November 13, 2019
Revised December 13, 2019

ENTECH
ENGINEERING, INC.
505 ELKTON DRIVE
COLORADO SPRINGS, CO 80907
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Pinnacle Homes
5260 Hidden Rock Road
Colorado Springs, CO 80908

Approved
By: Elizabeth Nijkamp
Date:04/06/2020
El Paso County Planning & Community Development

SF 1841

Attn: Tom Maher

Re: Pavement Recommendations
Settlers View Subdivision
El Paso County, Colorado

Dear Mr. Maher:

As requested, Entech Engineering, Inc. obtained samples of the pavement subgrade soil from the proposed roadways within the above referenced subdivision. Laboratory testing was performed in order to determine the pavement support characteristics of the soil at proposed subgrade. This letter presents the results of the laboratory testing and pavement recommendations for the rural local residential roadways.

Project Description

The project will consist of the paving of Elk Basin Court and a portion of Silver Nell Drive in the Settlers View Subdivision. Subsurface Soil Investigation and laboratory testing was performed to determine the pavement support characteristics on the soil. The general layout of the site is presented in the Test Boring Location Plan, Figure 1.

Subgrade Conditions

Four test borings were drilled in the proposed roadways spaced less than 500 feet apart. The test boring locations are shown in Figure No. 1. The Test Boring Logs are presented in Appendix A. Representative bulk samples of the subgrade soils were obtained from the test borings at the anticipated subgrade elevation. Soils encountered in the test borings within the subgrade influence zone consisted of silty to clayey sand fill, very silty sand fill, and native clayey sand. The surficial soils were classified into three soil types. The clayey to silty sand fill was grouped into Type 1 soil, the native clayey sand into Type 1A, and the very silty sand fill into Type 2.

Sieve Analyses was performed on the subgrade soils for the purpose of classification. The Sieve Analyses on the Type 1 subgrade soils indicated that approximately 20 to 27 percent of the soil particles passed the No. 200 sieve; the Type 1A subgrade soils indicated approximately 20 percent of the soil particles passed the No. 200 sieve, and approximately 44 to 49 percent for the Type 2 soils. The Type 1 and 1A soils classify as A-2-4; whereas, the Type 2 soils classified as A-4 soils using the AASHTO classification. The Type 1 & 1A soils typically provide good pavement support and the Type 2 soils typically provide fair pavement support characteristics. Groundwater was not encountered in the test borings during or subsequent to drilling. The results of laboratory testing are presented Appendix B. Swell/Consolidation testing was not required on the site soils due to the soil's plastic indices and AASHTO classifications. Mitigation for expansive soils will not be required.

California Bearing Ratio (CBR) testing was performed on a sample of the subgrade soils obtained from Test Boring No. 3, Soil Type 2. The entire subdivision pavement design will be based on Soil Type 2 due to the small size of the subdivision, uniformity of pavement sections, and straightforwardness of construction. The results of the CBR and classification testing are summarized in Table 1 and presented in the following tables, and in Appendix B, attached.

Soil Type 2 – Very Silty Sand Fill

R @ 90% = 12.0
R @ 95% = 40.0
Use R = 26.0 for design

Classification Testing

Liquid Limit	NV
Plasticity Index	NP
Percent Passing 200	49.2
AASHTO Classification	A-4
Group Index	0
Unified Soils Classification	SM

Pavement Design

The CBR testing was used to determine pavement sections for this site. The pavement sections were determined utilizing the El Paso County "Pavement Design Criteria and Report". All of the roadways classify as rural local residential roadways which used an 18K ESAL value of 36,500 for design. Pavement alternatives for asphalt over aggregate basecourse and full depth asphalt are provided. Design parameters used in the pavement analysis are as follows:

Reliability (Local Roads)	75%
Serviceability Index Local Low Volume, Local Roads	2.0
"R" Value Subgrade Soil Type 2	26.0
Resilient Modulus Soil Type 2	6,010 psi
Structural Coefficients:	
Hot Bituminous Pavement	0.44
Aggregate Basecourse	0.11

Pavement calculations are attached in Appendix C. Pavement sections recommended for the site are summarized as follows:

Pavement Sections – Soil Type 2

Rural Local – ESAL = 36,500 – Elk Basin Court and a portion of Silver Nell Drive

Alternative	Asphalt (in)	Basecourse (in)
1. Asphalt Over Basecourse	3.0*	6.0

* Minimum sections required per the El Paso County Pavement Design Criteria and Report.

Roadway Construction - Full Depth Asphalt and Asphalt on Aggregate Basecourse Alternatives

Prior to placement of the asphalt, the subgrade should be proofrolled and compacted to a minimum of 95 percent of its maximum Modified Proctor Dry Density, ASTM D-1557 at ±2 percent of optimum moisture content. Any loose areas should be removed and replaced with suitable materials. Basecourse materials should be compacted to a minimum of 95 percent of its maximum Modified Proctor Dry Density, ASTM D-1557 at ±2 percent of optimum moisture content. Special attention should be given to areas adjacent to manholes, inlet structures and valves.

If significant grading is performed, the soils at subgrade may change. Modification to the pavement sections should be evaluated after site grading is completed.

In addition to the above guidance, the asphalt, cement, subgrade conditions, compaction of materials and roadway construction methods shall meet the El Paso County specifications.

We trust that this has provided you with the information you required. If you have any questions or need additional information, please do not hesitate to contact us.

Respectfully Submitted,

ENTECH ENGINEERING, INC.

Daniel P. Stegman

DPS/ts
Encl.

