches, moisture conditioned within +/-2% of the optimum water content and recompacted to 95% of its maximum Modified Proctor dry density, ASTM D1557. The compacted surface below pavements should be proof-rolled with a fully loaded, tandem-axle, 10-yard dump truck or equivalent. Any areas that are delineated to be soft, loose, or yielding during proof-rolling should be removed and reconditioned, or replaced.

6.1.2 Import Fill, Placement, and Compaction

Import fill for the project, if required, shall consist of import granular fill. Granular fill placed as part of the subgrade overexcavation shall consist of non-expansive, granular soil, free of organic matter, unsuitable materials, debris and cobbles greater than 3-inches in diameter. Additionally, Any granular fill placed as part of the roadway subgrade should have a minimum CBR of 10. All granular fill placed within the pavement subgrade should be compacted to a minimum of 95% of its maximum Modified Proctor Dry Density (ASTM D1557) at +/-2% of optimum moisture content. Fill material should be placed in horizontal lifts such that each finished lift has a compacted thickness of six inches or less. Entech should approve any imported fill to be used within the pavement subgrade area prior to delivery to the site.

6.2 Aggregate Base Course

ABC materials shall conform to the Colorado Springs Standard Specifications, Section 300 Aggregate Base Course. ABC materials should be compacted to a minimum of 95% of its maximum Modified Proctor Dry Density (ASTM D1557) at +/-2% of optimum moisture content.

6.3 Concrete Degradation Due to Sulfate Attack

Sulfate solubility testing was conducted on samples recovered from the test borings and indicated between less than 0.01% soluble sulfate (by weight). The test results indicate the sulfate component of the in-place soils present a negligible exposure threat to concrete in contact with site soils.

Type I/II cement is recommended for concrete on the site. To further avoid concrete degradation during construction it is recommended that concrete not be placed on frozen or wet ground. Care should be taken to prevent the accumulation or ponding of water in the foundation excavation prior to the placement of concrete. If standing water is present in the foundation excavation, it should be removed by ditching to sumps and pumping the water away from the foundation area prior to concrete placement. If concrete is placed during periods of cold temperatures, the concrete must be kept from freezing. This may require covering the concrete with insulated blankets and adding heat to prohibit freezing.

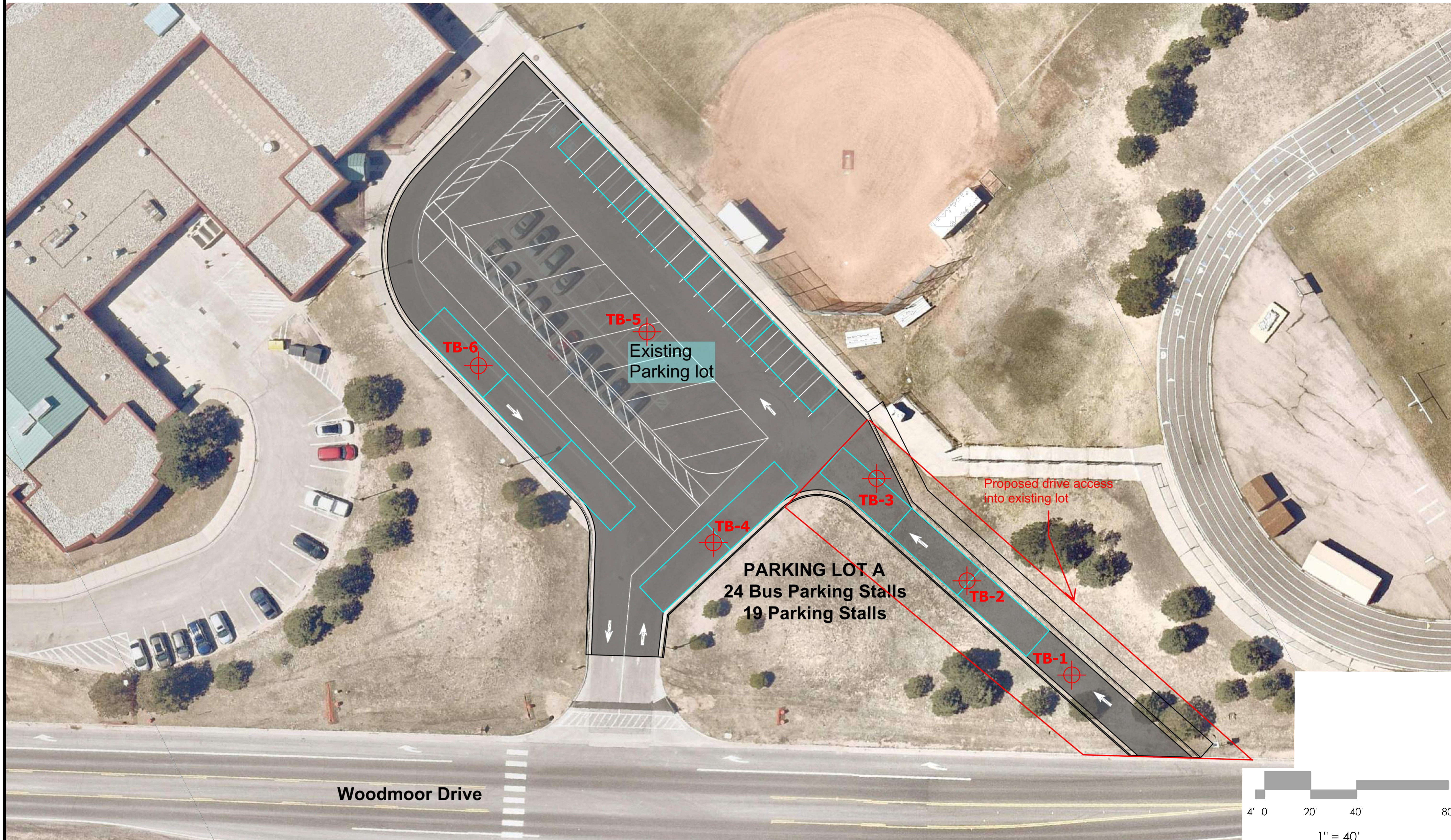
6.4 Construction Observation

Subgrade preparation for pavement structures should be observed by Entech in order to verify that (1) no anomalies are present, (2) materials similar to those described in this report have been encountered or placed, and (3) no soft spots, expansive or organic soil, or debris are present in the pavement subgrade prior to paving.

7 Closure

The subsurface investigation, geotechnical evaluation, and recommendations presented in this report are intended for use by Felsburg, Holt, and Ulevig, Inc. with application to the Lewis-Palmer Middle School Parking Lot Improvements in Monument, Colorado. In conducting the subsurface investigation, laboratory testing, engineering evaluation and reporting, Entech Engineering, Inc. endeavored to work in accordance with generally accepted professional geotechnical and geologic practices and principles consistent with the level of care and skill ordinarily exercised by members of the geotechnical profession currently practicing in the same locality and under similar conditions. No other warranty, expressed or implied, is made. During final design and/or construction, if conditions are encountered which appear different from those described in this report, Entech Engineering, Inc. requests to be notified so that the evaluation and recommendations presented herein can be reviewed and modified as appropriate.

If there are any questions regarding the information provided herein or if Entech Engineering, Inc. can be of further assistance, please do not hesitate to contact us.



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TB- APPROXIMATE TEST BORING LOCATION AND NUMBER

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SITE AND EXPLORATION PLAN
LEWIS-PALMER MIDDLE SCHOOL
FELSBURG HOLT & ULLEVIG

JOB NO.
231321

FIG. 1

APPENDIX A: Test Boring Logs

TEST BORING 1						
DATE DRILLED 8/10/2023						
REMARKS DRY TO 10', 8/10/23	Depth (ft)	Symbol	Samples	Blows per foot	Watercontent %	Soil Type
FILL 0-4', SAND, SILTY, BROWN, MEDIUM DENSE, MOIST				19	8.6	1
SAND, SILTY, TAN, MEDIUM DENSE, DRY to MOIST	5			16	2.7	2
	10			19	9.8	2
	15					
	20					

TEST BORING 2						
DATE DRILLED 8/10/2023						
REMARKS DRY TO 10', 8/10/23	Depth (ft)	Symbol	Samples	Blows per foot	Watercontent %	Soil Type
FILL 0-5', SAND, WITH SILT, TAN, MEDIUM DENSE, MOIST				19	7.9	1
	5			15	18.1	1
SAND, SILTY, TAN						2
SANSDTONE, VERY WEAK, TAN, SLIGHTLY WEATHERED, (SAND, SILTY, VERY DENSE, MOIST)	10			50/10"	9.6	3
	15					
	20					

ENTECH ENGINEERING, INC.

TEST BORING LOGS

LEWIS-PALMER MIDDLE SCHOOL
FELSBURG, HOLT & ULLEVIG

JOB NO.
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FIG. A-1

TEST BORING	3
DATE DRILLED	8/10/2023
REMARKS	DRY TO 10', 8/10/23

Description	Depth (ft)	Symbol	Samples	Blows per foot	Watercontent %	Soil Type
FILL 0-9', SAND, WITH SILT, TAN to RED, MEDIUM DENSE, MOIST	1.5		■	12	7.5	1
	5		■	16	11.7	1
SANDSTONE, EXTREMELY WEAK, TAN, HIGHLY WEATHERED, (SAND, SILTY, VERY DENSE, MOIST)	10		■	50/11"	9.8	3
	15					
	20					

TEST BORING	4
DATE DRILLED	8/10/2023
REMARKS	DRY TO 10', 8/10/23

Description	Depth (ft)	Symbol	Samples	Blows per foot	Watercontent %	Soil Type
4-1/2" ASPHALT, 2" BASE COURSE, FILL 0-5', SAND, SILTY, BROWN, LOOSE to MEDIUM DENSE,	1.5		■	8	8.5	1
	5		■	11	12.5	1
SAND, SILTY, BROWN						2
SANDSTONE, EXTREMELY WEAK, TAN, HIGHLY WEATHERED, (SAND, SILTY, VERY DENSE, MOIST)	10		■	50	10.4	3
	15					
	20					

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TEST BORING LOGS

LEWIS-PALMER MIDDLE SCHOOL
FELSBURG, HOLT & ULLEVIG

JOB NO. 231321

FIG. A-2

TEST BORING 5
DATE DRILLED 8/10/2023
REMARKS
DRY TO 10', 8/10/23

Description	Depth (ft)	Symbol	Samples	Blows per foot	Watercontent %	Soil Type
4-1/4" ASPHALT, 4" BASE COURSE, FILL 0-5', SAND, SILTY, BROWN, LOOSE to MEDIUM DENSE,				8	6.9	1
	5			20	13.7	1
SAND, SILTY, BROWN						2
SANDSTONE, EXTREMELY WEAK, TAN, HIGHLY WEATHERED, (SAND, SILTY, VERY DENSE, MOIST)	10			*	10.5	3
* - BULK SAMPLE TAKEN	15					
	20					

TEST BORING 6
DATE DRILLED 8/10/2023
REMARKS
DRY TO 10', 8/10/23

Description	Depth (ft)	Symbol	Samples	Blows per foot	Watercontent %	Soil Type
4" ASPHALT, 3" BASE COURSE FILL 0-4', SAND, SILTY, WITH GRAVEL, BROWN, MEDIUM DENSE, MOIST				16	9.6	1
SAND, WITH SILT and GRAVEL, TAN, MEDIUM DENSE, MOIST	5			23	6.9	2
SANDSTONE, EXTREMELY WEAK, TAN, EXTREMELY WEATHERED, (SAND, SILTY, VERY DENSE, MOIST)	10			42	7.0	3
	15					
	20					

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TEST BORING LOGS

LEWIS-PALMER MIDDLE SCHOOL
FELSBURG, HOLT & ULLEVIG

JOB NO. 231321

FIG. A-3

ENTECH
ENGINEERING, INC.
505 ELKTON DRIVE
COLORADO SPRINGS, CO 80907
PHONE (719) 531-5599

ASPHALT CORE ANALYSIS

Project: Lewis-Palmer Middle School

Client: Felsburg, Holt & Ullevig

Job No.: 231321

Asphalt Supplier: NA

Date Sampled: 8/10/2023 **Sampler:** MM

Sample No.:	TB-4	TB-5	TB-6
Thickness (inches):	4 ½”	4 ¼”	4”
Unit Weight (pcf):	142.2	143.8	144.5
Rice or Marshall * (pcf):	152.8	152.8	152.8
Compaction (%):	92	93	94
Recommended Compaction (%):	92-96	92-96	92-96

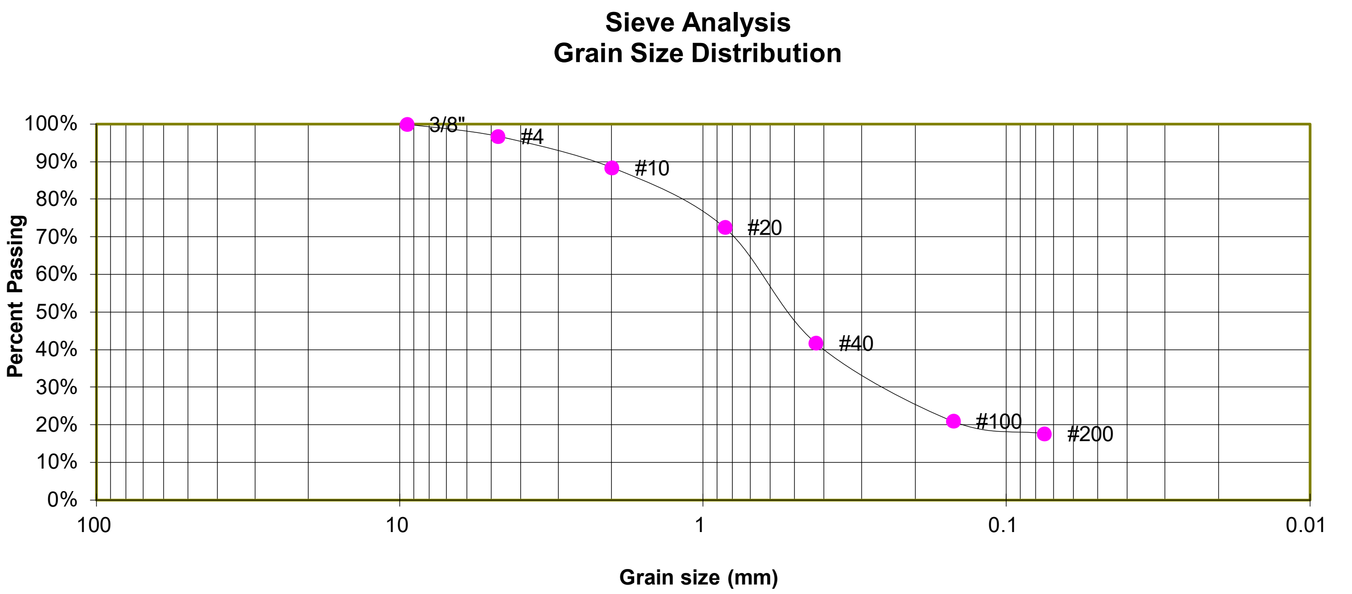
*Assumed value based on local experience.

APPENDIX B: Laboratory Test Results

TABLE B-1
SUMMARY OF LABORATORY TEST RESULTS

SOIL TYPE	TEST BORING NO.	DEPTH (FT)	PASSING NO. 200 SIEVE (%)	LIQUID LIMIT	PLASTIC LIMIT	PLASTIC INDEX	SULFATE (WT %)	AASHTO CLASS.	USCS	SOIL DESCRIPTION
1, CBR	5	0-3	17.7	NV	NP	NP		A-1-b	SM	FILL, SAND, SILTY
1	1	1-2	21.1	NV	NP	NP		A-1-b	SM	FILL, SAND, SILTY
1	2	1-2	6.8	NV	NP	NP	<0.01	A-1-b	SW-SM	FILL, SAND, WITH SILT
1	3	1-2	7.8	NV	NP	NP		A-1-b	SW-SM	FILL, SAND, WITH SILT
1	4	1-2	17.4	NV	NP	NP		A-1-b	SM	FILL, SAND, SILTY
1	5	1-2	14.7	NV	NP	NP	0.01	A-1-b	SM	FILL, SAND, SILTY
2	6	5	8.3	NV	NP	NP		A-1-b	SW-SM	SAND, WITH SILT
3	2	10	21.9	NV	NP	NP		A-1-b	SM	SANDSTONE, (SAND, SILTY)
3	3	10	15.2	NV	NP	NP	<0.01	A-1-b	SM	SANDSTONE, (SAND, SILTY)
3	4	10	18.6	NV	NP	NP		A-1-b	SM	SANDSTONE, (SAND, SILTY)
3	5	10	24.7	NV	NP	NP	<0.01	A-2-4	SM	SANDSTONE, (SAND, SILTY)
3	6	10	16.3	NV	NP	NP		A-2-4	SM	SANDSTONE, (SAND, SILTY)

TEST BORING	5	SOIL DESCRIPTION	FILL, SAND, SILTY
DEPTH (FT)	0-3	SOIL TYPE	1, CBR



GRAIN SIZE ANALYSIS

U.S. Sieve #	Percent Finer
3"	
1 1/2"	
3/4"	
1/2"	
3/8"	100.0%
4	96.8%
10	88.4%
20	72.5%
40	41.7%
100	21.0%
200	17.7%

ATTERBERG LIMITS

Plastic Limit	NP
Liquid Limit	NV
Plastic Index	NP

SOIL CLASSIFICATION

USCS CLASSIFICATION:	SM
AASHTO CLASSIFICATION:	A-1-b
AASHTO GROUP INDEX:	0

ENTECH ENGINEERING, INC.

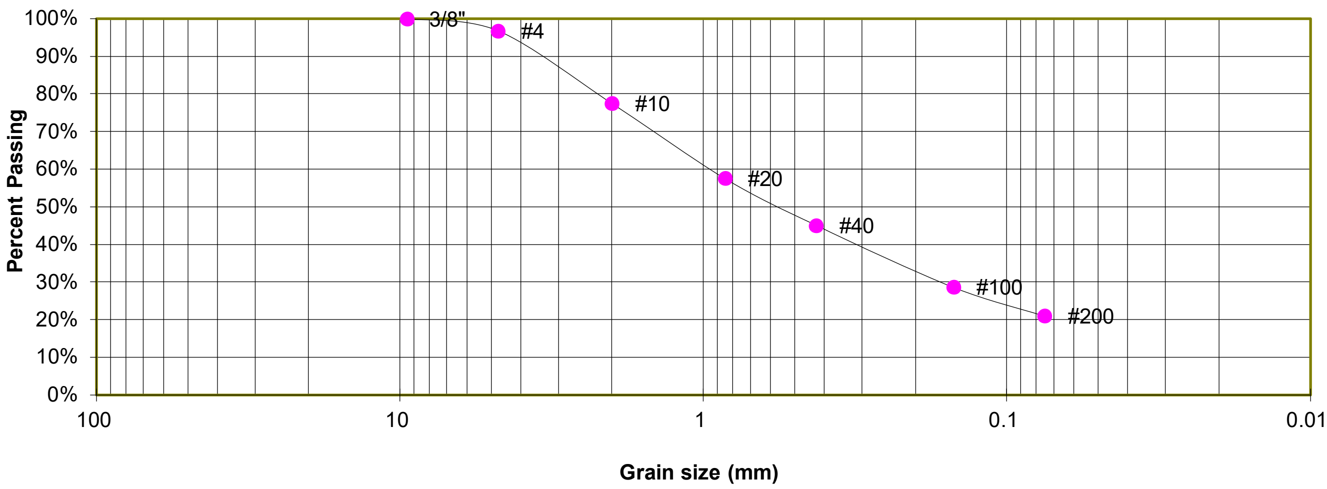
LABORATORY TEST RESULTS

LEWIS-PALMER MIDDLE SCHOOL
FELSBURG, HOLT & ULLEVIG

JOB NO.
231321

FIG. B-1

TEST BORING 1	SOIL DESCRIPTION FILL, SAND, SILTY
DEPTH (FT) 1-2	SOIL TYPE 1



GRAIN SIZE ANALYSIS

U.S. Sieve #	Percent Finer
3"	
1 1/2"	
3/4"	
1/2"	
3/8"	100.0%
4	96.7%
10	77.5%
20	57.6%
40	45.0%
100	28.6%
200	21.1%

ATTERBERG LIMITS

Plastic Limit	NP
Liquid Limit	NV
Plastic Index	NP

SOIL CLASSIFICATION

USCS CLASSIFICATION:	SM
AASHTO CLASSIFICATION:	A-1-b
AASHTO GROUP INDEX:	0

ENTECH ENGINEERING, INC.