Entech Job No. 191859
AAprojects/2019/191859/191859 pr-Rev

COLORADO LICENSED
MARK HOWARD HAUSCHILD
35140
12/13/19
PROFESSIONAL ENGINEER

Reviewed by:

Mark H. Hauschild, P. E.
Senior Engineer

TABLE

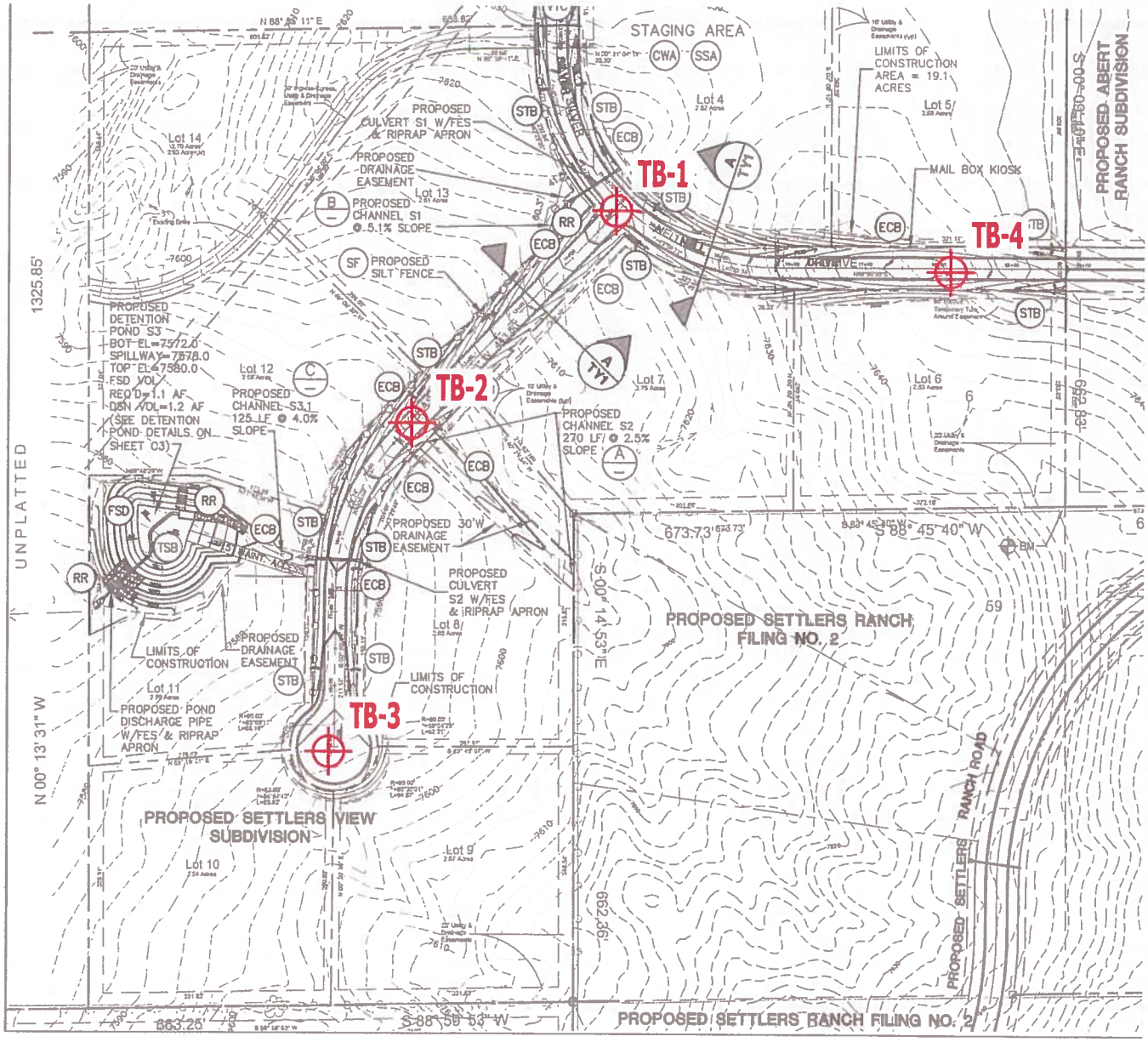
TABLE 1

SUMMARY OF LABORATORY TEST RESULTS

CLIENT PINNACLE HOMES
PROJECT SETTLERS VIEW
JOB NO. 191859

SOIL TYPE	TEST BORING NO.	DEPTH (FT)	WATER (%)	DRY DENSITY (PCF)	PASSING NO. 200 SIEVE (%)	LIQUID LIMIT (%)	PLASTIC INDEX (%)	SULFATE (WT %)	AASHTO CLASS.	SWELL/ CONSOL (%)	UNIFIED CLASSIFICATION	SOIL DESCRIPTION
1	1	1-2			27.1	27	8		A-2-4		SC	FILL, SAND, CLAYEY
1	2	1-2			19.6	NV	NP	0.00	A-2-4		SM	FILL, SAND, SILTY
1A	4	1-2			19.8	26	9	<0.01	A-2-4		SC	SAND, CLAYEY
2, CBR	3	0-3			49.2	NV	NP		A-4		SM	FILL, SAND, VERY SILTY
2	3	1-2			44.1	NV	NP		A-4		SM	FILL, SAND, VERY SILTY

FIGURE



TB-2 - APPROXIMATE TEST BORING LOCATION AND NUMBER

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TEST BORING LOCATION PLAN
SETTLERS VIEW SUBDIVISION
EL PASO COUNTY, CO
FOR: PINNACLE HOMES

DRAWN BY:	DATE DRAWN:	DESIGNED BY:	CHECKED:
SC	11/12/19	SC	

JOB NO.: 191859

FIG. NO.: 1

APPENDIX A: Test Boring Logs

TEST BORING NO 1
DATE DRILLED 10/17/2019
Job # 191859

REMARKS

DRY TO 10', 10/17/19

Depth (ft)	Symbol	Samples	Blows per foot	Watercontent %	Soil Type	
			28	6.9	1	FILL 0-4', SAND, CLAYEY, FINE TO MEDIUM GRAINED, BROWN, MEDIUM DENSE, MOIST
5			33	6.1	1A	SAND, VERY SILTY TO SILTY, FINE TO COARSE GRAINED WITH FINE GRAINED LENSES, TAN, DENSE TO MEDIUM DENSE, MOIST
10			28	5.4	1A	
15						
20						

TEST BORING NO 2
DATE DRILLED 10/17/2019
CLIENT PINNACLE HOMES
LOCATION SETTLERS VIEW

REMARKS

DRY TO 5', 10/17/19

Depth (ft)	Symbol	Samples	Blows per foot	Watercontent %	Soil Type	
			19	5.4	1	FILL 0-4', SAND, SILTY, FINE TO COARSE GRAINED, BROWN, MEDIUM DENSE, MOIST
5			20	2.4	1A	SAND, SILTY, FINE TO COARSE GRAINED, TAN, MEDIUM DENSE, DRY
10						
15						
20						

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TEST BORING LOG

DRAWN:	DATE:	CHECKED: DS	DATE: 11/13/19

JOB NO.: 191859
FIG NO.: A- 1

TEST BORING NO 3
DATE DRILLED 10/17/2019
Job # 191859

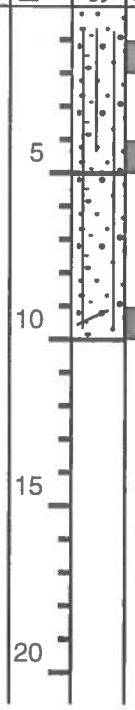
REMARKS

DRY TO 10', 10/17/19

FILL 0-5', SAND, VERY SILTY, FINE TO COARSE GRAINED, BROWN, MEDIUM DENSE, MOIST

SAND, SILTY, FINE TO COARSE GRAINED, TAN, MEDIUM DENSE, MOIST

CLAYEY LENSES



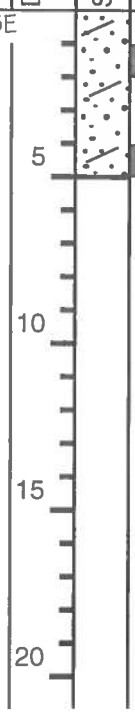
Depth (ft)	Symbol	Samples	Blows per foot	Watercontent %	Soil Type
0-5			12	7.8	2
5-10			12	18.6	2
10-15			15	11.6	1A

TEST BORING NO 4
DATE DRILLED 10/17/2019
CLIENT PINNACLE HOMES
LOCATION SETTLERS VIEW

REMARKS

DRY TO 5', 10/17/19

SAND, CLAYEY, FINE TO COARSE GRAINED, BROWN, DENSE TO MEDIUM DENSE, MOIST



Depth (ft)	Symbol	Samples	Blows per foot	Watercontent %	Soil Type
0-5			36	4.1	1A
5-10			25	7.6	1A

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TEST BORING LOG

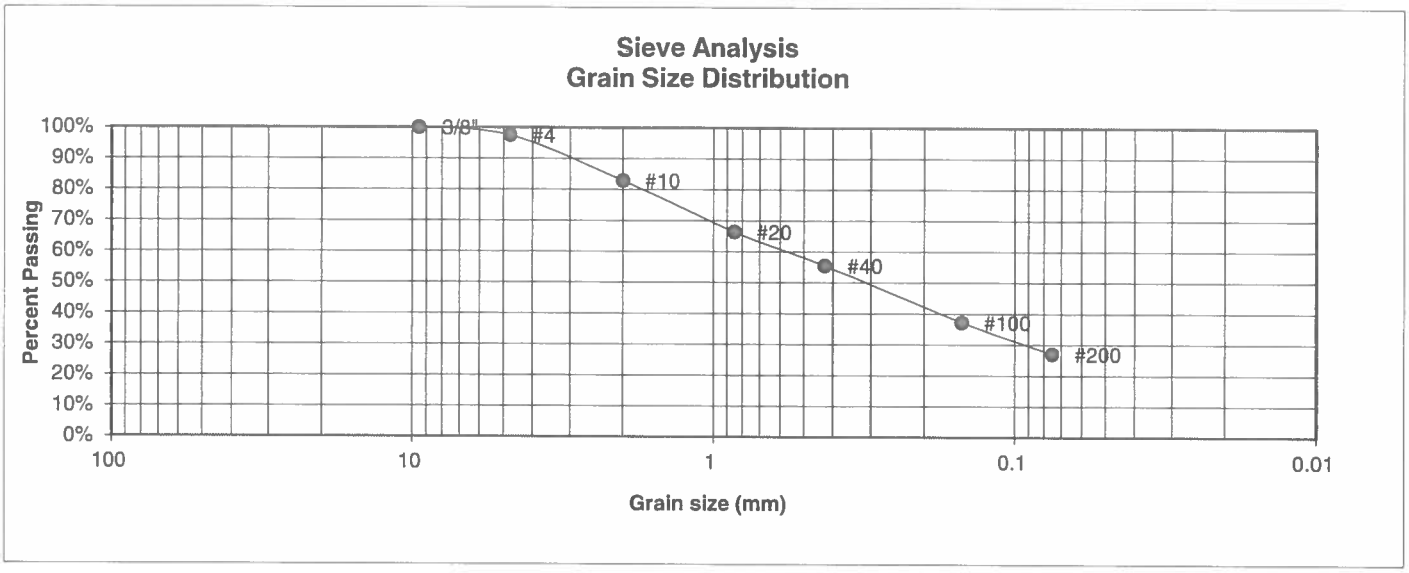
DRAWN:	DATE:	CHECKED:	DATE:
		DS	11/15/19

JOB NO.: 191859

FIG NO.: A- 2

APPENDIX B: Laboratory Test Results

UNIFIED CLASSIFICATION	SC	CLIENT	PINNACLE HOMES
SOIL TYPE #	1	PROJECT	SETTLERS VIEW
TEST BORING #	1	JOB NO.	191859
DEPTH (FT)	1-2	TEST BY	BL
AASHTO CLASSIFICATION	A-2-4	GROUP INDEX	0