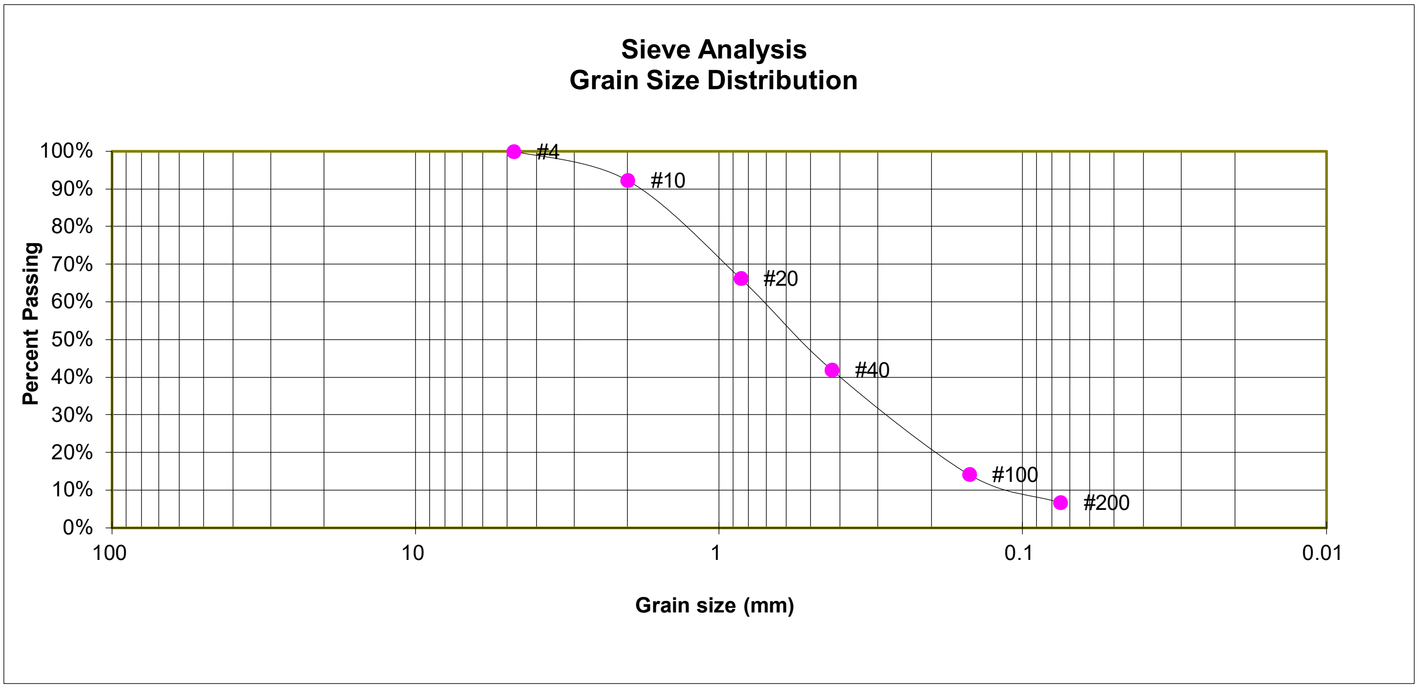
LABORATORY TEST RESULTS

LEWIS-PALMER MIDDLE SCHOOL
FELSBURG, HOLT & ULLEVIG

JOB NO. 231321

FIG. B-2

TEST BORING	2	SOIL DESCRIPTION	FILL, SAND, WITH SILT
DEPTH (FT)	1-2	SOIL TYPE	1



GRAIN SIZE ANALYSIS

U.S. Sieve #	Percent Finer
3"	
1 1/2"	
3/4"	
1/2"	
3/8"	
4	100.0%
10	92.3%
20	66.2%
40	41.9%
100	14.2%
200	6.8%

ATTERBERG LIMITS

Plastic Limit	NP
Liquid Limit	NV
Plastic Index	NP

SOIL CLASSIFICATION

USCS CLASSIFICATION:	SW-SM
AASHTO CLASSIFICATION:	A-1-b
AASHTO GROUP INDEX:	0

ENTECH ENGINEERING, INC.

LABORATORY TEST RESULTS

LEWIS-PALMER MIDDLE SCHOOL
FELSBURG, HOLT & ULLEVIG

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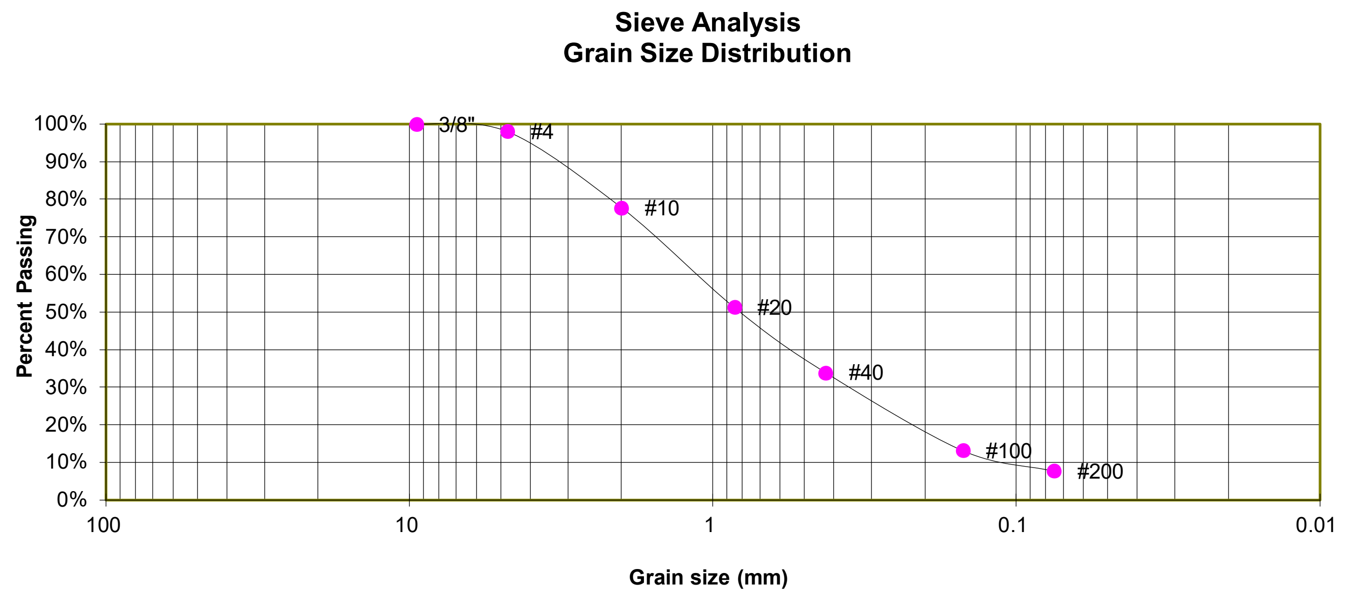
231321

FIG. B-3

TEST BORING	3	SOIL DESCRIPTION	FILL, SAND, WITH SILT
DEPTH (FT)	1-2	SOIL TYPE	1



GRAIN SIZE ANALYSIS

U.S. Sieve #	Percent Finer
3"	
1 1/2"	
3/4"	
1/2"	
3/8"	100.0%
4	98.0%
10	77.7%
20	51.3%
40	33.9%
100	13.2%
200	7.8%

ATTERBERG LIMITS

Plastic Limit	NP
Liquid Limit	NV
Plastic Index	NP

SOIL CLASSIFICATION

USCS CLASSIFICATION: SW-SM
AASHTO CLASSIFICATION: A-1-b
AASHTO GROUP INDEX: 0

ENTECH ENGINEERING, INC.