U.S. Sieve #	Percent Finer
3"	
1 1/2"	
3/4"	
1/2"	
3/8"	100.0%
4	97.5%
10	82.9%
20	66.4%
40	55.5%
100	37.3%
200	27.1%

Atterberg Limits	
Plastic Limit	19
Liquid Limit	27
Plastic Index	8

Swell	
Moisture at start	
Moisture at finish	
Moisture increase	
Initial dry density (pcf)	
Swell (psf)	

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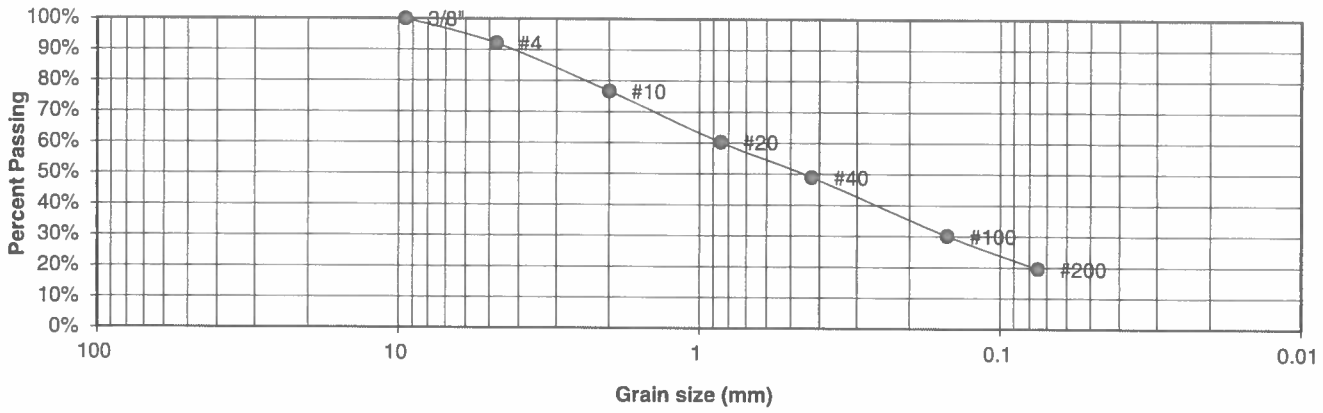
LABORATORY TEST RESULTS

DRAWN:	DATE:	CHECKED:	DATE:
		DS	11/15/19

JOB NO.: 191859
FIG NO.: B-1

UNIFIED CLASSIFICATION	SM	CLIENT	PINNACLE HOMES
SOIL TYPE #	1	PROJECT	SETTLERS VIEW
TEST BORING #	2	JOB NO.	191859
DEPTH (FT)	1-2	TEST BY	BL
AASHTO CLASSIFICATION	A-2-4	GROUP INDEX	0

Sieve Analysis
Grain Size Distribution



U.S. Sieve #	Percent Finer
3"	
1 1/2"	
3/4"	
1/2"	
3/8"	100.0%
4	92.1%
10	76.7%
20	60.2%
40	49.0%
100	30.1%
200	19.6%

Atterberg Limits

Plastic Limit	NP
Liquid Limit	NV
Plastic Index	NP

Swell

Moisture at start

Moisture at finish

Moisture increase

Initial dry density (pcf)

Swell (psf)

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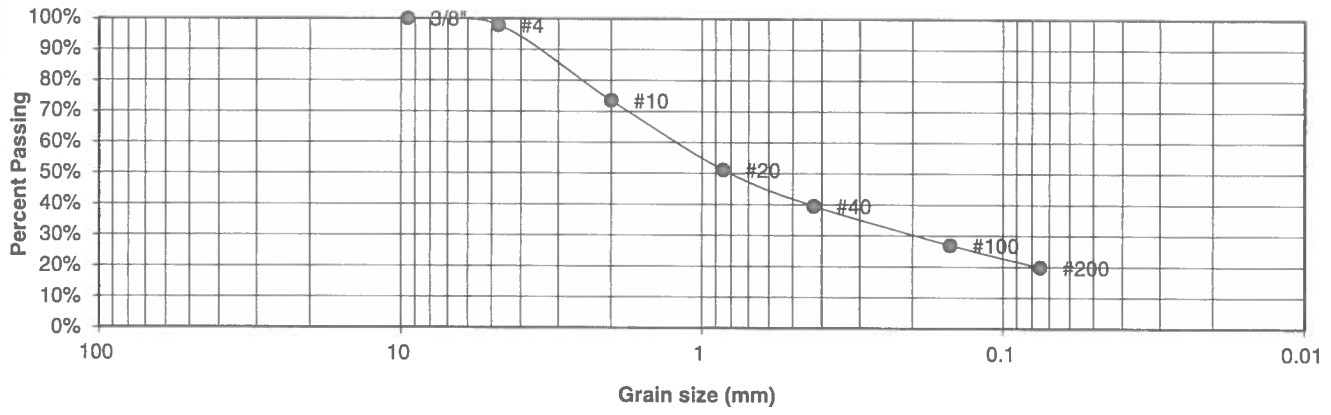
LABORATORY TEST RESULTS

DRAWN:	DATE:	CHECKED:	DATE:
		DS	11/19/13

JOB NO.: 191859
FIG NO.: B-2

UNIFIED CLASSIFICATION	SC	CLIENT	PINNACLE HOMES
SOIL TYPE #	1A	PROJECT	SETTLERS VIEW
TEST BORING #	4	JOB NO.	191859
DEPTH (FT)	1-2	TEST BY	BL
AASHTO CLASSIFICATION	A-2-4	GROUP INDEX	0

Sieve Analysis
Grain Size Distribution



U.S. Sieve #	Percent Finer
3"	
1 1/2"	
3/4"	
1/2"	
3/8"	100.0%
4	97.9%
10	73.5%
20	51.2%
40	39.6%
100	27.0%
200	19.8%

Atterberg Limits	
Plastic Limit	17
Liquid Limit	26
Plastic Index	9

Swell	
Moisture at start	
Moisture at finish	
Moisture increase	
Initial dry density (pcf)	
Swell (psf)	