LABORATORY TEST RESULTS

LEWIS-PALMER MIDDLE SCHOOL
FELSBURG, HOLT & ULLEVIG

JOB NO.
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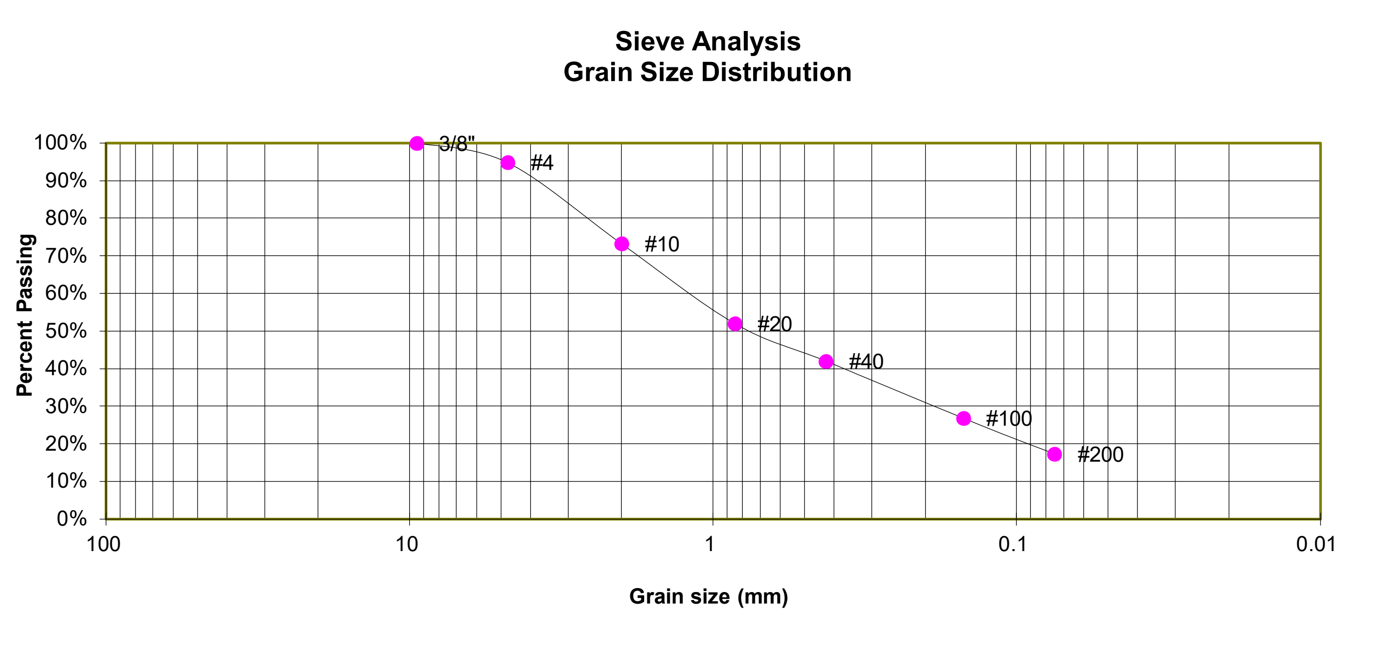
FIG. B-4

TEST BORING	4	SOIL DESCRIPTION	FILL, SAND, SILTY
DEPTH (FT)	1-2	SOIL TYPE	1



GRAIN SIZE ANALYSIS

U.S. Sieve #	Percent Finer
3"	
1 1/2"	
3/4"	
1/2"	
3/8"	100.0%
4	94.9%
10	73.2%
20	52.1%
40	42.0%
100	26.8%
200	17.4%

ATTERBERG LIMITS

Plastic Limit	NP
Liquid Limit	NV
Plastic Index	NP

SOIL CLASSIFICATION

USCS CLASSIFICATION:	SM
AASHTO CLASSIFICATION:	A-1-b
AASHTO GROUP INDEX:	0

ENTECH ENGINEERING, INC.

LABORATORY TEST RESULTS

LEWIS-PALMER MIDDLE SCHOOL
FELSBURG, HOLT & ULLEVIG

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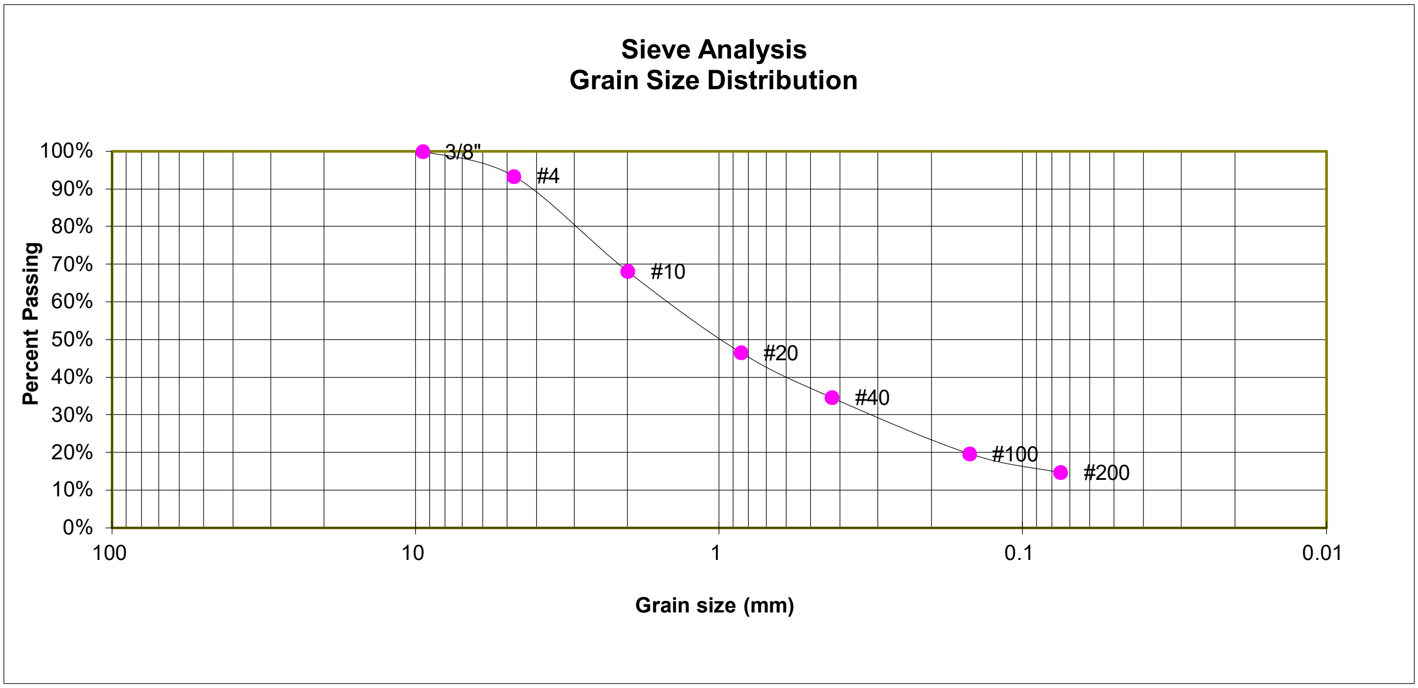
FIG. B-5

TEST BORING	5	SOIL DESCRIPTION	FILL, SAND, SILTY
DEPTH (FT)	1-2	SOIL TYPE	1



GRAIN SIZE ANALYSIS

U.S. Sieve #	Percent Finer
3"	
1 1/2"	
3/4"	
1/2"	
3/8"	100.0%
4	93.4%
10	68.1%
20	46.6%
40	34.6%
100	19.7%
200	14.7%

ATTERBERG LIMITS

Plastic Limit	NP
Liquid Limit	NV
Plastic Index	NP

SOIL CLASSIFICATION

USCS CLASSIFICATION:	SM
AASHTO CLASSIFICATION:	A-1-b
AASHTO GROUP INDEX:	0

ENTECH ENGINEERING, INC.

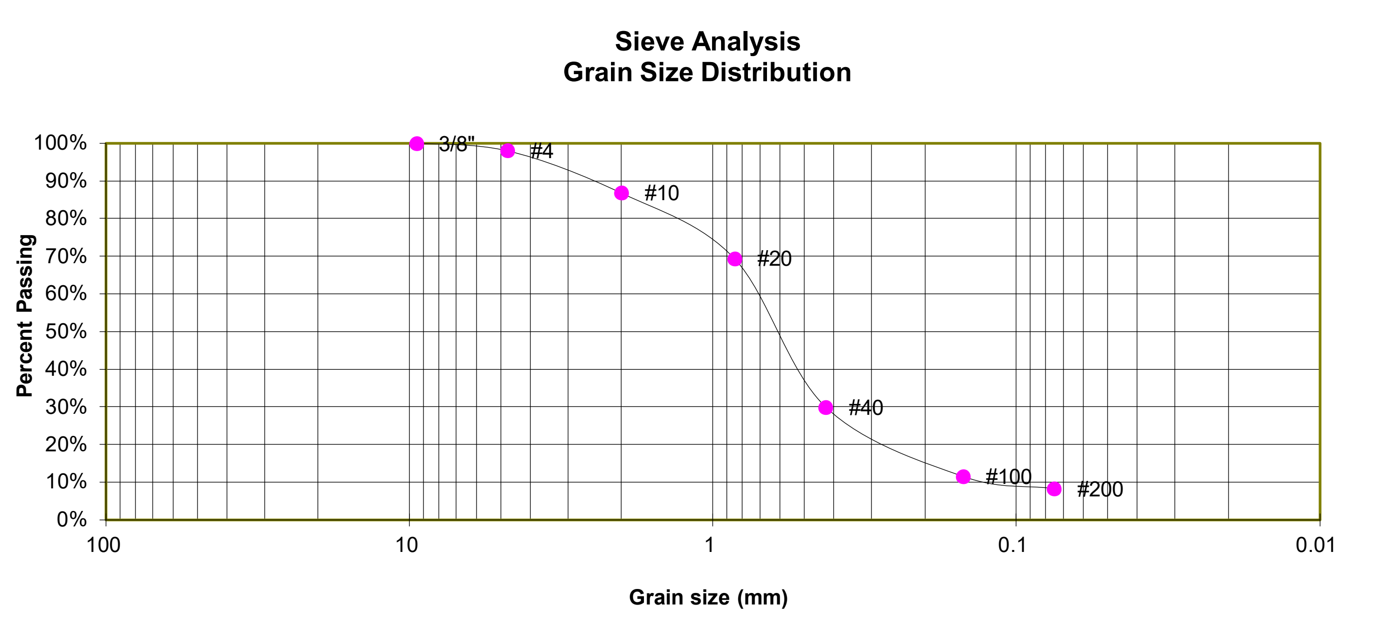
LABORATORY TEST RESULTS

LEWIS-PALMER MIDDLE SCHOOL
FELSBURG, HOLT & ULLEVIG

JOB NO.
231321

FIG. B-6

TEST BORING	6	SOIL DESCRIPTION	SAND, WITH SILT
DEPTH (FT)	5	SOIL TYPE	2



GRAIN SIZE ANALYSIS

U.S. Sieve #	Percent Finer
3"	
1 1/2"	
3/4"	
1/2"	
3/8"	100.0%
4	98.1%
10	86.8%
20	69.4%
40	29.9%
100	11.6%
200	8.3%

ATTERBERG LIMITS

Plastic Limit	NP
Liquid Limit	NV
Plastic Index	NP

SOIL CLASSIFICATION

USCS CLASSIFICATION: SW-SM
AASHTO CLASSIFICATION: A-1-b
AASHTO GROUP INDEX: 0

ENTECH ENGINEERING, INC.

LABORATORY TEST RESULTS

LEWIS-PALMER MIDDLE SCHOOL
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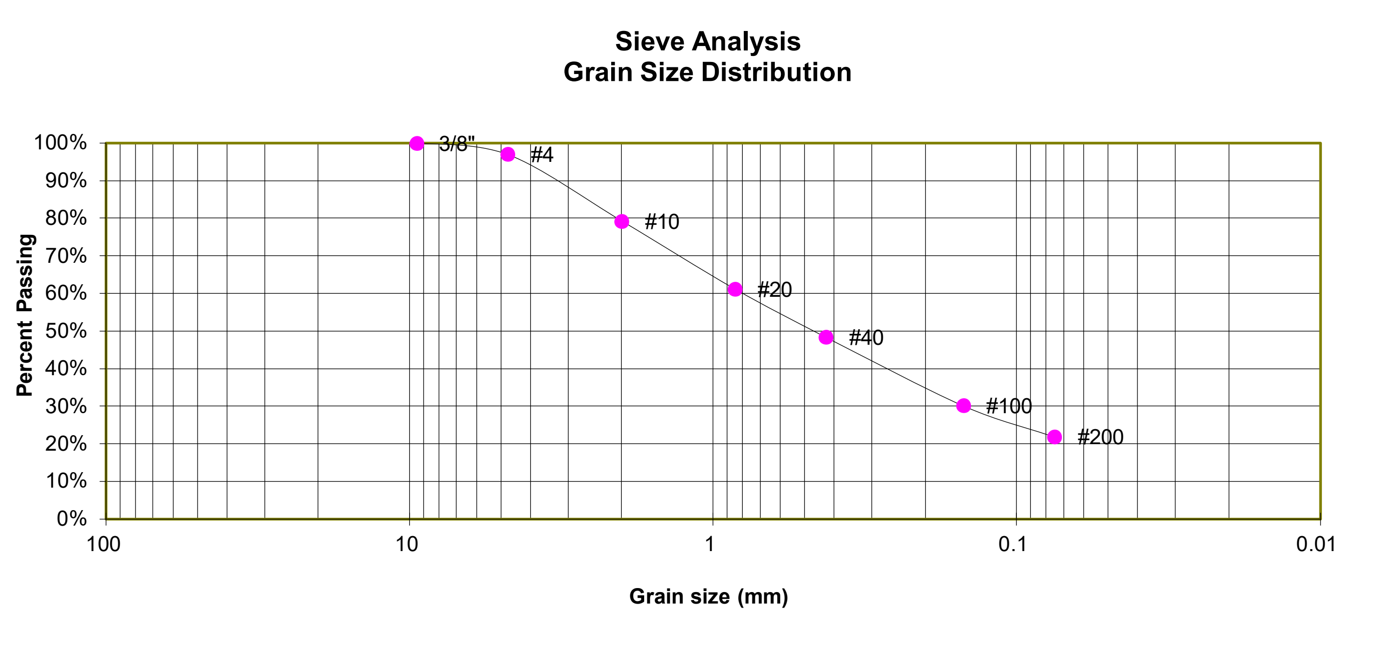
FIG. B-7

TEST BORING	2	SOIL DESCRIPTION	SANDSTONE, (SAND, SILTY)
DEPTH (FT)	10	SOIL TYPE	3



GRAIN SIZE ANALYSIS

U.S. Sieve #	Percent Finer
3"	
1 1/2"	
3/4"	
1/2"	
3/8"	100.0%
4	97.0%
10	79.3%
20	61.2%
40	48.4%
100	30.2%
200	21.9%

ATTERBERG LIMITS

Plastic Limit	NP
Liquid Limit	NV
Plastic Index	NP

SOIL CLASSIFICATION

USCS CLASSIFICATION:	SM
AASHTO CLASSIFICATION:	A-1-b
AASHTO GROUP INDEX:	0

ENTECH ENGINEERING, INC.

LABORATORY TEST RESULTS

LEWIS-PALMER MIDDLE SCHOOL
FELSBURG, HOLT & ULLEVIG

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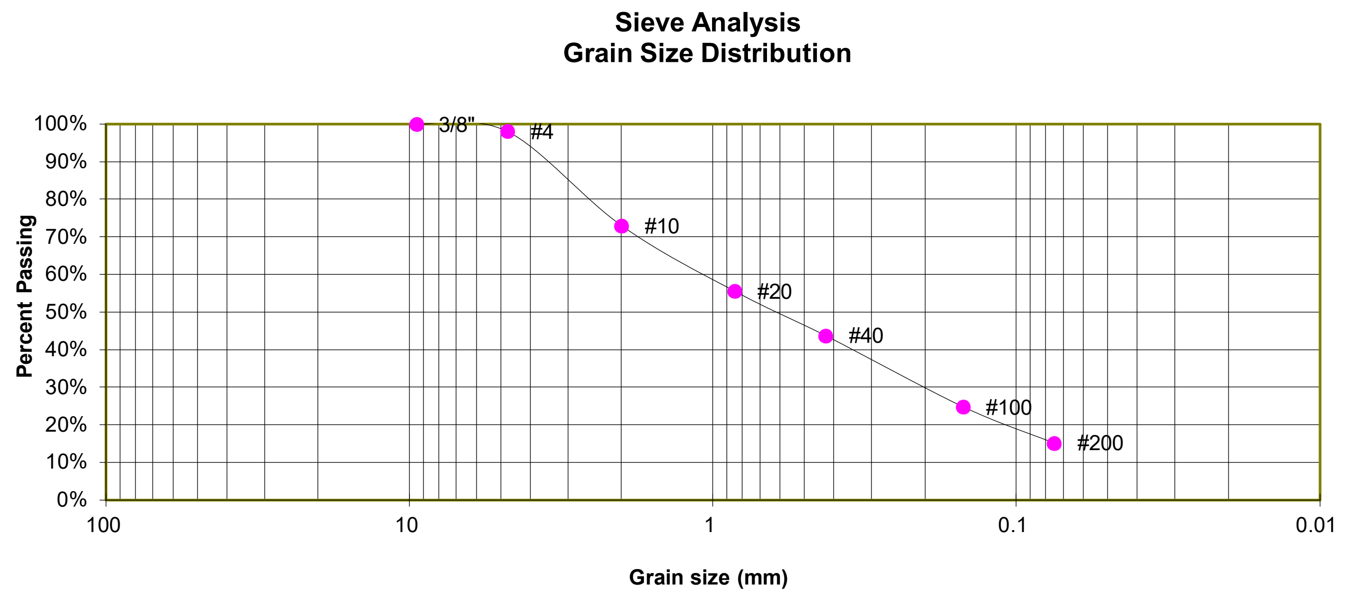
FIG. B-8

TEST BORING	3	SOIL DESCRIPTION	SANDSTONE, (SAND, SILTY)
DEPTH (FT)	10	SOIL TYPE	3



GRAIN SIZE ANALYSIS

U.S. Sieve #	Percent Finer
3"	
1 1/2"	
3/4"	
1/2"	
3/8"	100.0%
4	98.1%
10	73.0%
20	55.6%
40	43.8%
100	24.8%
200	15.2%

ATTERBERG LIMITS

Plastic Limit	NP
Liquid Limit	NV
Plastic Index	NP

SOIL CLASSIFICATION

USCS CLASSIFICATION:	SM
AASHTO CLASSIFICATION:	A-1-b
AASHTO GROUP INDEX:	0

ENTECH ENGINEERING, INC.