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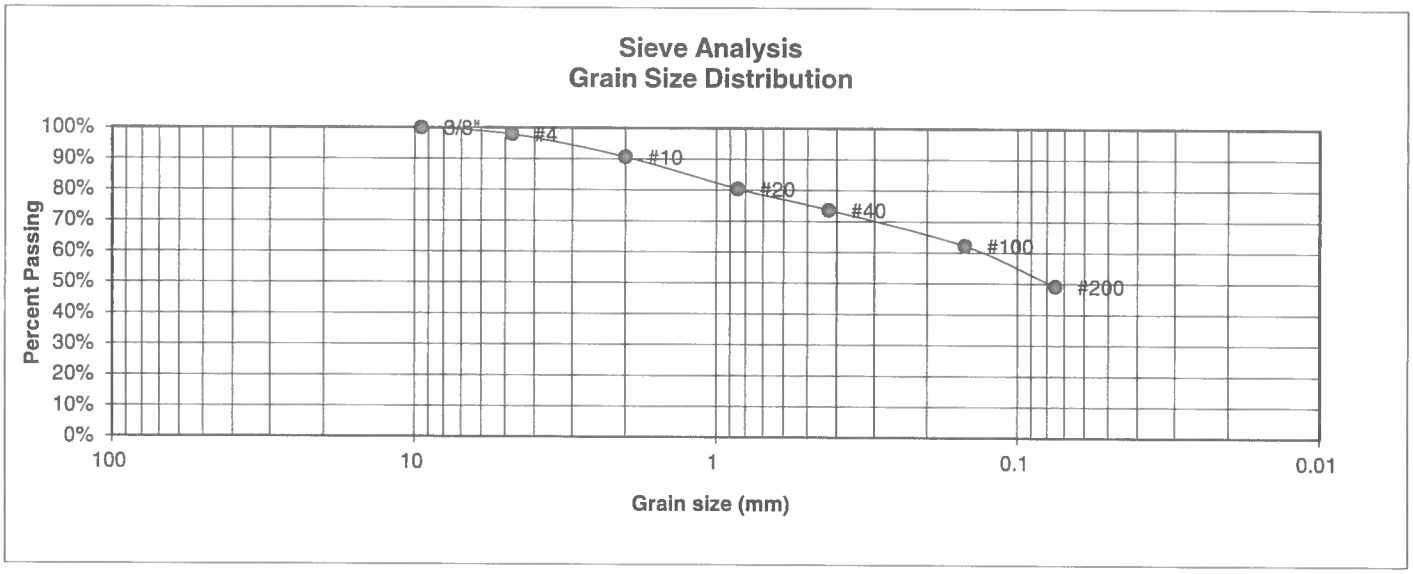
LABORATORY TEST RESULTS

DRAWN:	DATE:	CHECKED:	DATE:
		DD	11/13/19

JOB NO.: 191859
FIG NO.: B-3

UNIFIED CLASSIFICATION	SM	CLIENT	PINNACLE HOMES
SOIL TYPE #	2, CBR	PROJECT	SETTLERS VIEW
TEST BORING #	3	JOB NO.	191859
DEPTH (FT)	0-3	TEST BY	BL
AASHTO CLASSIFICATION	A-4	GROUP INDEX	0



U.S. Sieve #	Percent Finer
3"	
1 1/2"	
3/4"	
1/2"	
3/8"	100.0%
4	97.9%
10	90.7%
20	80.4%
40	73.7%
100	62.2%
200	49.2%

Atterberg Limits

Plastic Limit	NP
Liquid Limit	NV
Plastic Index	NP

Swell

Moisture at start

Moisture at finish

Moisture increase

Initial dry density (pcf)

Swell (psf)

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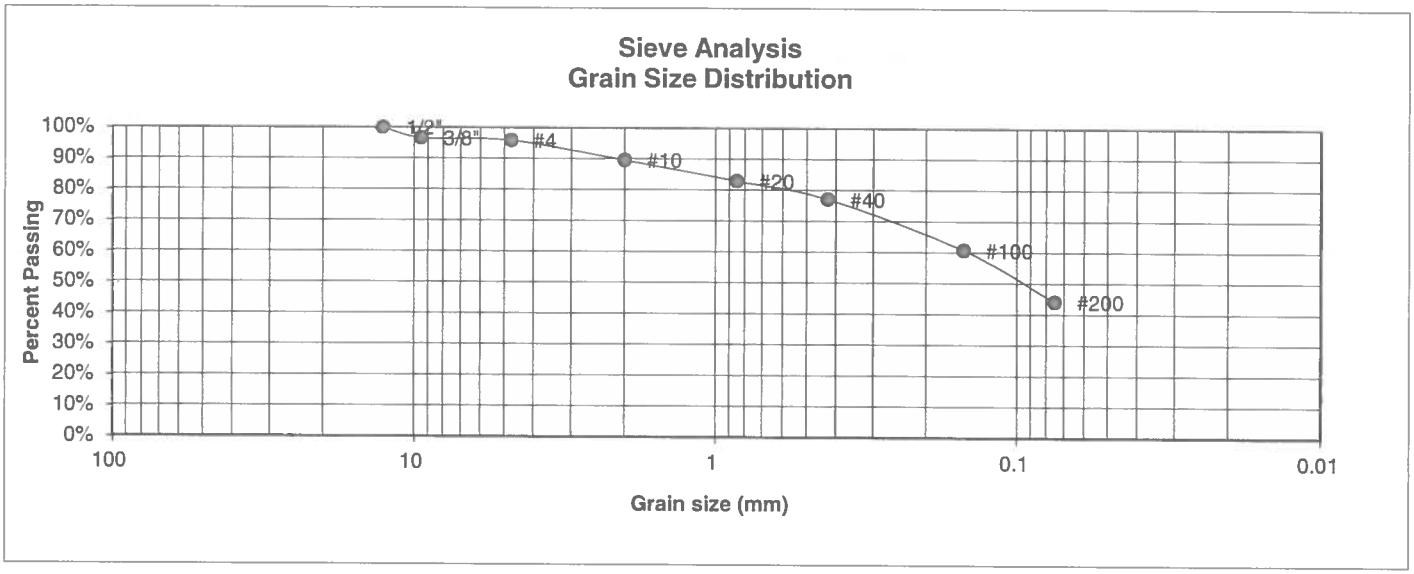
LABORATORY TEST RESULTS