LABORATORY TEST RESULTS

LEWIS-PALMER MIDDLE SCHOOL
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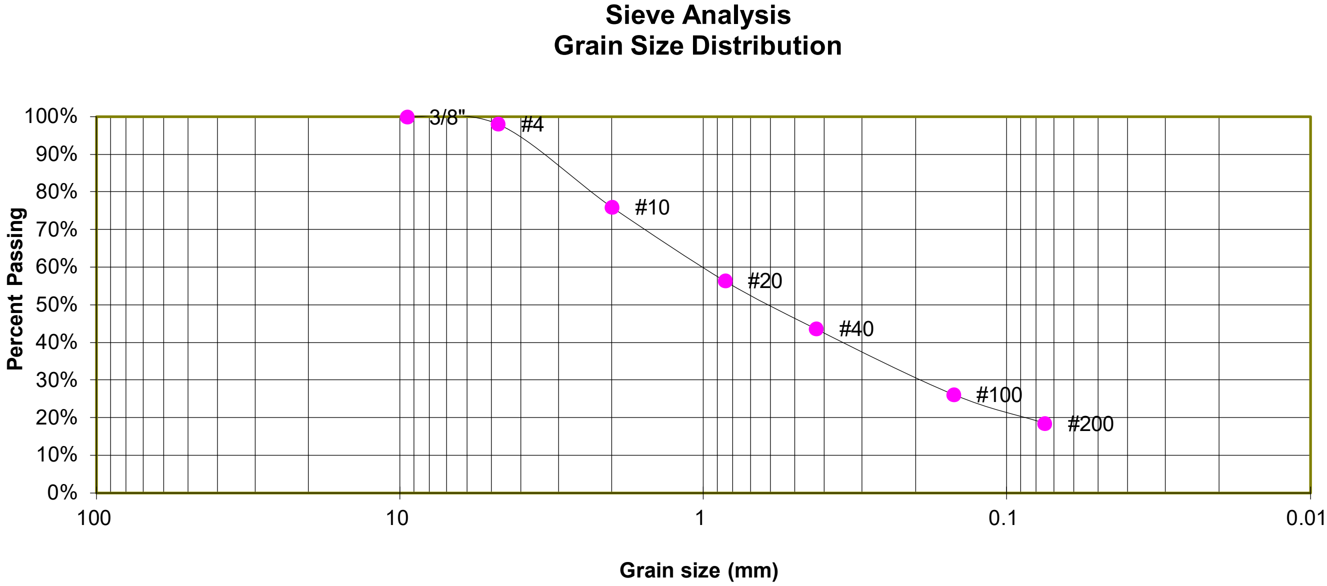
FIG. B-9

TEST BORING	4	SOIL DESCRIPTION	SANDSTONE, (SAND, SILTY)
DEPTH (FT)	10	SOIL TYPE	3



GRAIN SIZE ANALYSIS

U.S. Sieve #	Percent Finer
3"	
1 1/2"	
3/4"	
1/2"	
3/8"	100.0%
4	98.1%
10	76.0%
20	56.4%
40	43.6%
100	26.2%
200	18.6%

ATTERBERG LIMITS

Plastic Limit	NP
Liquid Limit	NV
Plastic Index	NP

SOIL CLASSIFICATION

USCS CLASSIFICATION:	SM
AASHTO CLASSIFICATION:	A-1-b
AASHTO GROUP INDEX:	0

ENTECH ENGINEERING, INC.

LABORATORY TEST RESULTS

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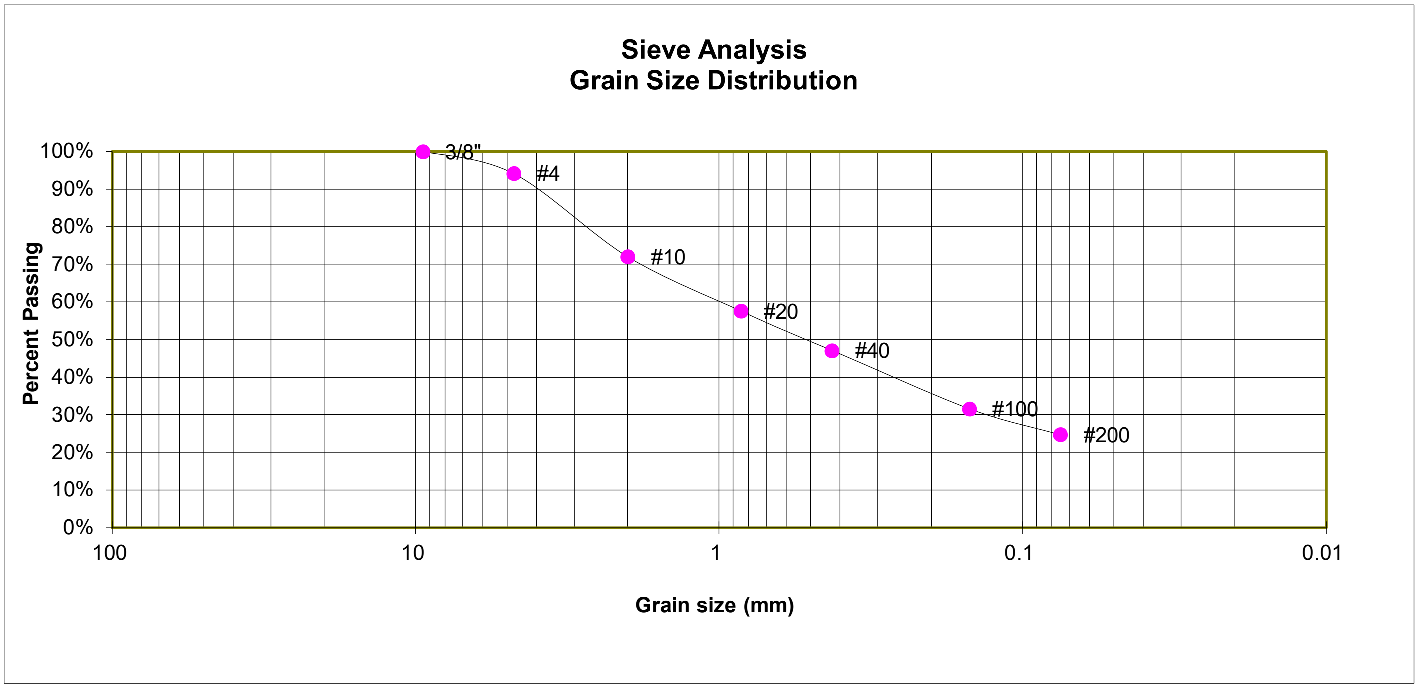
FIG. B-10

TEST BORING	5	SOIL DESCRIPTION	SANDSTONE, (SAND, SILTY)
DEPTH (FT)	10	SOIL TYPE	3



GRAIN SIZE ANALYSIS

U.S. Sieve #	Percent Finer
3"	
1 1/2"	
3/4"	
1/2"	
3/8"	100.0%
4	94.1%
10	72.0%
20	57.7%
40	47.2%
100	31.7%
200	24.7%

ATTERBERG LIMITS

Plastic Limit	NP
Liquid Limit	NV
Plastic Index	NP

SOIL CLASSIFICATION

USCS CLASSIFICATION:	SM
AASHTO CLASSIFICATION:	A-2-4
AASHTO GROUP INDEX:	0

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LABORATORY TEST RESULTS

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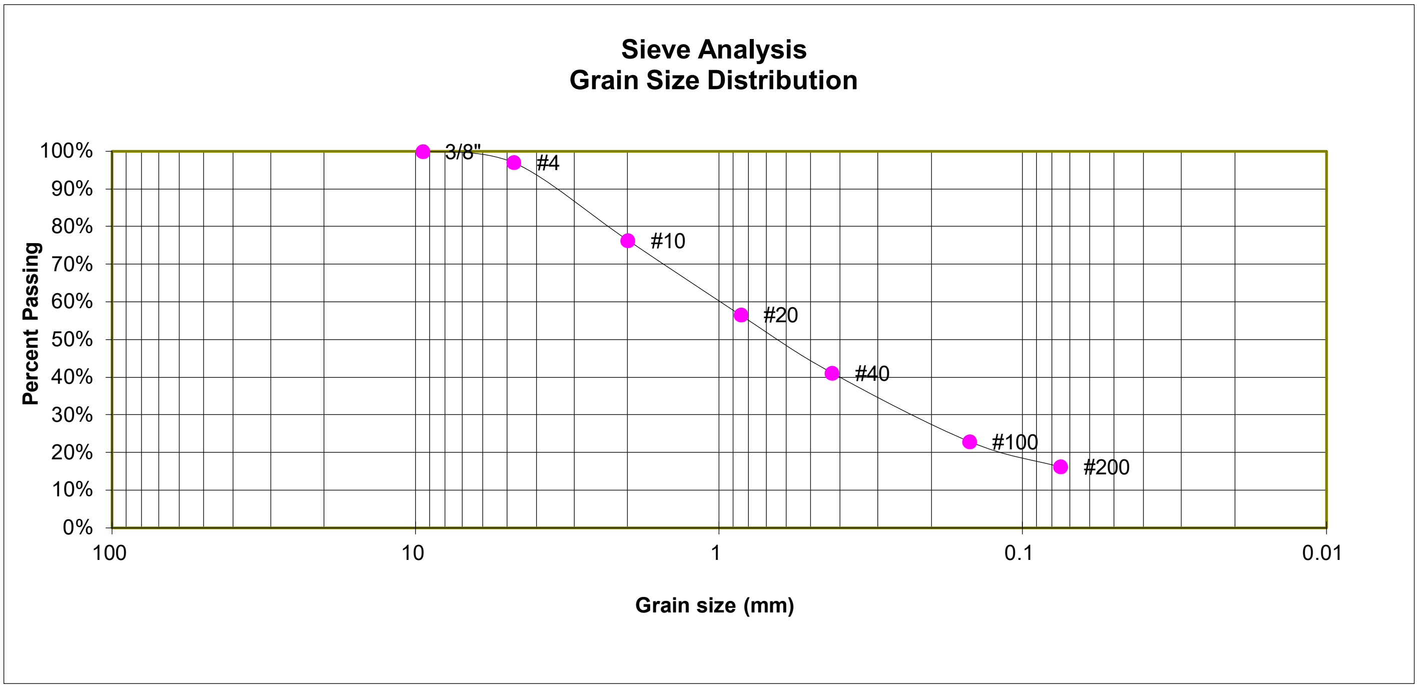
FIG. B-11

TEST BORING	6	SOIL DESCRIPTION	SANDSTONE, (SAND, SILTY)
DEPTH (FT)	10	SOIL TYPE	3



GRAIN SIZE ANALYSIS

U.S. Sieve #	Percent Finer
3"	
1 1/2"	
3/4"	
1/2"	
3/8"	100.0%
4	97.0%
10	76.3%
20	56.6%
40	41.1%
100	23.0%
200	16.3%

ATTERBERG LIMITS

Plastic Limit	NP
Liquid Limit	NV
Plastic Index	NP

SOIL CLASSIFICATION

USCS CLASSIFICATION:	SM
AASHTO CLASSIFICATION:	A-2-4
AASHTO GROUP INDEX:	0

ENTECH ENGINEERING, INC.