DRAWN:	DATE:	CHECKED:	DATE:
		DS	4/3/19

JOB NO.: 191859
FIG NO.: B-4

UNIFIED CLASSIFICATION	SM	CLIENT	PINNACLE HOMES
SOIL TYPE #	2	PROJECT	SETTLERS VIEW
TEST BORING #	3	JOB NO.	191859
DEPTH (FT)	1-2	TEST BY	BL
AASHTO CLASSIFICATION	A-4	GROUP INDEX	0



U.S. Sieve #	Percent Finer
3"	
1 1/2"	
3/4"	
1/2"	100.0%
3/8"	96.5%
4	95.8%
10	89.5%
20	82.8%
40	77.0%
100	60.7%
200	44.1%

Atterberg Limits

Plastic Limit	NP
Liquid Limit	NV
Plastic Index	NP

Swell

Moisture at start

Moisture at finish

Moisture increase

Initial dry density (pcf)

Swell (psf)

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LABORATORY TEST RESULTS

DRAWN:	DATE:	CHECKED:	DATE:
		DS	4/12/19

JOB NO.: 191859
FIG NO.: B-5

CLIENT	PINNACLE HOMES	JOB NO.	191859
PROJECT	SETTLERS VIEW	DATE	11/7/2019
LOCATION	SETTLERS VIEW	TEST BY	BL

BORING NUMBER	DEPTH, (ft)	SOIL TYPE NUMBER	UNIFIED CLASSIFICATION	WATER SOLUBLE SULFATE, (wt%)
TB-2	1-2	1	SM	0.00
TB-4	1-2	1A	SC	<0.01

QC BLANK PASS

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COLORADO SPRINGS, COLORADO 80907

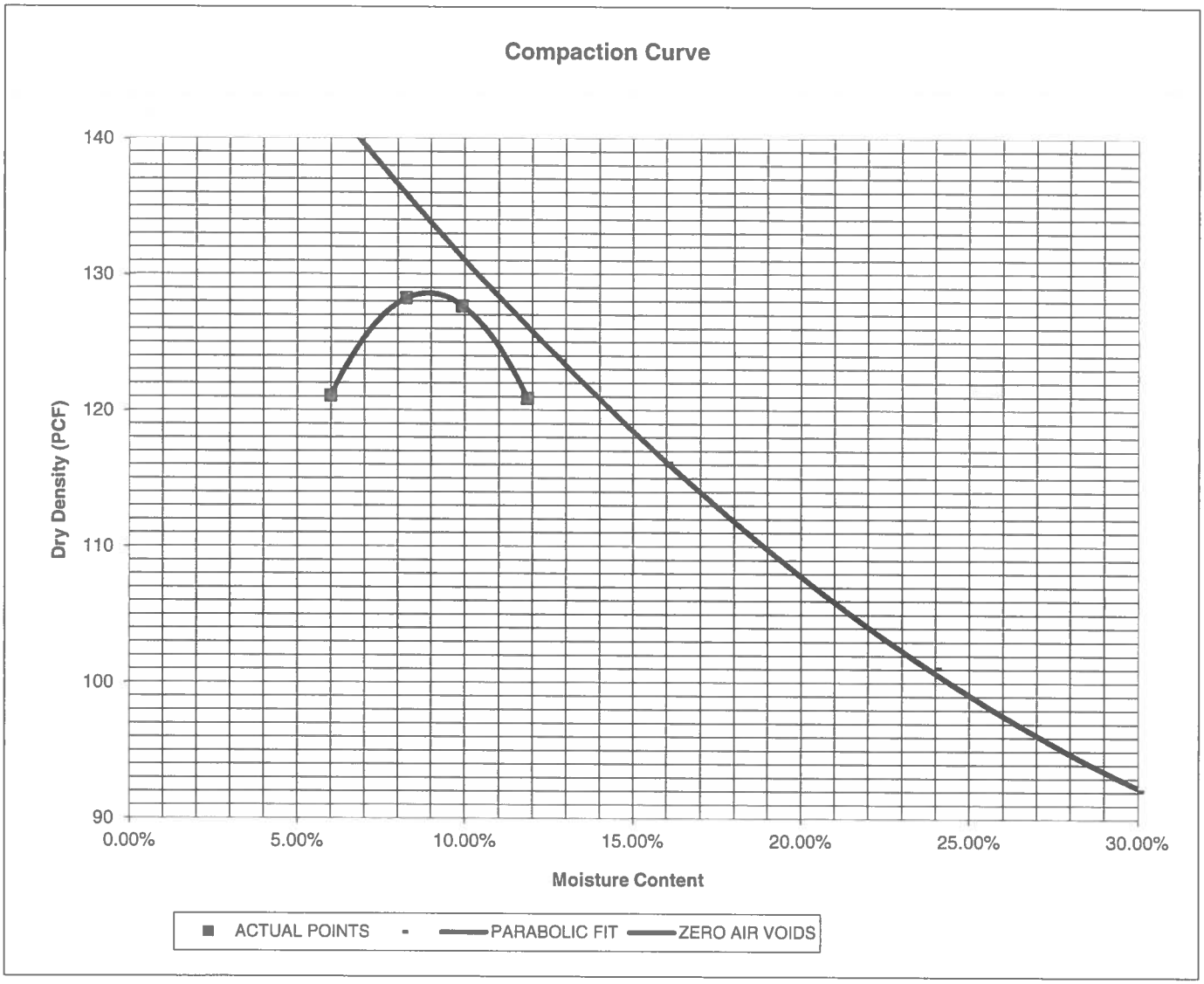
LABORATORY TEST
SULFATE RESULTS

DRAWN:	DATE:	CHECKED:	DATE:
		DS	11/13/19

JOB NO.: 191859
FIG NO.: B-6

PROJECT	SETTLERS VIEW	CLIENT	PINNACLE HOMES
SAMPLE LOCATION	TB-3 @ 0-3'	JOB NO.	191859
SOIL DESCRIPTION	SAND, VERY SILTY, TAN	DATE	10/17/19

IDENTIFICATION	SM	COMPACTION TEST #	1
TEST DESIGNATION / METHOD	ASTM D-1557-A	TEST BY	AL
MAXIMUM DRY DENSITY (PCF)	128.7	OPTIMUM MOISTURE	9.0%



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MOISTURE DENSITY RELATION

DRAWN:	DATE:	CHECKED:	DATE:
		DS	11/12/19

JOB NO.: 191859

FIG NO.: B-7

CBR TEST LOAD DATA

JOB NO: 191859
CLIENT: PINNACLE HOMES
PROJECT: SETTLERS VIEW
SOIL TYPE: 2

PISTON DIAMETER (cm)	PISTON AREA (in^2)
4.958	2.99250919

PENETRATION DEPTH (INCHES)	*10 BLOWS* MOLD # 1 LOAD(LBS) (LBS)	STRESS (PSI)	*25 BLOWS* MOLD # 2 LOAD(LBS) (LBS)	STRESS (PSI)	*56 BLOWS* MOLD # 3 LOAD(LBS) (LBS)	STRESS (PSI)
0.000	0	0.00	0	0.00	0	0.00
0.025	166	55.47	207	69.17	372	124.31
0.050	251	83.88	375	125.31	546	182.46
0.075	302	100.92	472	157.73	643	214.87
0.100	335	111.95	570	190.48	768	256.64
0.125	387	129.32	691	230.91	1058	353.55
0.150	455	152.05	832	278.03	1097	366.58
0.175	483	161.40	955	319.13	1146	382.96
0.200	522	174.44	1153	385.30	1286	429.74
0.300	588	196.49	1533	512.28	1643	549.04
0.400	655	218.88	1875	626.56	1993	666.00
0.500	738	246.62	2156	720.47	2287	764.24

FINAL MOISTURE CONTENT

	MOLD # 1	MOLD # 2	MOLD # 3
CAN #	354	353	358
WT. CAN	6.93	6.73	6.68
WT. CAN+WET	172.64	157.43	191.3
WT. CAN+DRY	153.38	142	172.58
WT. H20	19.26	15.43	18.72
WT. DRY SOIL	146.45	135.27	165.9
MOISTURE CONTENT	13.15%	11.41%	11.28%

WET DENSITY (PCF)		131.1	138.3	139.9
DRY DENSITY (PCF)		120.3	126.9	128.4
BEARING RATIO		11.19	19.05	25.66
90% OF DRY DENSITY	115.8			
95% OF DRY DENSITY	122.3			