LABORATORY TEST RESULTS

LEWIS-PALMER MIDDLE SCHOOL
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FIG. B-12

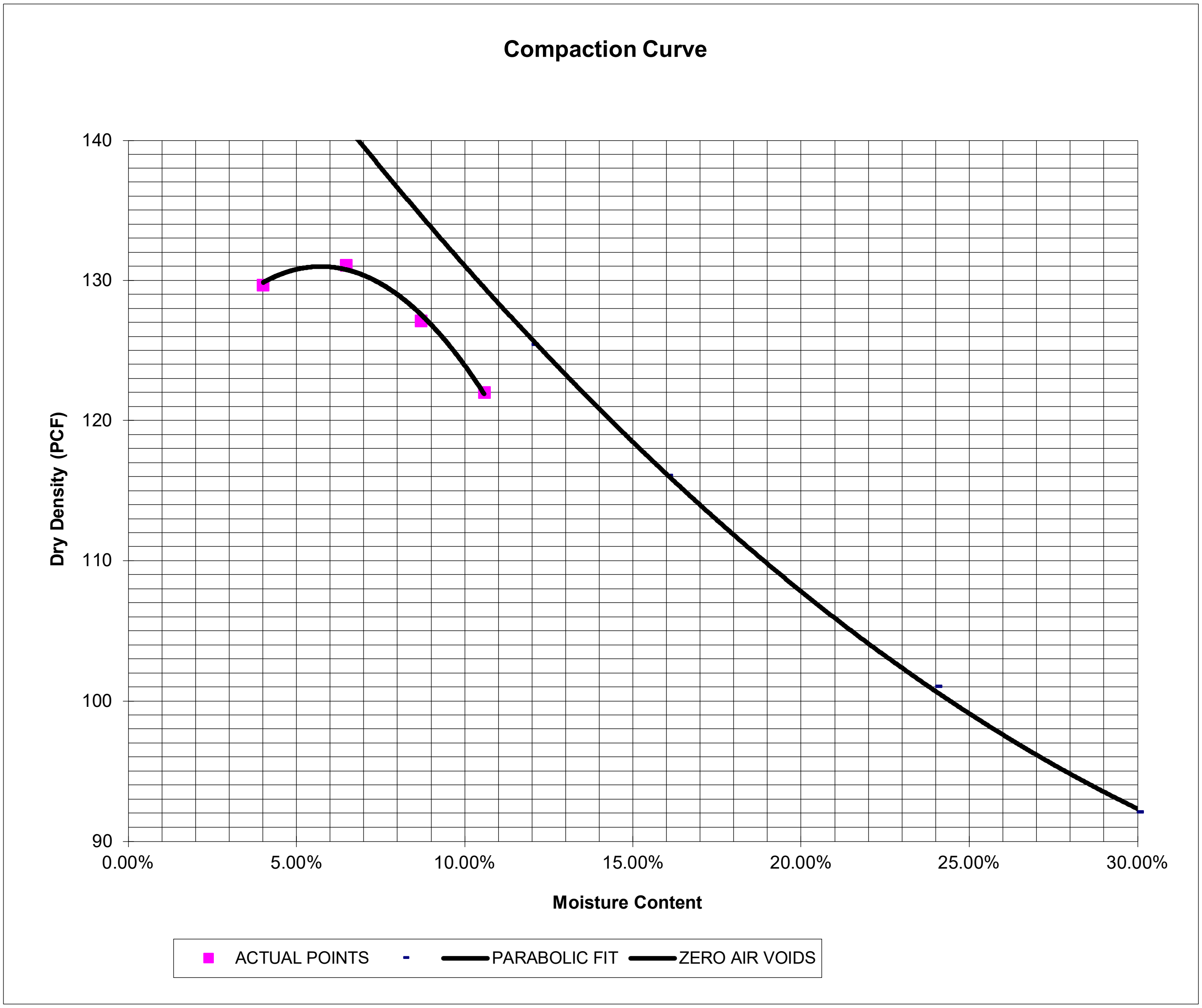
SAMPLE LOCATION TB-5 @ 0-3'

SOIL DESCRIPTION FILL, SAND, SILTY, BROWN

SOIL TYPE 1

PROCTOR DATA

IDENTIFICATION:	SM
PROCTOR TEST #:	1
TEST BY:	DK
TEST DESIGNATION:	ASTM-1557-A
MAXIMUM DRY DENSITY (PCF):	131.0
OPTIMUM MOISTURE:	5.9



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LABORATORY TEST RESULTS

LEWIS-PALMER MIDDLE SCHOOL
FELSBURG, HOLT & ULLEVIG

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FIG. B-13

SAMPLE LOCATION TB-5 @ 0-3'	SOIL DESCRIPTION FILL, SAND, SILTY, BROWN	
DEPTH (FT) 0	SOIL TYPE 1	1

CBR TEST LOAD DATA

Piston Diameter (cm): 4.958
Piston Area (in^2): 2.993

Penetration	10 BLOWS		25 BLOWS		56 BLOWS	
	Mold # 1		Mold # 2		Mold # 3	
Depth	Load	Stress	Load	Stress	Load	Stress
(inches)	(lbs)	(psi)	(lbs)	(psi)	(lbs)	(psi)
0.000	0	0.00	0	0.00	0	0.00
0.025	78	26.07	143	47.79	158	52.80
0.050	125	41.77	261	87.22	298	99.58
0.075	155	51.80	314	104.93	404	135.00
0.100	175	58.48	426	142.36	506	169.09
0.125	212	70.84	531	177.44	720	240.60
0.150	246	82.21	597	199.50	989	330.49
0.175	270	90.23	688	229.91	1124	375.60
0.200	309	103.26	830	277.36	1482	495.24
0.300	444	148.37	1207	403.34	2301	768.92
0.400	582	194.49	1521	508.27	2883	963.41
0.500	687	229.57	1622	542.02	3013	1006.85

MOISTURE AND DENSITY DATA

	Mold # 1	Mold # 2	Mold # 3
Can #	300	306	314
Wt. Can	6.76	6.64	6.51
Wt. Can+Wet	334.27	370.57	342.48
Wt. Can+Dry	297.42	335.06	311.13
Wt. H20	36.85	35.51	31.35
Wt. Dry Soil	290.66	328.42	304.62
Moisture Content	12.68%	10.81%	10.29%
Wet Density (PCF)	119.1	124.2	128.1
Dry Density (PCF)	112.5	117.3	120.9
% Compaction	86%	90%	92%
CBR	5.85	14.24	16.91

PROCTOR DATA

Maximum Dry Density (pcf)	131.0
Optimum Moisture	5.9
90% of Max. Dry Density (pcf)	117.9
95% of Max. Dry Density (pcf)	124.5

CBR at 90% of Max. Density = 14.68	~ R VALUE 45
CBR at 95% of Max. Density = 19.49	~ R VALUE 70

ENTECH ENGINEERING, INC.