BEARING RATIO AT 90% OF MAX	5.93	~ R VALUE	12
BEARING RATIO AT 95% OF MAX	13.55	~ R VALUE	40

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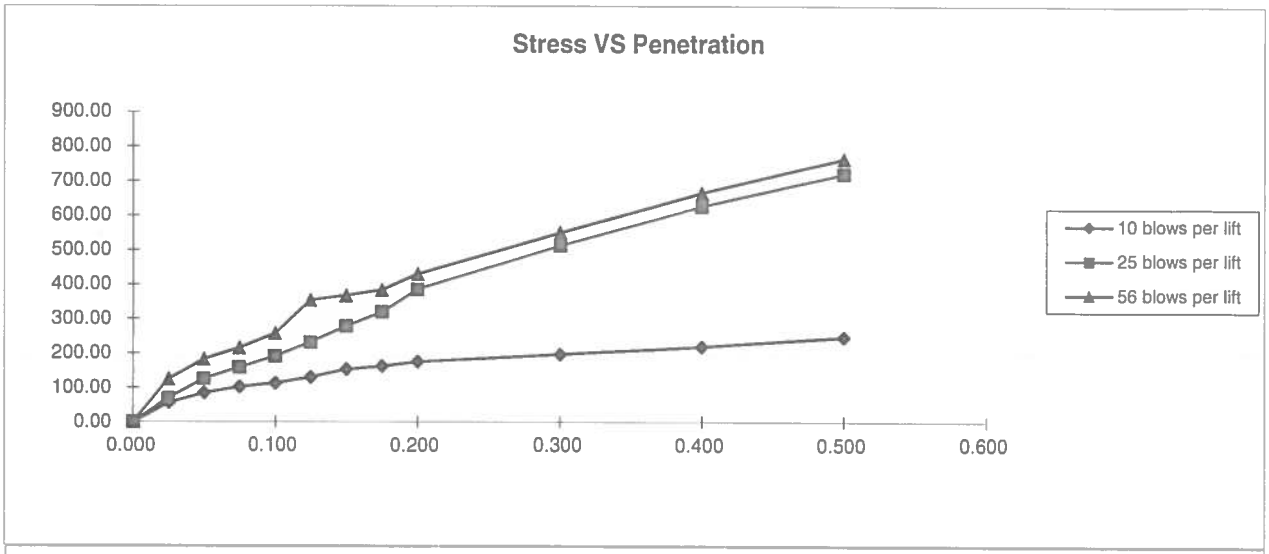
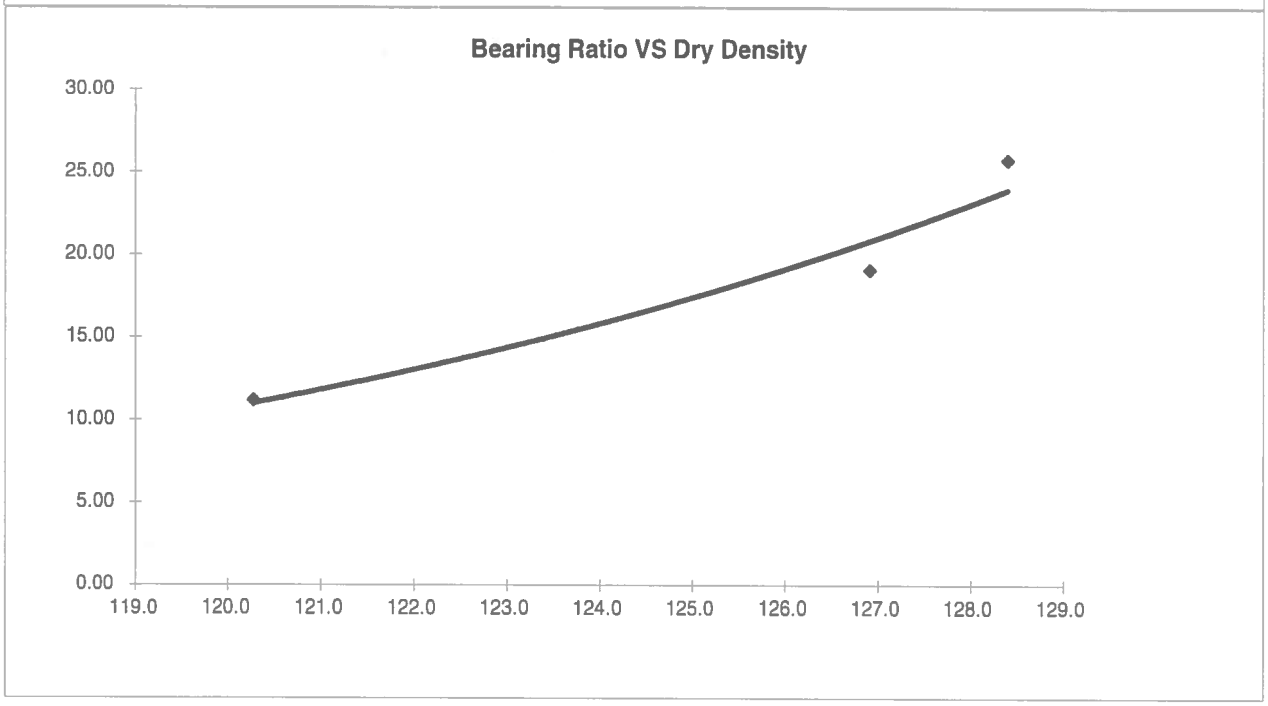
CBR TEST DATA

DRAWN:	DATE:	CHECKED:	DATE:
		DS	11/13/19

JOB NO.: 191859
FIG NO.: B-2





BEARING RATIO AT 90% OF MAX	5.93	~ R VALUE	12.00
BEARING RATIO AT 95% OF MAX	13.55	~ R VALUE	40.00

JOB NO: 191859
SOIL TYPE: 2

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CALIFORNIA BEARING RATIO

DRAWN:	DATE:	CHECKED:	DATE:
		DS	11/13/19

JOB NO.: 191859
FIG NO.: B-9

APPENDIX C: Pavement Design Calculations

FLEXIBLE PAVEMENT DESIGN

DESIGN DATA — PINNACLE HOMES - SETTLERS VIEW SUBDIVISION
RURAL LOCAL ROADS - SOIL TYPE 2
ALL ROADWAYS

Equivalent (18 kip) Single Axle Load Applications (ESAL):	ESAL (W_{18}) =	36,500
Hveem Stabilometer (R Value) Results:	R =	26
Standard Deviation	S_o =	0.45
Loss in Serviceability	Δpsi =	2.0
Reliability	Reliability =	75
Reliability (z-statistic)	Z_R =	-0.67
Soil Resilient Modulus	M_R =	6010

Weighted Structural Number (WSN): → WSN = 1.95

DESIGN TABLES AND EQUATIONS

$S_1 = [(R - 5) / 11.29] + 3$

$M_R = 10^{[(S_1 + 18.72) / 6.24]}$

$k = M_R / 19.4$

Where:

M_R = resilient modulus (psi)

S_1 = the soil support value

R = R-value obtained from the Hveem stabilometer

CBR = California Bearing Ratio

Reliability (%)	Z_R (z-statistic)
75	-0.67
80	-0.84
85	-1.04
90	-1.28
94	-1.56
95	-1.65
96	-1.75
97	-1.88
98	-2.05
99	-2.33
99.9	-3.09
99.99	-3.75

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

Left	Right	Difference
4.56	4.56	0.0

Job No. 191859
Fig. No. C-1

DESIGN CALCULATIONS

DESIGN DATA PINNACLE HOMES - SETTLERS VIEW SUBDIVISION
RURAL LOCAL ROADS - SOIL TYPE 2
ALL ROADWAYS

Equivalent (18 kip) Single Axle Load Applications (ESAL):	ESAL =	36,500
Hveem Stabilometer (R Value) Results:	R =	26
Weighted Structural Number (WSN):	WSN =	1.95

DESIGN EQUATION

$$WSN = C_1D_1 + C_2D_2$$

C_1 = 0.44 Strength Coefficient - Hot Bituminous Asphalt
C_2 = 0.11 Strength Coefficient - Aggregate Basecourse

D_1 = Depth of Asphalt (inches)
D_2 = Depth of Basecourse (inches)

FOR ASPHALT + AGGREGATE BASECOURSE SECTION

Asphalt Thickness (t) = [3] inches
$D_2 = ((WSN) - (t)(C_1))/C_2$ = 5.7 inches of Aggregate
Basecourse, use 6.0 inches

RECOMMENDED ALTERNATIVES

1. 3.0 inches of Asphalt + 6.0 inches of Aggregate Basecourse, or

Job No. 191859
Fig. No. C-2