LABORATORY TEST RESULTS

LEWIS-PALMER MIDDLE SCHOOL
FELSBURG, HOLT & ULLEVIG

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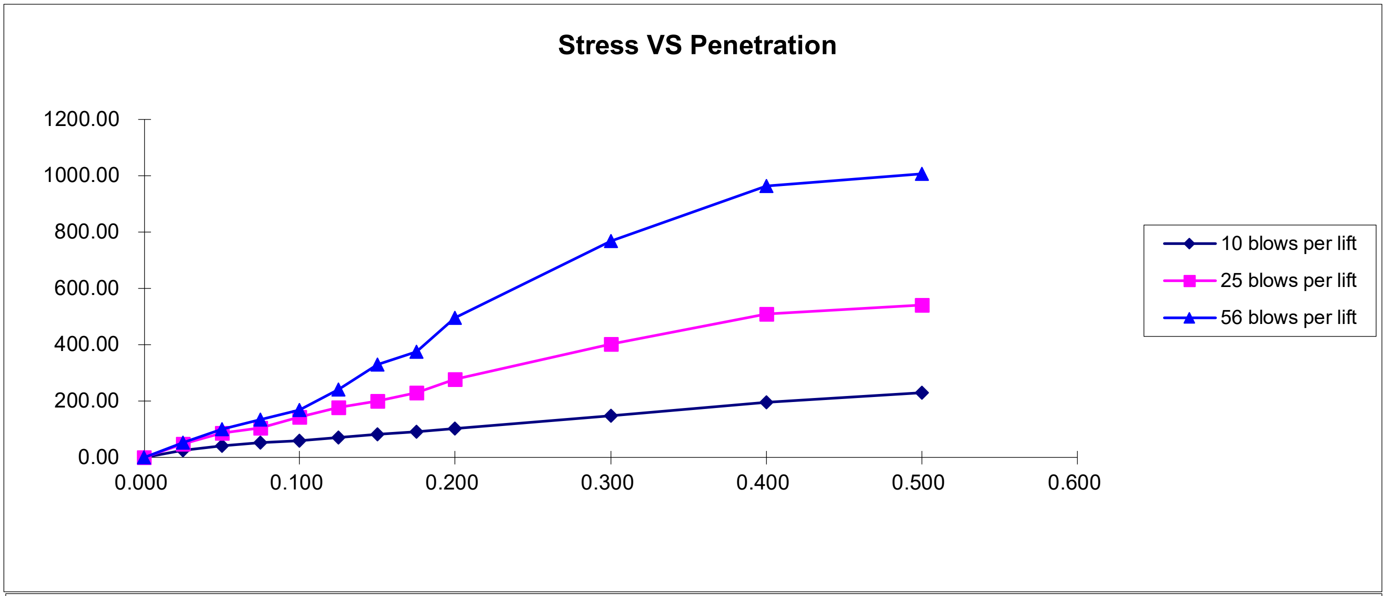
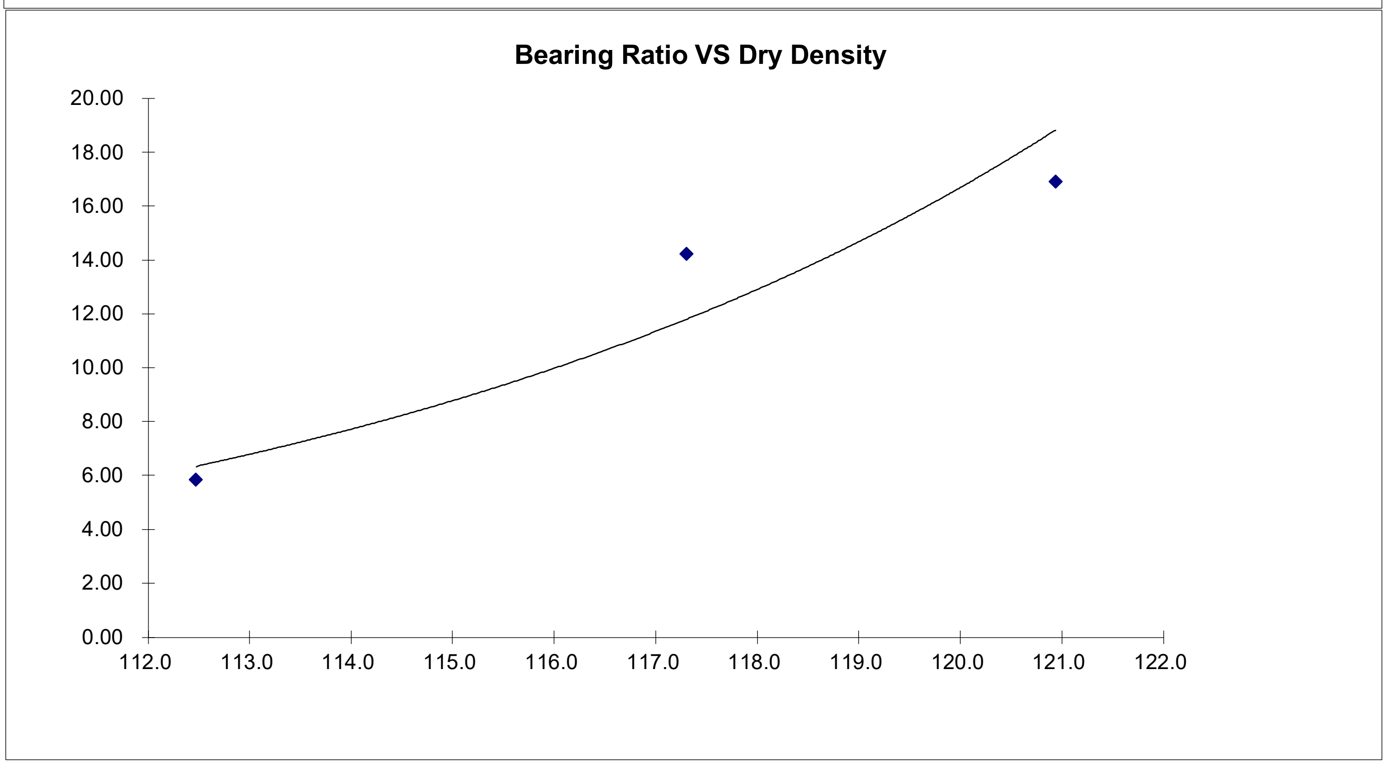
FIG. B-14

SAMPLE LOCATION TB-5 @ 0-3'

SOIL DESCRIPTION FILL, SAND, SILTY, BROWN

SOIL TYPE 1





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LABORATORY TEST RESULTS

LEWIS-PALMER MIDDLE SCHOOL
FELSBURG, HOLT & ULLEVIG

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FIG. B-15

APPENDIX C: Pavement Design Calculations

FLEXIBLE PAVEMENT DESIGN

PROJECT DATA

Project Location LEWIS-PALMER MIDDLE SCHOOL - PARKING AND DRIVE LANES

Job Number: 231321 Design Life = 20

DESIGN DATA

Equivalent (18-kip) Single Axle Load Applications (ESAL):	ESAL (W_{18}) =	450,000
Design CBR	CBR =	10
Standard Deviation	S_o =	0.44
Loss in Serviceability	Δpsi =	2.5
Reliability	Reliability =	85
Reliability (z-statistic)	Z_R =	-1.04
Soil Resilient Modulus	M_R =	15,000 psi

Required Structural Number (SN): → SN = 2.18

DESIGN EQUATIONS

Resilient Modulus

If using CBR:

$M_R = (CBR) \times 1{,}500$

If using R-Value:

$M_R = 10^{[(S_1 + 18.72)/6.24]}$ where: $S_1 = [(R\text{-value} - 5)/11.29] + 3$

Required Structural Number

$$\log_{10}W_{18} = Z_R * S_O + 9.36*\log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left[\dfrac{\Delta PSI}{4.2 - 1.5}\right]}{0.40 + \dfrac{1094}{(SN+1)^{5.19}}} + 2.32*\log_{10}M_R - 8.07$$

Pavement Section Thickness

$SN^* = C_1D_1 + C_2D_2$ where:

C_1 = Strength Coefficient - Hot Bituminous Asphalt

C_2 = Strength Coefficient - Aggregate Base Course

D_1 = Depth of Asphalt (inches)

D_2 = Depth of Base Course (inches)

RECOMMENED THICKNESSES

Layer	Material	Structural Layer	Thickness (D^*_i)	SN^*_i	SN
1	HMA	C_1 = 0.44	4.0 inches	1.760	-
2	ABC	C_2 = 0.12	6.0 inches	0.720	
				SN* = 2.480	2.18

Pavement SN > Required SN, Design is Acceptable

FIG. C-1

FLEXIBLE PAVEMENT DESIGN

PROJECT DATA

Project Location LEWIS-PALMER MIDDLE SCHOOL - PARKING AND DRIVE LANES

Job Number: 231321 Design Life = 4

DESIGN DATA

Equivalent (18-kip) Single Axle Load Applications (ESAL):	ESAL (W_{18}) =	85,000
Design CBR	CBR =	10
Standard Deviation	S_o =	0.44
Loss in Serviceability	Δpsi =	2.5
Reliability	Reliability =	85
Reliability (z-statistic)	Z_R =	-1.04
Soil Resilient Modulus	M_R =	15,000 psi

Required Structural Number (SN): → SN = 1.66

DESIGN EQUATIONS

Resilient Modulus

If using CBR: $M_R = (CBR) \times 1{,}500$

If using R-Value: $M_R = 10^{[(S_1 + 18.72)/6.24]}$ where: $S_1 = [(R\text{-value} - 5) / 11.29] + 3$

Required Structural Number

$$\log_{10}W_{18} = Z_R * S_O + 9.36*\log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left[\frac{\Delta PSI}{4.2 - 1.5}\right]}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32*\log_{10}M_R - 8.07$$

Pavement Section Thickness

$SN^* = C_1D_1 + C_2D_2$ where:

C_1 = Strength Coefficient - HMA
C_2 = Strength Coefficient - Existing HMA
C_3 = Strength Coefficient - ABC
D_1 = Depth of HMA (inches)
D_2 = Depth of Existing HMA (inches)
D_3 = Depth of Existing ABC (inches)

RECOMMENED THICKNESSES

Layer	Material	Structural Layer	Thickness (D^*_i)	SN^*_i	SN
1	HMA	C_1 = 0.44	2.0 inches	0.880	-
2	Ex. HMA	C_2 = 0.24	2.0 inches	0.480	
3	Ex. ABC	C_3 = 0.10	3.0 inches	0.300	
			SN* =	1.660	1.66

Pavement SN > Required SN, Design is Acceptable

FIG. C-2

FLEXIBLE PAVEMENT DESIGN

PROJECT DATA

Project Location LEWIS-PALMER MIDDLE SCHOOL - PARKING AND DRIVE LANES

Job Number: 231321 Design Life = 8

DESIGN DATA

Equivalent (18-kip) Single Axle Load Applications (ESAL):	ESAL (W_{18}) =	180,000
Design CBR	CBR =	10
Standard Deviation	S_o =	0.44
Loss in Serviceability	Δpsi =	2.5
Reliability	Reliability =	85
Reliability (z-statistic)	Z_R =	-1.04
Soil Resilient Modulus	M_R =	15,000 psi

Required Structural Number (SN): → SN = 1.88

DESIGN EQUATIONS

Resilient Modulus

If using CBR:

$M_R = (CBR) \times 1{,}500$

If using R-Value:

$M_R = 10^{[(S_1 + 18.72)/6.24]}$ where: $S_1 = [(\text{R-value} - 5) / 11.29] + 3$

Required Structural Number

$$\log_{10} W_{18} = Z_R * S_O + 9.36 * \log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left[\dfrac{\Delta PSI}{4.2 - 1.5}\right]}{0.40 + \dfrac{1094}{(SN+1)^{5.19}}} + 2.32 * \log_{10} M_R - 8.07$$

Pavement Section Thickness

$SN^* = C_1D_1 + C_2D_2$ where:

C_1 = Strength Coefficient - HMA
C_2 = Strength Coefficient - Existing HMA
C_3 = Strength Coefficient - ABC
D_1 = Depth of HMA (inches)
D_2 = Depth of Existing HMA (inches)
D_3 = Depth of Existing ABC (inches)

RECOMMENED THICKNESSES

Layer	Material	Structural Layer	Thickness (D^*_i)	SN^*_i	SN
1	HMA	C_1 = 0.44	2.5 inches	1.100	-
2	Ex. HMA	C_2 = 0.24	2.0 inches	0.480	
3	Ex. ABC	C_3 = 0.10	3.0 inches	0.300	
			SN* =	1.880	1.88

Pavement SN > Required SN, Design is Acceptable

FIG. C-3